CORNELL UNIVERSITY TURFGRASS TIMES

CUTT

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Modern Turfgrass Development

Any effort to improve resource efficiency begins with the selection of a properly adapted turfgrass. Adaptation is the precursor to determining competitiveness. Simply if a turfgrass is well adapted to an environment (soils, management and traffic) it will be competitive with pests, especially invading species such as annual bluegrass. Increased competitiveness will allow for more efficient use of resources.

An important tenet of integrated pest management (IPM) is utilizing all available resources to maintain pests below a population that would cause unacceptable injury or reduction in visual quality. Too often any discussion of IPM moves past turfgrass selection and immediately to altering the growing environment or using pesticides. For example, several years ago a new bentgrass variety was released with known susceptibility to dollar spot. Several industry leaders argued that this was an "easy disease to control" and the grass should be used because of other technical benefits.

Most turfgrass managers are unwilling to broach the subject of using new cultivars because of the disruption associated with the process. Research has shown that to successfully incorporate new cultivars, competition from the existing turf must be eliminated. Elimination can involve drastic vegetation management with herbicides or soil fumigants. Attention will be paid to the process by the athletes and the risks can be great.

In this day of "fast" greens and perfect lawns, using a grass with high shoot density seems prudent. Yet, few turfgrass stands over the age of 30 are renovated to utilize new cultivars. Is it because of the inconvenience of resurfacing? Are the new cultivars better in a way that matters, i.e., pest resistance, competitive with annual bluegrass or stress tolerant? Did the breeders miss the mark with new grasses or do we just not know enough yet?

The Process

Doug Brede, Research Director of Jacklin Golf, says "turfgrass managers need to hear about grasses from friends, touch them and

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This Times

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Clippings

Emmons Receives GCSAA Honor

Bob Emmons, Professor of Turfgrass Management at SUNY Cobleskill, received the 2003 Distinguished Service Award from the Golf Course Superintendent Association of America at the International Golf Course Show in Atlanta, GA. This is one of the association's highest honors and recognizes a lifetime achievement for one of the leaders of the turfgrass industry in New York State.

Over 60 letters were submitted from former students and members of the turfgrass industry in support of Bob's nomination. Tim O'Neill, GCSAA Director said, "It was an overwhelming package, filled with letters and testimonials how Emmons had made a difference in so many people's lives."

In his typical humble way, Emmons deflects the praise saying, "this is so important for the continued success of the program here at Cobleskill. We have an excellent team of instructors who have helped to develop a high quality graduate."

Cornell Graduate Student Watson Fellow

Cornell University graduate student Micah Woods was selected as one of the James Watson Fellows. The Watson Fellowships recognize an outstanding graduate student in turfgrass science and is named for the legendary agronomist Dr. Jim Watson.

Woods, currently pursuing his Ph.D. with Professor Frank Rossi at Cornell University, is attempting to address current deficiencies in soil testing procedures that are significantly reducing the precision in modern nutrient management programs. This is truly foundational research that demonstrates Micah's interest in assisting golf course superintendents not sure about the value of soil testing and interpretations. Of course, as a former superintendent himself, Micah is able to bridge the gap between basic soil chemistry and developing a nutrient management program for golf turf.

In supporting Woods, Rossi writes, "I had the pleasure of becoming friends with "Doc" Watson during my tenure on the USGA Research Committee and say without reservation that he would be pleased to know a person like Micah was a candidate for this honor. Micah's international experience and desire to continue to contribute on an international scale bodes well for his establishing a global influence in golf turf management."

NYSTA Keeps You Informed

The 2002 season will be remembered for concerns over water use, devastating diseases and how to meet consumer demand for perfect turf with less pesticides. Each year, meeting consumer expectations grows more challenging. The New York State Turfgrass Association is committed to assisting members to meet that challenge through dedication to supporting research and education.

For more than a decade NYSTA has provided over a half million dollars for turfgrass research. This research has helped to develop new technologies at Cornell such as emerging IPM and biological control products. Cornell researchers have determined the movement of fertilizers and pesticides applied to turf, identifying key areas for managers.

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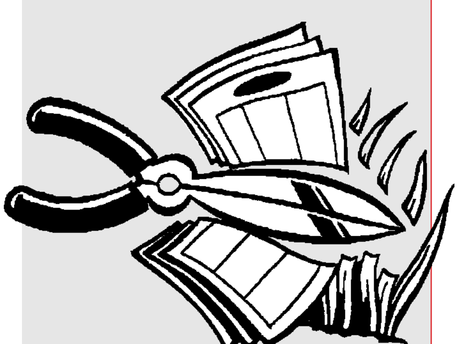

Exploring Turfgrass Salt Tolerance

Continued pressure on water resources in the northeast as a result of population growth and development demands creative approaches to potable water use. In the desert southwest, almost 40% of all golf courses use reclaimed or recycled water. Several communities in Florida have begun constructing reverse osmosis (RO) plants to harvest sea water, in fact some golf courses have their own RO plants. If the turfgrass industry is going to embrace recycled, reclaimed or salty water (as it should) there needs to be improvements in turfgrass salt tolerance.

Researchers at Colorado State University have been investigating salt tolerance in turfgrasses from many different angles. For example, for several years they have searched for alternative turfgrasses, such as Inland Saltgrass, and development is underway. Most recently the researchers have begun investigating salt tolerance in bluegrasses, mainly Kentucky (KBG) and Texas (TBG) bluegrasses.

The results demonstrated a broad range of salt tolerance among the species and hybrids that would allow for successful breeding. Interestingly, it was concluded through a variety of tests and statistical analysis that the aggressive, compact types of KBG, such as Limousine, were more salt tolerant than a common type, such as Kenblue. However, even the most salt tolerant BG type was significantly less salt tolerant than most tall fescue species.

A significant research factor was identified that could further enhance the search for increased salt tolerance. The researchers identified a significant influence of temperature on expressed salt tolerance that future experiments could more thoroughly address.

It is unlikely the bluegrasses will replace other more salt tolerant turfgrasses in their present form. Yet, for areas that demand high turf quality with only modest salt water problems, this research suggests it is possible with the aggressive, compact KBG-types.

From: Suplick-Ploense, M.R., Y.L. Qian, and J.C. Reid. 2002. Relative salt tolerance of Kentucky bluegrass, Texas bluegrass and their hybrids. Crop Sci. 42:2025-2030.

Turfgrass Can Reduce Phosphorus Loading

National concern for water quality resulted in the Clean Water Act of 1973. Over the last three decades that concern has resulted in significant regulation and a persistent search for sources of pollution. The result has been significantly higher water quality.

Agriculture has been a focus of specific groundwater issues relative to pesticide and nutrient leaching. However, recent focus has been on the nutrient loading of surface water from land application of manure, most notably from concentrated animal feeding operations (CAFO's) typical of large scale operations. Simply, there is not enough land to absorb the nitrogen (N) and phosphorus (P) from applied manure.

Researchers at Texas A&M University, in cooperation with turfgrass research Professor Richard White, investigated how sod production following land application of manure can export N and P from the watershed and serve to reduce overall nutrient loading. While the research was conducted on Bermudagrass, buffalograss and Texas bluegrass, some important conclusions can be drawn.

When compared to harvesting hay from fields treated with manure, removing the sod layer that includes the soil removes almost tenfold more P and N. Interestingly, there was no difference in the amount of N or P removal when additional inorganic N was added. Therefore, it was suggested that additional inorganic N that allowed for more rapid crop production would thereby increase N and P removal from the farm and subsequent watershed.

At a time when animal-based agricultural operations are increasing in scale, manure management has emerged as an important environmental concern. Encouraging sod production at these facilities can capitalize on the benefits of turfgrass. Additionally, sod is a high value crop that when installed to bare soil further increases the filtering capacity of the land. The filtering capacity of turf will preserve and protect water quality in environments with high percentages of impervious (paved) surfaces.

From: Vietor, D.M., E.N. Griffith, R.H. White, T.L. Provin, J.P. Muir, and J.C. Reid. 2002. Export of manure phosphorus and nitrogen in turfgrass sod. J. of Environ. Qual. 31:1731-1738.

Scanning the Journals

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Modern Turfgrass Development

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This study questions one of the longest held principles of turf establishment, i.e., August and September are the best months for establishing turfgrasses from seed in northern climates. Also, it demonstrates the variable competitiveness of bentgrass species and cultivars.

In areas with light disease pressure such as more arid climates, the selection of L-93 or other disease resistant turfgrasses could significantly reduce fungicide use. Additionally, lower fungicide rates and strictly curative disease management programs that use less fungicide are possible with more disease resistant turfgrasses.

bond with them before they are willing to use them. In fact," Brede continues, "it is difficult to get turf managers to agree on what is the most important feature in a turfgrass."

Professor Jim Murphy and colleagues at Rutgers University investigated the relationship between bentgrass cultivar and time of seeding for annual bluegrass invasion. An existing bentgrass and annual bluegrass putting green was killed with a nonselective herbicide. This leaves the annual bluegrass seed bank intact.

After the existing turf was killed, different bentgrass species and cultivars were seeded in May, June, August, September, or October. Most surprisingly, June seeding dates consistently produced the highest bentgrass populations. Penncross consistently had lower bentgrass populations than the other cultivars. Providence had similar bentgrass populations compared to Penn A-4, L-93 and SR7200 (velvet bentgrass) for June, August and September dates. Providence had less bentgrass than the same cultivars at the May and October seeding dates. Penn A-4 and L-93 had consistently higher bentgrass population except for SR7200 over all seeding dates.

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A subtle finding of this study addresses those interested in maintaining consistency among existing greens when one is renovated. For example an older course with mostly bentgrass and annual bluegrass greens desires the new green to perform like the other greens. This could be accomplished by seeding the new green with a poor competitor such as Penncross at a time such as August when the annual bluegrass would invade successfully. This would result in mixed bentgrass and annual bluegrass surface with improved rootzone or enhanced growing environment and do little to exploit the advantages of new bentgrass cultivars.

Disease Advantages

With pending drought conditions across the US, more water use efficient cultivars would be the highest priority for many golf course superintendents. However, little meaningful differences exist among commercially available turfgrass for putting greens. The next most important trait from an environmental perspective would be a cultivar that required less pesticides to provide acceptable quality as a first step in an IPM program.

A study was conducted at Kansas State University by Professors Jack Fry and Ned Tisserat to evaluate the influence of bentgrass cultivar on disease management programs. Crenshaw, L-93, Penncross and Providence were managed under typical putting green regimes for KS. Various fungicide programs for dollar spot and brown patch were implemented as preventative or curative (after infection).

Untreated plots of L-93 were the most resistant to dollar spot providing acceptable quality on 70% of the rating dates in the first year then less than half of the rating dates in the following two seasons. Interestingly, all of the unacceptable rating dates for L-93 occurred after the mid-July stress period. Fry and his colleagues suggest this could allow for reduced fungicide use in the early season on L-93.

Crenshaw is very susceptible to brown patch and dollar spot. This was evidenced by the complete inability to produce acceptable quality ratings without fungicides. Moreover, the length of control afforded by certain fungicide programs was reduced on Crenshaw presumably as a result of the susceptibility.

In areas with light disease pressure such as more arid climates, the selection of L-93 or other disease resistant turfgrasses could significantly reduce fungicide use. Additionally, lower fungicide rates and strictly curative disease management programs using less fungicide are possible with more disease resistant turfgrasses.

Change Species?

"If fungicides are not available for use," states Professor Jim Murphy of Rutgers University, "maybe we have to change grass species." Looking more closely at the research at Rutgers University led by Professor Bill Meyer, the reasons become clear. Meyer, Murphy and the rest of the Turfgrass Team at Rutgers are exploring the velvet and colonial bentgrasses.

The experimental velvet and colonial bentgrasses are performing as well as creeping bentgrasses under the battery of tests performed on traffic, pests and other stresses. These species appear to be more competitive against annual bluegrass, provide high quality under low light and are more resistant to certain pests than the average creeping bentgrass.

In an effort to exploit the dollar spot resistance (almost immunity) velvet bentgrass was installed on three putting greens on the Bethpage Green Course. The Green Course is the site of the USGA-sponsored project to develop nonchemical approaches to putting green management (see related story on page 8). The three greens were completely devastated by dollar spot in 2001 when not treated with fungicides. Many questions remain unanswered about this grass, but several golf courses in the northeast are using it successfully. The key might be managing it properly and keeping the annual bluegrass from invading the site.

Implications and Modifications

Performance factors such as tolerance to low mowing have been improved with many of the new bentgrasses and Bermudagrasses. However, there are some consequences from these developments. When the turfgrasses are mowed lower, ball roll distance (green speed) increases. This is forcing many golf course architects to design less dramatic undulations in their putting greens for fear of rendering the surface unplayable. Also, there are challenges to incorporating surface drainage into the design when surfaces are "flatter".

I often wonder why in our pursuit of turfgrasses that help superintendent's meet increasing golfer expectations, there weren't more turfgrasses that address society's interests. The 88% of the American public that does not care about green speed, does care about water use on golf courses as well as pesticides and fertilizers that could contaminate drinking water.

Paradoxically, genetically modified turfgrasses offer the best opportunity for rapid development of turfgrasses that meet society's needs. Yet it is this technology that inspires the wrath of that same society it might serve best. The ability to insert particular traits into turfgrasses needs more research.

Roundup Ready turfgrasses will be with us shortly and the debate will continue. How will we plant these turfgrasses? When is the best time? What is the best management program? Ultimately the real benefit of this technology will be realized when it is fully integrated into course design and management, not looked at in a vacuum.

Frank S. Rossi

Clippings

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Subsequently, the information is transferred in a meaningful way through the quarterly newsletter, *Cornell University Turfgrass Times (CUTT)*. Yet it seems that information is needed in a more timely fashion than ever before. Also, NYSTA members must be aware of research beyond New York's borders so that the best thinking can be brought to bear.

Several years ago the Cornell Turfgrass Team began the weekly electronic newsletter *ShortCUTT* to meet the needs of an information hungry industry. Not only is the information the latest, but it is delivered in a timely fashion, right when you need it—during the growing the season!

For 30 weeks, a succinct 2-page newsletter is emailed to NYSTA members with the latest weather records and forecast with exclusive access to a weather web site. Also, regional observations from experts in the field and an update from Frank Rossi. Finally there is a current topic that is discussed by the leading expert in the world. Much of the information is not available through any other source because of Cornell's unique access to university and industry experts.

The cost to you as a NYSTA member is supplying your email address. A major grant from NYSTA allows us to provide this service to members at no charge. So, send your email address today to shortcutt@nysta.org and be ready when the 2003 season begins.

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Need your irrigation water tested?

Not sure of the nutrient content of your fertilizers?

Need an inexpensive tissue nutrient test?

Check out the Horticulture Analytical Laboratory.

HORTICULTURE

Elemental/Nutrient

Analytical

LABORATORY

The Horticulture Elemental/Nutrient Analytical Laboratory is one of a small number of university laboratories nationwide dedicated to assisting growers and homeowners in evaluating the nutritional and environmental status of their plants, water and soil.

The lab has been performing plant nutrient analyses for growers and researchers since the 1950s. Cornell faculty work closely with lab personnel to provide fertilizer recommendations and consultations on growers' specific problems. Soil or plant samples may also be submitted for total carbon/nitrogen ratios.

In the last decade, lab services have expanded to include environmental testing of water, plants, amended soil, and sewage sludge. This provides homeowners, turf managers and municipalities with levels of potentially toxic heavy metals so that they can evaluate the safety of their environment. State-of-the-art plasma emission technology is used to provide simultaneous elemental analysis of 30 elements.

The Horticulture Elemental/Nutrient Analytical Laboratory is committed to quality data, and the operation is tested quarterly through the North American Proficiency Testing Service. Please contact the lab for more information on sample preparation, available services and prices. The Horticulture Elemental/Nutrient Analytical Laboratory, 20 Plant Science, Cornell University, Ithaca, NY 14853-5908; (607) 255-1785; www. hort.cornell.edu/department/facilities/icp/index.html.

Enhancing Precision Through Better Sprayer Design

One of the implicit goals of integrated pest management (IPM) programs is to add precision to turf management. The implementation of IPM begins with detailed records resulting from a comprehensive scouting program. The records will indicate location and population of specific pests. Once a pest reduces turfgrass quality, some form of pest management must be implemented. But, how precise are control methods? How time consuming are the management programs?

Pest control programs can be cultural, biological or chemical based. Mowing height can be increased to relieve stress, an organism can be introduced to antagonize a pest and reduce injury, or chemicals can be applied. While many strive for cultural and biological control, ultimately, chemical control is the cornerstone of modern pest management programs.

Application 101

The 1998 Virginia Turfgrass Industry Survey reported that the 318 golf courses in the state spent about $9 million on pesticides. The same courses spent another $4.5 million on the pesticide application, or approximately 5% of total labor expenses. Of course, mowing represents the largest portion of labor expenses, at 38%. Still, after mowing and irrigation (7%), pesticide application is the largest labor expense.

The labor involved in applying pesticides is more than simply operating the sprayer. Once a sprayer is properly calibrated to deliver the proper amount of material, pesticide handling follows. After application, the tank has to be triple rinsed, nozzles cleaned and rinsate managed. Often, pesticide handling occurs in dedicated areas to minimize the potential movement of concentrate that could contaminate water. Such handling areas can be costly, especially if large volumes of rinsate are to be handled.

Little has changed over the years in the basics of pesticide application. A tank is filled with water, pesticide is mixed in, then pumped under pressure to pipes that deliver it to nozzles and apply it to the turf. The amount of pesticide applied is determined by the mix concentration, pressure, ground speed, and nozzle type. Innovations have made applications more consistent and parts more durable but these have been evolutionary, not revolutionary.

Application Precision

Production agriculture has utilized a variety of new technologies to enhance pesticide application efficiency and reduce environmental pollution. One popular method has been the use of global positioning systems and geographic information systems (GPS/GIS). This technology identifies site-specific information that can regulate pesticide application.

Often referred to as precision agriculture, this approach has led to significant reductions in pesticide use with little or no added labor costs. This system is starting to be applied to turf management but has met with limited acceptance outside the irrigation field. The GPS/GIS approach could work for fairway turf, but the site-specificity of putting greens is on a smaller scale, creating practical challenges.

Direct-Injection

When Walt Smith, assistant superintendent at Missoula (Mont.) Country Club, wanted to make weekly light applications of materials easier, he found nothing on the market to meet his needs. He questioned why he was constrained by having to mix all the products in the tank with the water.

Mixing products in the tank limits the ability to alter application rates in the field. It leaves superintendents with no ability to apply different products to different areas. The only way to do so now is to mix up a separate tank. But this requires a significant amount of cleanup time to rinse a 100 gallon sprayer. In fact, studies from the Royal Agricultural College in Cirencester, U.K., conducted by Prof. Andrew Landers, found that decontaminating a 150 gallon sprayer required 500 gallons of water and took an hour. Interestingly, about 0.5 ounces of active ingredient remained in the tank.

At Missoula CC, Smith decided to revolutionize the application procedure. He procured various spray components that would be configured to allow the application of four different products without mixing them in the tank with the water. This type of system has been used in agriculture and also tested at Cornell University's Robert Trent Jones Golf Course.

The heart of the system is a proportional

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Program Spotlight

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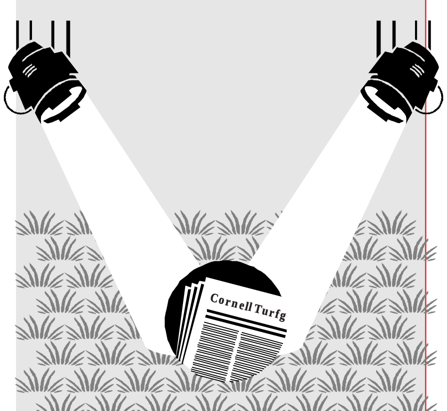
Evaluating Reduced and Nonchemical Turf Management

Program Spotlight

Golf turf managers faced with operating their facilities under constraints on the use of chemical technology need information on how to maintain acceptable, playable golf course turf. At the same time, those advocating pesticide restrictions need to be aware of the costs of implementing the policies and the resulting impacts on golf turf performance.



This project was designed to provide information on the feasibility and performance of golf course turf managed with an IPM approach to reduce or completely eliminate chemical pesticide use. The need for this information is urgent in light of recently passed and pending legislation in New York State and other regions of the country. Golf turf managers faced with operating their facilities under constraints on the use of chemical technology need information on how to maintain acceptable, playable golf course turf. At the same time, those advocating pesticide restrictions need to be aware of the costs of implementing the policies and the resulting impacts on golf turf performance.

Our objective is to evaluate the aesthetic and functional performance of golf putting greens managed under various cultural and pest management systems for feasibility, biological/physical response and golfer satisfaction. The project explores total management systems, as practiced by turf managers, rather than focusing on individual technologies and isolated practices. The work is being conducted on the Bethpage Green Course, Long Island, New York. This course accommodates more than 50,000 rounds of golf annually, has greens constructed of native sandy soil, and is typical of a high-use public course in New York State.

The experiment was designed as a 2 x 3 factorial, with 3 pest management and 2 cultural management regimes.

Pest Management

Unrestricted: All legal and currently available chemical pesticides in New York State may be used to manage pests, both preventatively and curatively. Practices similar to the Bethpage Black Course management were followed.

IPM: Pest management practices are determined by the specific needs of individual greens. Actions are based on scouting information, action thresholds (when feasible) and site history. Cultural and biological approaches to prevent and minimize pest problems are emphasized, but any legal practice or pesticide may be used. When pesticides are deemed necessary, the least-toxic one is selected based on potential risk factors such as water quality impact, effects on nontarget organisms and toxicity to humans. In this system, acceptable turfgrass performance is not intentionally sacrificed. Therefore, it is sometimes necessary to select a more toxic method in order to maintain expected performance (e.g. quality ratings above 6 on the NTEP rating scale and ball roll distance >2.4 meters) and to avert significant damage to or loss of turf. Prophylactic chemical treatments are used only when justified by significant site history of problems and lack of curative strategies that are acceptable in the risk assessment process.

Nonchemical: As in the IPM treatments, cultural and biological approaches to prevent and minimize pest problems are emphasized and decisions are based on the specific needs of individual greens. However, no pesticides registered in class I (danger), II (warning), or III (caution) by the EPA may be used. This mimics conditions legislated for implementation by 2003 and beyond in several municipally owned golf courses and other turf facilities in New York State.

Cultural Management

Current Standard: Cultural practices currently being employed at the golf courses of the Bethpage State Park.

Alternative: Modified Bethpage cultural practices that are expected to reduce turfgrass stress and minimize pest problems, while striving to maintain minimum performance standards (e.g., quality ratings above 6 on the NTEP rating scale and ball roll distance > 2.4 meters). Practices such as double-cutting and rolling are implemented if necessary to maintain these performance standards.

The experimental design results in six management systems as shown in Table 1. Each green serves as a replicate, and we are using all 18 greens of the Bethpage Green Course to accommodate 3 replications of the 6 management systems.

Table 1. Treatment Regimes

Pest Management	**Cultural Practices**	
	Current Standard	Alternative
Unrestricted	I	II
IPM	III	IV
Nonchemical	V	VI

System I is typical management for a high quality public golf course. Systems III and V, are the same management systems with restrictions on pesticide use. The standard and alternative cultural practices are summarized in Table 2. Practices were frequently adjusted during the season to respond to turfgrass quality and weather conditions.

- A winter compost cover of AgreSoil to reduce disease severity.

2002

- Increased fertility to aid recovery from dollar spot injury, increased use of ammonium sulfate and use of Sustane fertilizer.
- Regular applications of *Trichoderma harzianum* (TurfMate).

Table 2. Cultural Management Practices

Practice	Cultural Management: Standard	Cultural Management: Alternative
Mowing Ht. Range (bench settings; mowing performed with triplex units)	2.8–3.6 mm (0.110–0.140")	3.8–4.8 mm (0.175"–0.188") *except velvet bentgrass, mowed at 3.3 mm (0.130")
Mowing Frequency	1x/day, 7 days/week	2x/day, 5 days/week 1x/day, 2 days/week
Roller	groove	solid
Irrigation	automatic, 3-4:00 AM	manually activated, 6-8:00 AM
Hand Watering	when wilting visible	water known dry spots prior to wilting
Fertilization	1/8 to 1/4 lb. N every 2-3 weeks	1/8 to 1/4 lb. N every 2-3 weeks + 1/8 lb. Amm. Sulfate
Topdressing	every 2-3 weeks	weekly, no brushing
Rolling	1x/week	3x/week (if needed for ball roll)
Vertical Mowing	occasional	every 2-3 weeks except during stress periods
Hydro-Ject	occasional	every 3 weeks, May-Sept.
Clean Up Pass	4x/week	2x/week

*Practices adjusted to attain >2.6 m (8 ft) ball roll distance

The three greens in system VI were renovated to velvet bentgrass in November 2001. These greens required a different cultural regime than others in the alternative culture treatments. In June 2002, the course was closed for approximately 14 days during the U.S. Open Championship. At that time, the velvet bentgrass greens were quad tined twice, cores were processed and greens overseeded with SR 7200 velvet bentgrass seed at a rate of 1 pound per 1000 square feet.

Some cultural and biological practices were employed specifically to prevent or reduce pest problems. These practices were implemented on some or all of the nonchemical and IPM greens (when and where appropriate), such as:

2001

- Rolling greens in the morning to reduce incidence and severity of dollar spot.
- Increased fertility to aid recovery from dollar spot injury.
- Application of entomopathogenic nematodes (*Heterorhabditis bacteriophora*) against annual bluegrass weevil larvae and cutworm caterpillars.
- Manual removal of weeds.
- Green closure to reduce traffic and allow for renovation (2 greens, 2-3 months).
- Renovation with velvet bentgrass (discussed in results section).
- Manual removal of weeds.
- Green closure to reduce traffic and allow for recovery (1 green, 3 weeks).
- A winter compost cover (will occur only if ground freezes).
- Occasional applications of compost tea.
- Nutrigrow phosphite product for summer stress or decline.
- Standard fertility supplied with kelp based materials from Turf Products.

Performance Management and Pest Evaluations

Putting greens systems were evaluated throughout the growing season for aesthetic and functional performance, pest occurrence, species population dynamics, and tissue and soil nutrient content. Greens were inspected 3-6 times per week for signs and symptoms of disease-causing organisms, agronomic stress, insect pests and weeds. Occurrence was mapped and quantified. Additional insect monitoring techniques such as irritant sampling (soap flushes), cutworm pheromone traps, pine litter flotation and soil core examination were used

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Nonchemical Turf Management

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at appropriate times to detect and quantify insect populations. In 2002 bimonthly, putting green visual quality was assessed using the NTEP rating system (1-9, with 1= dead turf, 9= ideal turf and 6= acceptable turf) from August through October. Ball roll distance was measured with a Stimpmeter (6 rolls at designated permanent location on green, 3x in 2 directions) for monitoring and adjusting treatment practices, but was not recorded as a quality indicator in 2002. Annual bluegrass populations have been monitored approximately once a month since the beginning of the project using the point quadrat method. Samples were taken to monitor populations of free-living and plant parasitic nematodes in 2001 and will be again in 2003.

Economic Analysis and Golfer Satisfaction

In an effort to address the practical implications of each management system, this project is accounting for feasibility and end-user satisfaction with golfer surveys and economic analysis. Additional costs for labor and materials for each management regime are being recorded and will be comprehensively analyzed in 2003. A golfer satisfaction survey will also be conducted in 2003.

Results: Pests and Pest Management

In the first year, dollar spot was the primary pest in all treatments throughout the season. It was the target of most pesticide applications made, and severely reduced the visual and performance quality of the nonchemical greens. Anthracnose was also problematic at times on greens cut at lower heights, but was usually considered to have stemmed from turfgrass stress rather than primary pathogenic agents. Brown patch was the target of at least one fungicide application on the unrestricted pest management greens, but did not result in loss of turf on any greens. Other diseases were occasionally detected, but were not the target of pesticide applications and did not result in loss of turf.

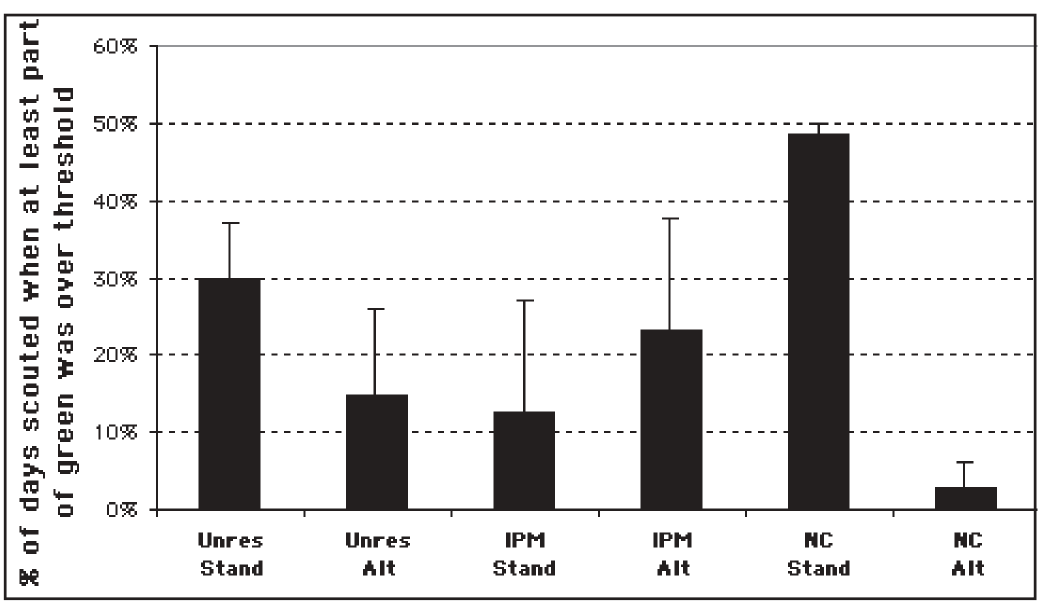
Velvet bentgrass is a regionally adapted turfgrass species known to be resistant to many turfgrass diseases encountered in the northeastern US. We considered use of this grass to be a radical attempt to culturally minimize disease occurrence and severity. Therefore, the three nonchemical, alternative culture greens were stripped of their poa/creeping bentgrass cover in November 2001, and sodded with velvet bentgrass. In addition to the resodding of greens, two of the three collars were resodded with Kentucky bluegrass to minimize weed encroachment—especially of annual bluegrass which is highly disease susceptible and can pro-

In the first year, dollar spot was the primary pest in all treatments throughout the season. It was the target of most pesticide applications made, and severely reduced the visual and performance quality of the nonchemical greens. Anthracnose was also problematic at times on greens cut at lower heights, but was usually considered to have stemmed from turfgrass stress rather than primary pathogenic agents.

Velvet bentgrass is a regionally adapted turfgrass species known to be resistant to many turfgrass diseases encountered in the northeastern US. We considered use of this grass to be a radical attempt to culturally minimize disease occurrence and severity.

Figure 1.

Dollar Spot: Percent of days scouted when any part of the green was over threshold.



vide inoculum for spreading pathogens onto the green. Another significant change was the removal of trees around several greens (#2, 3, and 7). However, these greens were targeted because of shading problems, not according to their cultural or pest management treatments. In addition, all nonchemical and IPM greens (except the newly sodded velvets) were covered with compost (1/4 to 1/2 inch thick) from late December to early February for microbial protection from snow mold. The compost cover blew off a few greens requiring a second application of compost to be applied in January to several greens. The use of the biological control agent *Trichoderma harzianum* on the IPM and nonchemical greens and the fertilizer Sustane (exclusively on the alternative culture greens) may also have impacted disease occurrence and severity in 2002.

In 2002, dollar spot remained the primary target of pesticide applications. The disease was first detected on May 12, and was over threshold on 1-40% of the area of four greens during May. All of these greens were managed with "unrestricted" pest management (3 standard culture greens, 1 alternative), and the first dollar spot fungicide was applied on May 23. Dollar spot was most severe on the nonchemical pest management, standard culture greens (Fig. 1). Areas of these greens did not go over threshold until late June, but then rose dramatically and rapidly in July (Fig. 2). One emergency fungicide application was made to these three greens on August 5th, and subsequent disease levels were low in August. Dollar spot severity climbed to high levels again in late September, but subsided in October, and acceptable quality was maintained (discussed later).

Fairy ring became a prevalent and sometimes severe problem in 2002 (Fig. 3). We associated its occurrence with greens that had been covered in compost the previous winter, and the velvet bentgrass sod. The disease was often severe enough to create hydrophobic conditions and was managed with wetting agents, hydrojecting and fungicides on the IPM greens. Anthracnose was negligible in 2002. Rhizoctonia, however, became more prevalent and was most severe in the nonchemical pest management treatments (Fig. 4).

Insects of significance were black cutworms and annual bluegrass weevils (ABW). In 2001, an application of the biological insecticide *Heterorhabditis bacteriophora* nematodes was targeted for second generation ABW control with the benefit of cutworm population reductions also expected. Nematodes were not applied in 2002 because of their expense and apparent lack of efficacy the previous year. It should be noted, however, that nematode-infected ABW have been detected at low levels in both years. In 2002, the six unrestricted pest management greens each received four insecticide treatments, for management of ABW (1), grubs (1) and cutworms (2). The IPM greens received an insecticide application for cutworms in early July, and again in early September. Cutworm damage was significantly worse on the velvet bentgrass than its poa/creeping bentgrass counterpart (Fig. 5), but no specific insect management actions were taken.

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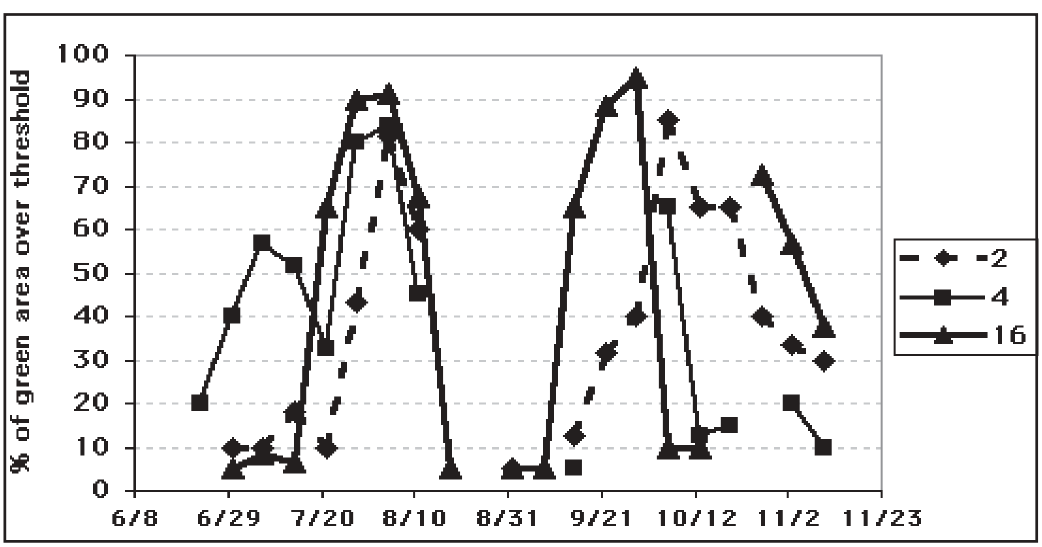
Figure 2

Dollar Spot on nonchemical, standard culture greens



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Nonchemical Turf Management

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Weed concerns in both years were dominated by crab and goosegrass in the poa/creeping bentgrass greens, and *Poa annua* was considered a weed in the new velvet bentgrass greens. Goosegrass incidence was much higher in the standard cultural treatments as opposed to the alternative treatments (Fig. 6). However, differences were not significant due to high variation among greens. Weeds were removed manually from IPM and nonchemical greens, and were treated by one herbicide treatment to all unrestricted greens in both 2001 and 2002. Some IPM greens were also treated, 4 in 2001 and 2 in 2002. Note that both greens requiring treatment this year were in the standard cultural treatment.

The number of chemical pesticide applications is summarized in Table 3. In both years, most pesticide applications that were avoided on IPM greens occurred early in the season, before dollar spot was fully and widely established. This year, the three nonchemical, standard culture greens received one emergency fungicide application in early August. No chemical pesticides were used on the velvet bentgrass greens.

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Figure 3

Fairy Ring: Percent of days scouted when any part of the green was over threshold

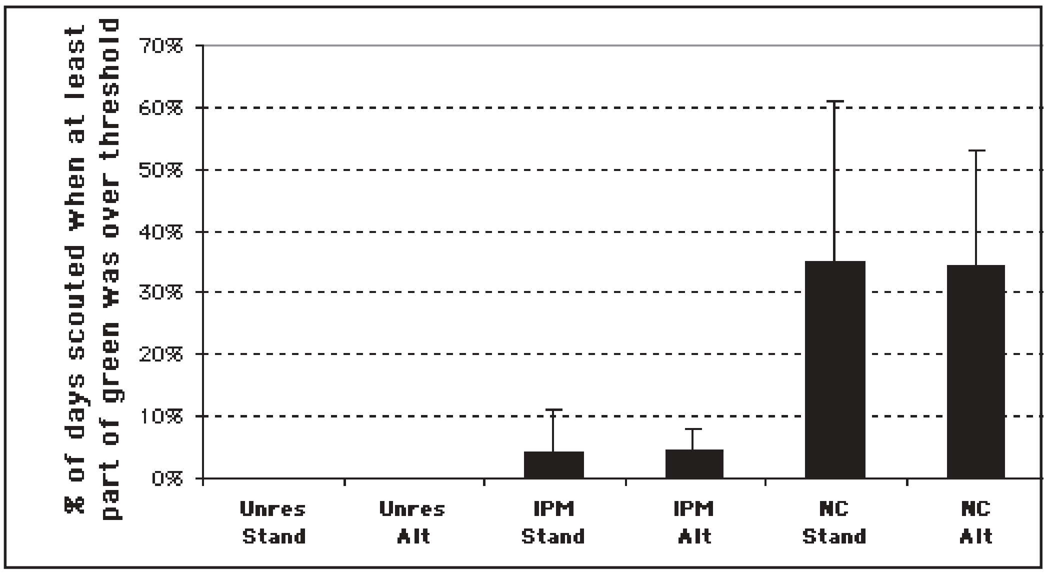

Figure 4.

Rhizoctonia: Percent of days scouted when any part of the green was over threshold

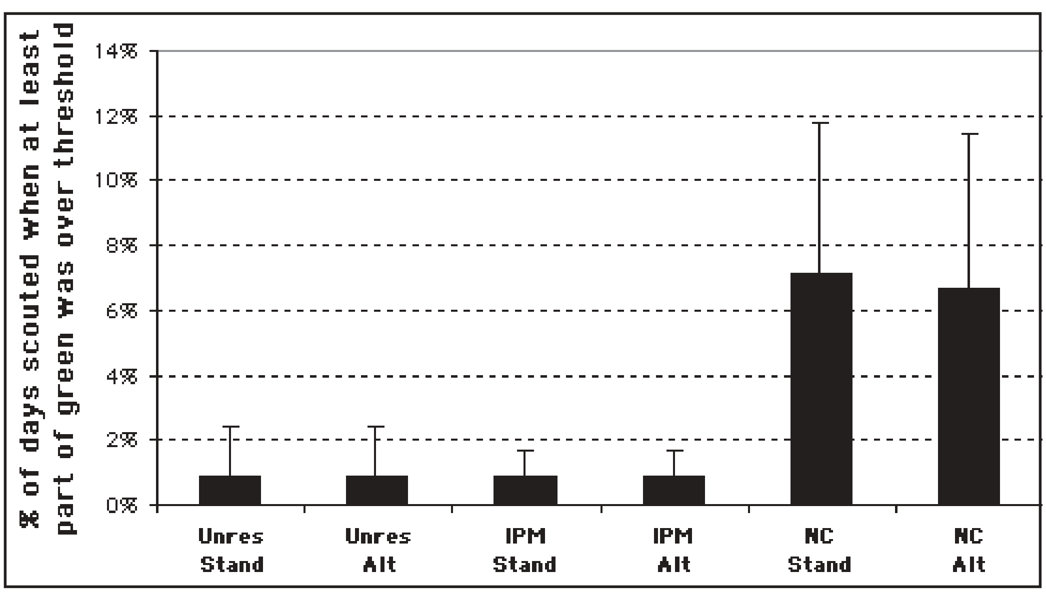

Figure 5

Black Cutworm Damage: Percent of days scouted when any part of the green was over threshold

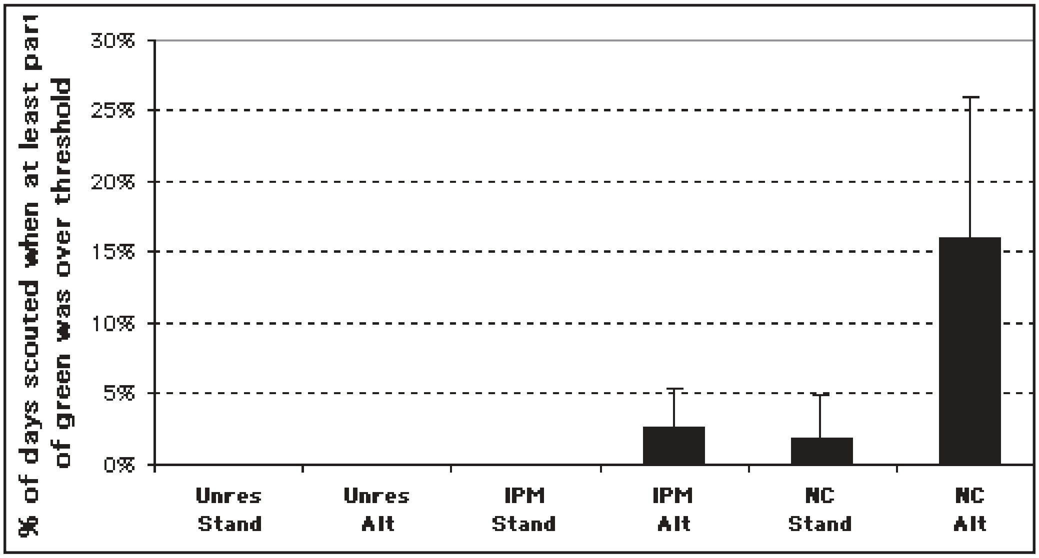

Figure 6

Goosegrass: Percent of days scouted when any part of the green was over threshold

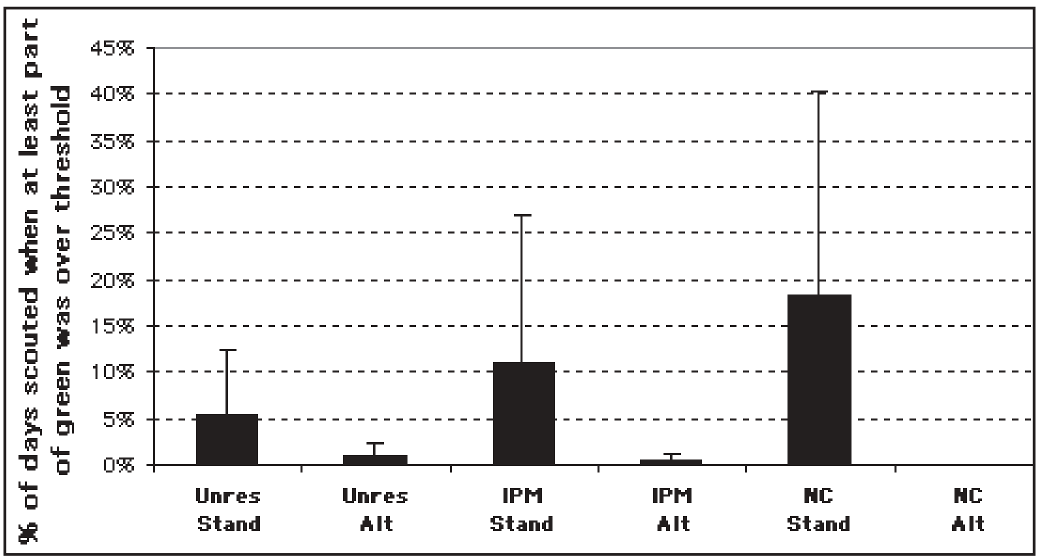

Table 3. Mean Number of Pesticide Applications in Unrestricted and IPM Pest Management Systems

	Unrestricted	IPM—Standard Culture (reduction)		IPM—Alternative Culture (reduction)	
2001					
Insecticides	2	1	-50%	1	-50%
Herbicides	1	0.67	-33%	0.67	-33%
Fungicides	11	8	-27%	7.67	-30%
Total	14	9.67	-31%	9.34	-33%
2002					
Insecticides	4	2	-50%	2	-50%
Herbicides	1	0.67	-33%	0	-100%
Fungicides	14	10.3	-26%	8.30	-41%
Total	19	12.97	-32%	10.30	-46%

Nonchemical Turf Management

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In 2002, the quality of the nonchemical standard greens was very low in August, but was acceptable in September. The velvet greens were marginally unacceptable in August but also improved in the fall. In all treatments, the quality of the alternative culture greens was usually higher than their standard culture counterparts.

Other labor issues to be considered are that many of these tasks must be performed early in the morning in order to be effective, and scouting time may double if the scout does not stay ahead of golfers when play is heavy.

Visual and Performance Quality

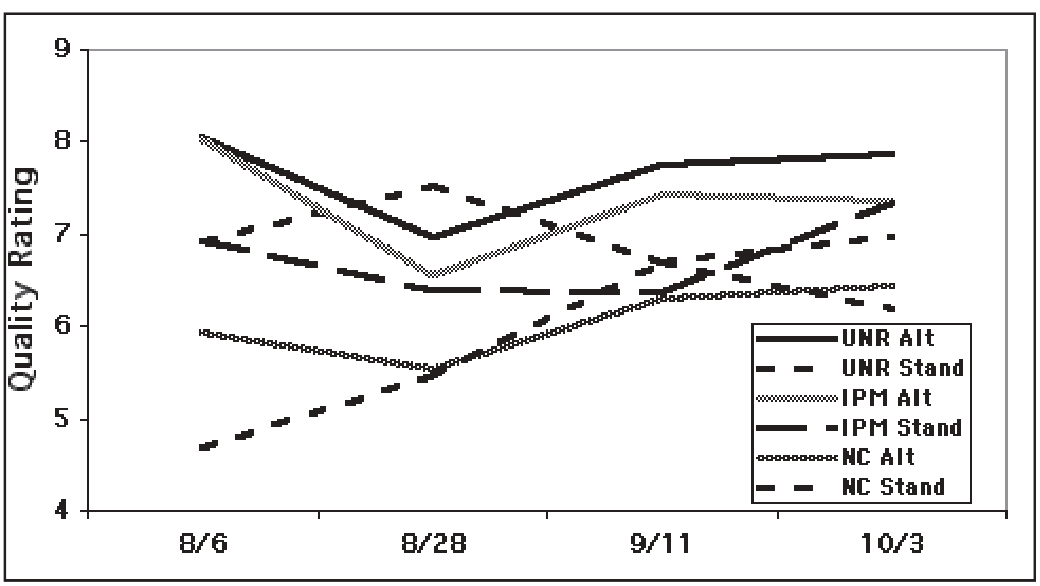
In 2001, the quality of all greens was below acceptable in the early season, but quality of 5 of the 6 IPM greens equaled that of the unrestricted treatments. In 2002, all IPM and unrestricted treatments maintained acceptable quality throughout the season (Fig. 7). In 2001, quality of all nonchemical greens was unacceptable as of late August to early September, resulting in closed or very low quality greens for the remainder of the season. In 2002, the quality of the nonchemical standard greens was very low in August, but was acceptable in September. The velvet greens were marginally unacceptable in August but also improved in the fall. In all treatments, the quality of the alternative culture greens was usually higher than their standard culture counterparts.

Turfgrass Populations

Annual bluegrass populations were monitored throughout both seasons. Incidence ranged from 67-100% in 2002, and 27-100% in 2002 (except the velvet bentgrass greens which were all < 1%) (Fig. 8). Counts did not differ by management regime in the first season. In 2002, the poa counts in the creeping bentgrass greens were lowest in the nonchemical, standard culture greens, but were not significantly different.

Figure 7.

Quality Ratings 2002 (< 6 is unacceptable)



Labor

Increased labor needs are an obvious component of both IPM and nonchemical management. Basic scouting requires 2-3 hours a day, and additional time when specific measurements or sampling protocols must be done (e.g. insect flotations, poa population counts). Other practices essential to these management regimes are listed as follows, with the approximate amount of labor hours required to perform each duty on 18 holes: Rolling (5 hrs), topdressing (6-8 hrs), hydrojecting (6 hrs), verticutting (4 hrs), double cutting (4 hrs), hand watering (5-8 hrs), and manual weeding (variable). In addition, extra time was spent repairing and fine tuning the irrigation system, mixing small individual batches of pesticides, and keeping maintenance equipment in excellent condition for proper IPM.

Other labor issues to be considered are that many of these tasks must be performed early in the morning in order to be effective, and scouting time may double if the scout does not stay ahead of golfers when play is heavy. The Bethpage Green Course operates with one course supervisor, one IPM scout, 4 full-time and 2 part-time employees. This count does not include other park employees such as mechanics and the irrigation specialist, and interns that are sometimes available during the summer months. Nevertheless, it was very difficult for them to carry out the practices mandated by the various management systems in this experiment. A few tasks were made more labor in-

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tensive by the nature of the experiment (e.g. mowing at 2 different heights). However, most labor needs would be multiplied when implementing one of the management regimes on all 18 holes of a golf course. The course supervisor estimates that a minimum of 9-10 employees would be necessary to replicate the IPM or nonchemical systems on an 18 hole course.

Discussion

In 2001, no clear differences were seen between the quality of greens managed with standard vs. alternative cultural practices. In 2002, the alternative culture greens generally performed better in all pest management treatments. Less pesticide was also required to maintain alternative greens under both the IPM and nonchemical strategies. Overall, quality was highest in the unrestricted pest management, alternative culture greens. Also, the quality of the IPM alternative culture greens was usually higher than that of the unrestricted standard culture greens. This demonstrates two management strategies that may be superior to those currently practiced on many public golf courses. However, it must be noted that we had difficulty maintaining acceptable ball roll distances (> 8 ft.), especially on the alternative culture greens.

All greens that received the compost application greened up more rapidly in spring and produced significantly more clippings than the non-composted treatments. In addition, there was general consensus that the compost cover may have aided in reducing early season dollar spot invasion. One of the greens that is typically among the first infected in the park did not show symptoms of dollar spot until mid-June this year, a month later than other areas. A conundrum we faced was that increased fertility in the early season resulted in healthy turf with high density and rapid growth that prohibited us from achieving acceptable ball roll distances. Several attempts were made to vertical mow and thin the turf, but we were not able to reconcile the desire for a healthy turf stand with the unacceptable ball roll distances in the mid 7 foot range.

The spoon feeding approach on the standard cultural management greens provided acceptable turf quality, but we still had difficulty attaining ball roll distances in excess of 7.5 feet. Soil tests indicated a significant lack of potassium, whereas tissue tests did not reveal the deficiency—possibly a result of the light frequent fertilizer approach. Furthermore, we often fell behind on the 1:1 N:K ratio we strove for, yet tissue samples did not reveal any deficiencies.

The alternative cultural systems utilized Sustane 5-2-4 fertilizer to supply greater than 50% of the nitrogen for the season. The remaining N was supplied with ammonium sulfate in an effort to reduce surface pH and thereby minimize certain pathogens of annual bluegrass associated with higher surface pH. Also, elemental sulfur was applied (3 pounds per 1000) to the velvet greens in an effort to reduce the pH. Theoretically, this would make the surface more hospitable to the velvet bentgrass and less so for the annual bluegrass.

The fertility on the velvet bentgrass was considerably higher than we expected it would be yet the surfaces still appeared to be off-color for much of the season. Also, while there has been concern for the recuperative potential of velvet bentgrass, we found no evidence to suggest that the velvet was any less tolerant of the 50,000+ annual rounds of play than the previous mixed stand of creeping bentgrass and annual bluegrass. The velvet, however, was more attractive to cutworms and perhaps more susceptible to their damage.

The major disease this season on the velvet bentgrass was fairy ring—thought to have been brought in on the sod from Rhode Island. While the disease was visually problematic, it did not scar the surface severely and did not appear to disrupt ball roll. The collar of one velvet green was not resodded to Kentucky bluegrass and had high populations of annual bluegrass that was infested with dollar spot. We believe that pressure from this inoculum built up over the season, which eventually resulted in over 50% of the green being over threshold levels for dollar spot in October. Only one of the two other velvet greens ever went over threshold for dollar spot, and that was only 5% of the green for a brief period in October. These observations are critical, as they suggest the role of inoculum, pressure, and the need to renovate an entire area (not just the putting surface) when expecting to reduce pesticide use.

Pesticide use in the IPM systems could have been reduced further in both 2001 and 2002 if it were easier for the superintendent to quickly respond to rising pest levels. Currently, a sprayer is not always available for the Green Course, because equipment is shared among the five

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Nonchemical Turf Management

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This prototype unit would allow the operator to change active ingredients and rates on the fly, thereby minimizing the need to refill with separate additives. For example, if the front of a green was diagnosed as being above threshold but the rest of the green was not showing symptoms, just the front would be treated with the curative rate. The remaining green would either not be treated, or treated with a preventative (typically lower) rate and thereby reduce overall usage.

courses at Bethpage. Also, the large spray tank makes small spot treatments difficult. These factors encourage the superintendent to include IPM greens when spraying the unrestricted greens. To solve this problem, we sought an injection sprayer that could easily apply small quantities of material in a custom fashion and would be designated to the Green Course only. Such a machine was donated in 2002 by the Toro company and Raven Technologies. This prototype unit ($40,000) would allow the operator to change active ingredients and rates on the fly—thereby minimizing the need to refill with separate additives. For example, if the front of a green was diagnosed as being above threshold but the rest of the green was not showing symptoms, just the front would be treated with the curative rate. The remaining green would either not be treated, or treated with a preventative (typically lower) rate and thereby reduce overall usage. The sprayer was not in full working order until late in the season, so had little impact on 2002 practices. We expect significantly greater reductions in pesticide use in the IPM systems in 2003 because of this enhanced ability to spot treat.

Additional biological products are being assessed and reviewed for performance during the winter season, and will be incorporated into future management systems if data suggests adequate efficacy. Similarly, cultural modifications such as mowing in the very early morning for cutworm control will be added as appropriate. A few course improvements will also be made such as resodding the collar around the third velvet bentgrass green.

Economic Analysis

A major goal of this project is to assess the economic impact of each management regime. We are collecting data on the cost and labor required for all practices, and will provide a detailed analysis of the cost of each regime after the 2003 season. We are also monitoring the level of play to see if golfer loyalty to the Green Course is maintained, and next season we will survey golfers to determine their satisfaction specifically with each management regime.

Implementation of this project has already impacted the reputation and perhaps the revenues of the Green Course. Outings on the Green Course were cancelled for the late summer and fall of 2001 because of the poor condition of several of the nonchemical greens, and the number of outings for 2002 was reduced. Bethpage State Park luckily has the unique situation of having 5 contiguous golf courses. The park superintendent believes that most golfers who are aware of and are upset by conditions on the Green Course, simply play an alternate Bethpage course. A solitary golf course with playing conditions similar to our nonchemical treatments would likely lose customers. Meanwhile, we continue to strive to improve the quality and performance of all greens, under all management systems, in this project.

Jennifer A. Grant and Frank S. Rossi

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Sprayer Design

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injector similar in concept to what homeowners use as hose-end applicators. Small amounts of chemical are injected into the spray line immediately prior to the solution leaving the nozzle. This allows the operator to select the products to apply during the application. It reduces the time and space dedicated to pesticide handling and reduces clean up because the large water volume in the tank is not mixed with product.

From an IPM perspective, a direct injection sprayer can utilize precise records, possibly including GPS/GIS information, that can treat small areas with only the products needed. For example, if the back corner of a putting green is prone to pythium blight and the walk-on/walk-off area is prone to dollar spot, they will require different chemicals—especially as each area does not suffer the other disease.

Traditionally, the entire green is treated for pythium with a traditional sprayer. Then, the chipping area beyond the green is treated for dollar spot. This is done either by tank mixing products or with two sprayers. A direct injection sprayer, by contrast, allows the operator to apply one active ingredient to one area and another ingredient to a separate area, resulting in significant overall reductions in pesticide use without any reduction in turfgrass quality. The right product can be applied at the correct rate to the affected area. For example, Smith reported in the March/April issue of the *USGA Green Section Record* that Missoula CC has reduced applicator exposure to pesticides, sprays 17 acres in 2.5 hours, using only 25 gallons of water to decontaminate a 100 gallon system.

Oddly, this approach has not received much attention from golf course superintendents. It is not widely used in the industry. In a raw survey of sprayer companies at the 2002 GCSAA show, I found only one out of ten companies were aware of this technology. It is possible that superintendents would be wary of not treating an entire green if a disease is noticed in one area, or possibly that most treat preventively to avoid the possibility of injury that would require curative control. Still, the labor reduction and environmental benefits of eliminating large volumes of material should be welcomed.

The Future

As superintendents become familiar with their golf courses, they are able to predict specific problem areas or observe subtle color changes that might require fertilization. This familiarity is as much an art as a science because many of the pest and nutrient challenges are not well understood or scientifically predictable. In the end, the action might require chemical application. As mentioned previously, this is not always as precise as we might like.

Researchers at Oklahoma State University, led by Professor Greg Bell, have been investigating the use of optical sensing and variable rate technology to more precisely apply fertilizer based on turf nutrient needs. The optical sensing devices are mounted on the sprayer and are able to assess the color and the tissue nitrogen level in one half square foot increments.

Once the sensors assess the nutrient needs a signal is sent to a system that controls the application rate. The rate is adjusted accordingly and applies the amount of material needed to bring the turf to sufficient nitrogen content. The device used by the OSU researchers had the ability to apply 15 different rates of fertilizer.

The system has been evaluated for weed control in agriculture. The optical units can detect different plant species and apply herbicide only where an undesirable species is present. It might be possible in the future to detect pathogen infection before disease symptoms are obvious, allowing disease control before injury and potential overall reductions from site specific management.

With all the attention paid to reducing pesticide use in turf, little attention seems to be focused on application systems. This seems odd with so little success achieved with biological control of turf pests, increased turf stress that creates new pest challenges, and development of pesticide resistance from chronic use.

Real reductions in pesticide amounts could be realized when an effective scouting program is used in conjunction with GPS/GIS and more precise sprayer technology. With small investments in equipment, significant labor reductions, maintain turf quality and reduced risk to the environment, we could have a revolution in pest management.

Frank S. Rossi

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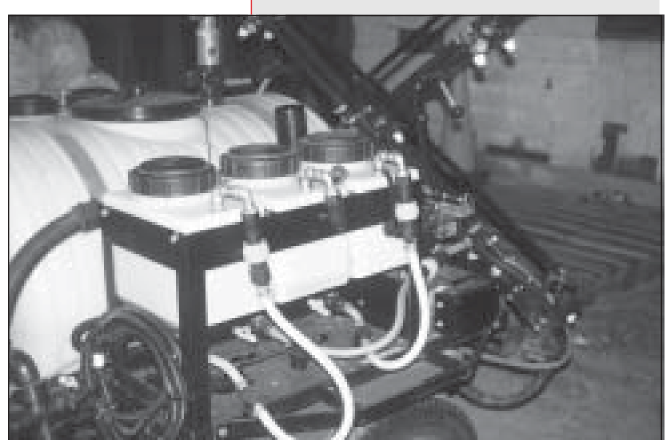

Side view of prototype injection sprayer donated to the Bethpage project by Toro and Raven Technologies.

Biological Control

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tion frequency. Some inoculants, however, were strongly affected by application timing. In each of the two years of the study, *Enterobacter cloacae* strain EcCT-501 and *Pseudomonas aureofaciens* strain Tx-1 were significantly more effective in controlling dollar spot following nighttime applications than when applied during the daytime. *Azospirillum brasiliense* strain Cd-1 was inconsistent in dollar spot control but unaffected by application timing and frequency. *Trichoderma harzianum* strain 1295-22 was also unaffected by application timing and frequency.

Populations of *E. cloacae* and *P. aureofaciens* were introduced at ~10^7 cells/g dry wt rhizosphere soil. When applications ceased, populations declined, independent of the application frequency or timing, one to two orders of magnitude after a three-week period. These results indicate that the time of day in which some microbial inoculants are applied may strongly influence their efficacy. Such improvement in efficacy is most likely due to the synchronization of biological control activities with the activities of the pathogen.

Mechanisms of Biological Control

Inconsistent performance of microbial inoculants may be related to inconsistencies in the expression of specific traits critical to pathogen and disease suppression. Knowledge of the manner in which pathogens and diseases are suppressed by microorganisms and how the expression of these mechanisms is regulated is critical to the development of strategies for ensuring consistent and efficacious performance. Nearly all of the studies on biological control mechanisms have come from studies with crop plants other than turfgrasses. However, many of the same processes may also play important roles in turfgrass ecosystems.

Of the traits common to soil microbes, there are at least three that have been consistently linked with biological control processes. These include 1) antibiotic biosynthesis, 2) resource competition, and 3) hyperparasitism. Some microorganisms may express various combinations of these mechanisms for successful biological control.

Antibiotic biosynthesis. Antibiotic biosynthesis, particularly in bacterial systems, has been the most commonly studied trait related to biological control. Antibiotic compounds produced by species of *Pseudomonas*, *Bacillus*, and *Streptomyces* are known to play key roles in the biological control of *Pythium*, *Rhizoctonia*, and *Gaeumannomyces* diseases and, more recently, have been shown to play roles in the suppression of *Sclerotinia homoeocarpa* and *Drechslera poae* in bentgrass and Kentucky bluegrass, respectively.

A number of ecologically important antibi-

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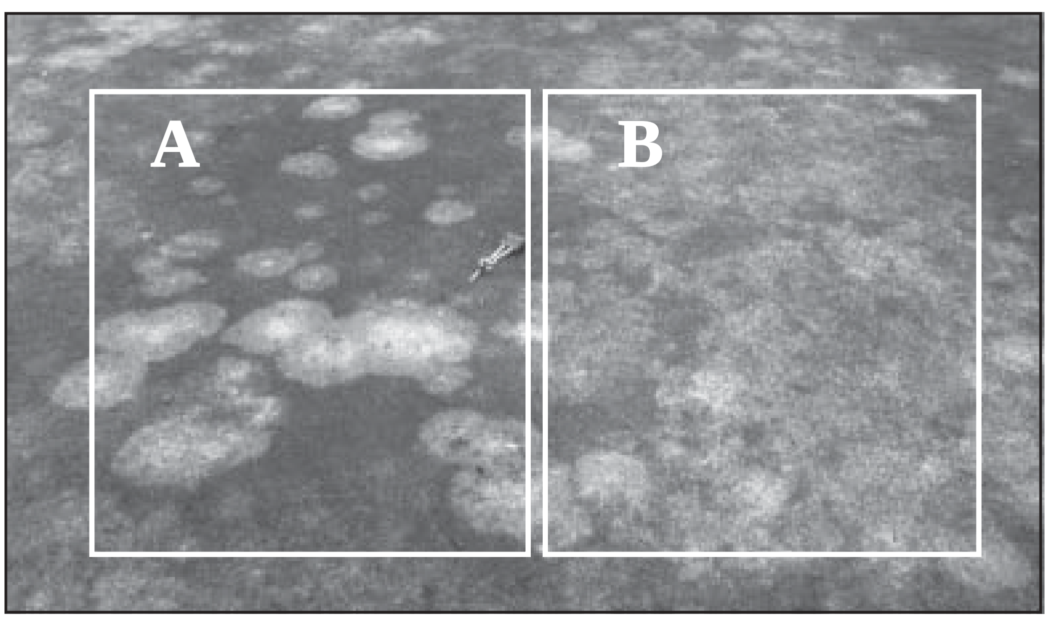

Differential suppression of snow mold diseases on creeping bentgrass putting greens with topdressing applications of a turkey litter compost (Sustane). A) compost treated plot. B) nontreated plot. Plots were treated with compost at the rate of 20 lbs./1000 ft^2 at monthly intervals the entire previous season. The photo was taken the following April.

otics have been described in biocontrol systems, including pyrollnitrin, pyoluteorin, 2,4-diacetylphloroglucinol, phenazine-1-carboxylic acid, and oomycin A. New antibiotics are constantly being described that could potentially play important roles in the biological control of plant diseases. The majority of studies on antibiotic biosynthesis and its relation to biological control have been limited primarily to fluorescent *Pseudomonas* species; the majority of research encompassing only 5 to 10 strains of *Pseudomonas fluorescens*, a few strains of *P. aureofaciens*, and a couple of strains of *P. putida*. Compelling evidence now exists for the link between production of antibiotics in the rhizosphere and the role of these antibiotics in suppressing root rot.

Resource competition. Microbial competition often occurs when two or more microorganisms compete for the same nutrient resource. Despite the fact that competition has been proposed as a mechanism of biological control, no definitive evidence to support this hypothesis currently exists. Although intuitively, competition should be an important mechanism of biological control, the complexities of the soil environment make the proof of competition mechanisms difficult to obtain. The best current examples of competition in biological control are competition for iron and seed exudate fatty acids.

Siderophore-mediated iron competition. Siderophores are low molecular weight iron chelates that are produced by many soil microbes under iron-limiting conditions. They chelate ferric iron and serve as a major vehicle for iron transport into microbial cells. Nearly all organisms produce siderophores, but those produced by species of *Pseudomonas* and enteric bacteria generally have higher affinities for iron than do other fungal siderophores. In a number of specific pathosystems, the biological control of soilborne pathogens has been attributed to the production of siderophores, whereas in other cases no role for siderophores in biological control processes can be found. Although siderophore competition has generally been considered a direct form of biological control, it is possible that some siderophores may be acting indirectly by enhancing natural plant defense mechanisms under iron-limiting conditions. More work is needed to resolve the functional relationships between siderophore production and biological control.

Fatty acid competition. Seed and root exudates play an important role in the initiation of soilborne plant diseases by serving as stimulants of fungal propagules. Without the release of stimulatory molecules in these exudates, pathogenic relationships between plants and soil pathogens do not occur. Recently, there has been interest in understanding the interaction of biocontrol organisms with stimulatory components of seed and root exudates. Since soilborne fungal pathogens are highly dependent on exudate molecules to initiate plant infec-

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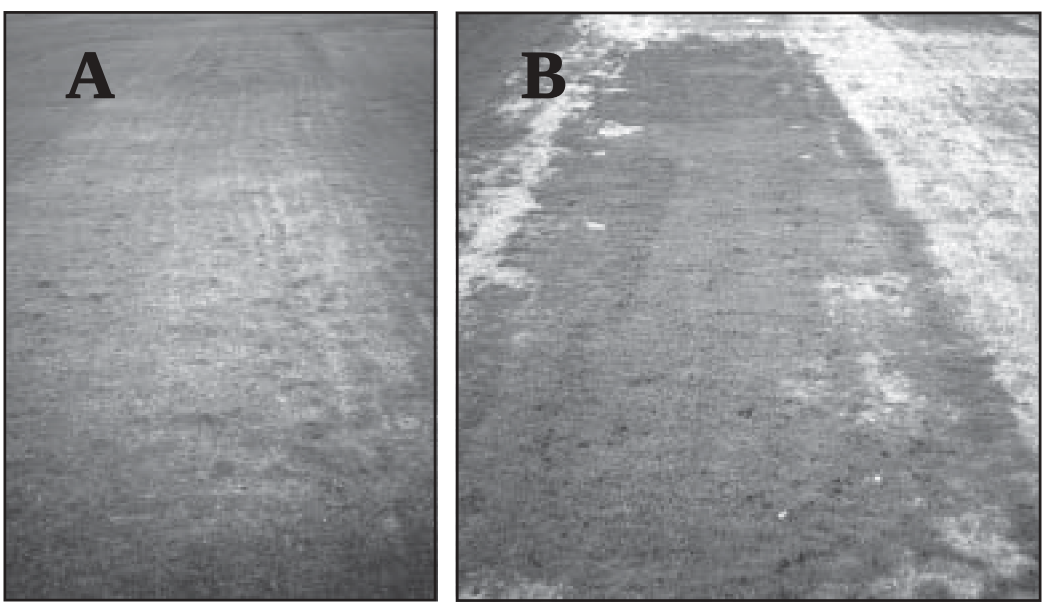

Establishment of creeping bentgrass on unamended or compost-amended sand-based root zones. A) seedling stands 6 weeks after seeding into 100% silica sand root zone. B) seedling stands 6 weeks after seeding into silica sand root zone amended with composted brewery sludge at the rate of 20% by volume.

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tions, microbial interference with the production and activity of exudate stimulants could be an effective mechanism of biological control among seed-applied spermosphere bacteria.

Recent studies have shown that *Enterobacter cloacae* strain EcCT-501 and other seed-associated bacteria that are effective in suppressing *Pythium* seed rot and damping-off of various plant species can also reduce the stimulatory activity of plant seed exudates to sporangia of the seed-rotting Oomycete, *Pythium ultimum*. Many of the seed-associated bacterial strains tested could reduce the stimulatory activity within 24 hours to levels supporting germination of less than 20% of *Pythium sporangia*. In particular, strains of *E. cloacae* can rapidly metabolize linoleic acid, a major *Pythium*-stimulatory molecule found in seed exudates, making it unavailable for the stimulation of *Pythium* pathogenesis. Strains of *E. cloacae* deficient in fatty acid metabolism fail to protect bentgrass seedlings from infection by *P. ultimum*, *P. graminicola*, and *P. aphanidermatum*.

Hyperparasitism. Hyperparasitism is a complex process by which microorganisms parasitize other microorganisms. This process is generally mediated by the attachment and production of cell wall degrading enzymes, such as chitinases, glucanases, and proteinases, by the biocontrol strain that destroys the host (i.e., turfgrass pathogen) cell. Species of the biocontrol fungus *Trichoderma* are well known for this property. However, to date, there is no proof that this process plays a significant role in the biological control of turfgrass diseases by *Trichoderma* and other mycoparasitic fungi.

Bacteria may also be parasitic to pathogenic fungi. In these cases biocontrol efficacy is mediated by the production of chitinase enzymes. *Serratia marcescens* is known not only for its chitinase production, but also for its activity as a biological control agent for soilborne diseases, including summer patch on KBG caused by *Magnaporthe poae*. Much of the success of *S. marcescens* as a biological control agent is believed to result from its production of chitinolytic enzymes inhibitory to chitin-containing soilborne fungi. Similarly, strains of *Stenotrophomonas maltophilia* that produce chitinase are also effective in suppressing *Magnaporthe poae Bipolaris sorokiniana*, and *Rhizoctonia solani*.

Commercialization of Microbial Inoculants

One of the greatest disappointments of biological control over the past decade is that more potentially useful inoculants have not been commercialized, despite the diversity, efficacy, and availability of various microorganisms from various research laboratories around the world. As mentioned before, two inoculants are currently registered for control of turfgrass diseases in the United States with only four others that are currently in the registration pipeline.

The turfgrass industry has been particularly reluctant to embrace biological control technologies for a number of reasons. First, fungicides have been the mainstay of turfgrass disease management since the early 1900s primarily because they have been effective, proven, and nothing else was as effective. Breaking into such a fungicide dependent industry with rela-

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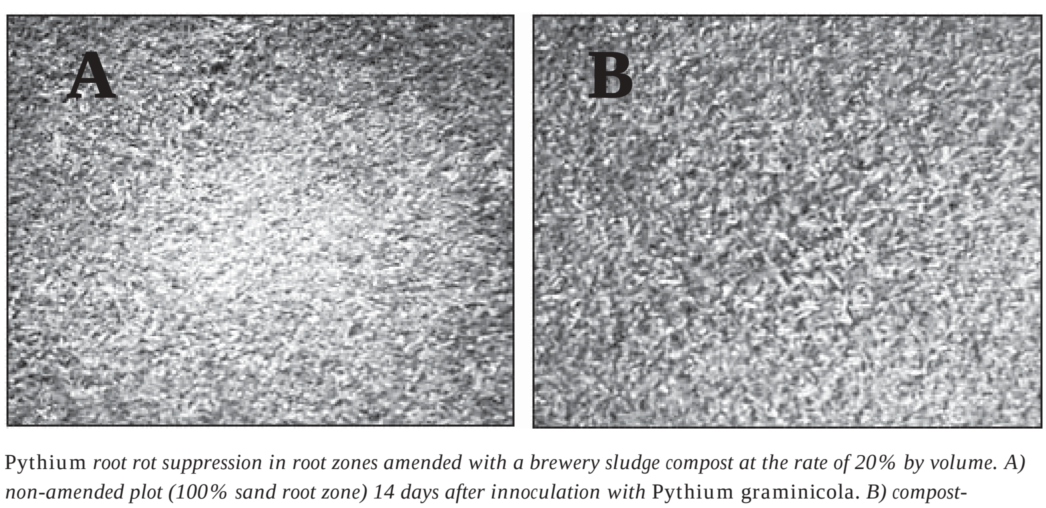

Pythium *root rot suppression in root zones amended with a brewery sludge compost at the rate of 20% by volume. A) non-amended plot (100% sand root zone) 14 days after innoculation with* Pythium graminicola. *B) compost-amended plot 14 days after innoculation.*

tively unproven biological technologies that require a greater level of knowledge and skill for their effective use, cannot be accomplished easily. Second, fungicides are generally cheaper, easier to store, and easier to apply than microbial inoculants. Turfgrass managers are not particularly interested in complicating their jobs by introducing what is perceived to be difficult-to-implement technologies. Third, fungicides generally have a broader spectrum of activity and are effective over a broader range of environmental conditions than many inoculants, making the decision making process of which approach to use easier for the turfgrass manager. Fourth, there is very little financial incentive for companies to develop biological control products when the market potential is relatively small and uncertain.

Harman has argued for developing different product concepts for microbial inoculants in which niche markets are found where these organisms can provide advantages that go beyond those provided by fungicides. These would include: 1) situations where fungicides are lost due to regulatory action. This is occurring at a higher frequency today in the turfgrass industry; 2) replacements or reductions of fungicides in environmentally-sensitive area, many of which are found on or near golf courses; 3) applications where inoculants accomplish tasks not possible with chemical fungicides, such as plant growth promotion and enhanced nutrient uptake; and 4) applications for organic turf management programs. There is a growing interest in management programs characterized by reduced or no applications of chemical fungicides. It is likely that biological control inoculants may serve as important tools for disease management in this important area in the future.

Another major problem with commercialization of microbial inoculants for the turfgrass industry is that many small companies are developing microbial-based products for use on turfgrasses. These companies generally lack the capital to support the licensing and development efforts required for the successful registration, development, and implementation of microbial inoculants. Literally dozens of new microbial-based products for use in turfgrass management show up in the marketplace every year. Various microbial concoctions are used in these products with little rationale as to the choice of strains or the application strategy used. Product claims are often outrageous and in many cases disease control claims may not be based on sound science. With many of these products, there is little or no research to back up the claims that are made and, in many cases,

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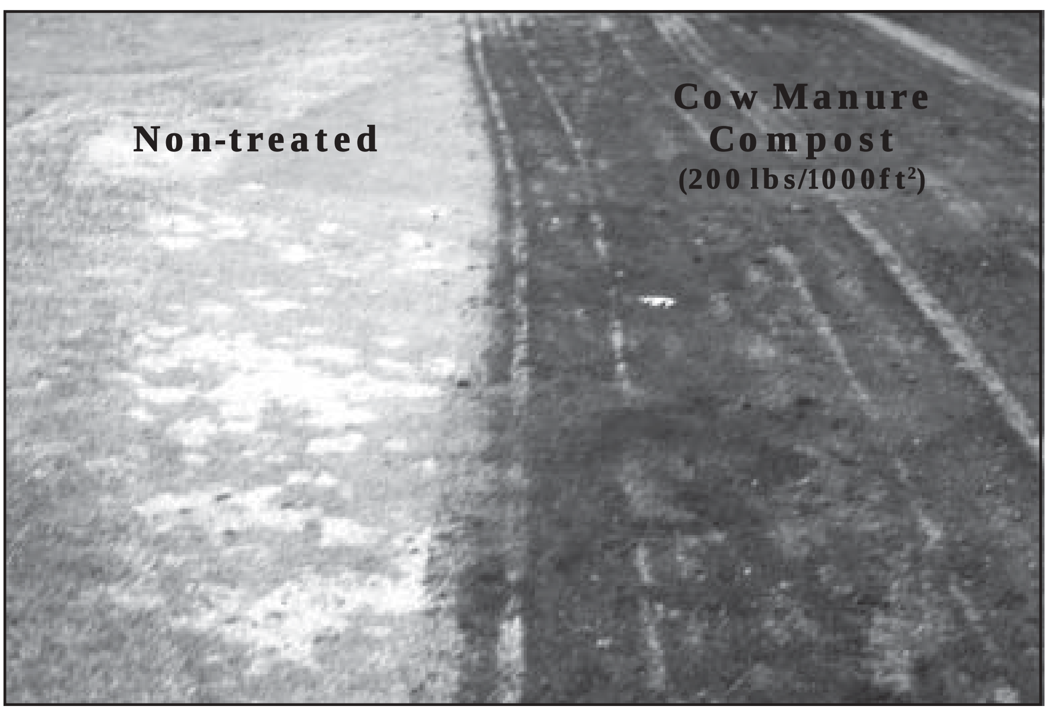

Suppression of Typhula *blight on a creeping bentgrass putting green with heavy dormant applications of composted cow manure applied at 200 lbs./1000 ft^2. Typical symptoms of* Typhula *blight in nontreated plot. Compost-treated plot remained disease free.*

Biological Control

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the products are ineffective in controlling diseases. This has become such a problem that some scientists are calling for turfgrass managers to exercise more caution and common sense in deciding whether to use such products.

Unfortunately most turfgrass managers develop an impression of a technology based on the commercial products that represent that technology. This is one reason that fungicide products have been so widely accepted and used. A fear with microbial inoculants is that turfgrass managers will reject the entire technology because the products currently on the market are faulty and fail to match the claims made on the label. Clearly, these types of products need to be replaced by those based on strains and application technologies developed from numerous years of research. Only then will we begin to see the effective use of microbial inoculants in the turfgrass industry for the biological control of turfgrass diseases.

Eric B. Nelson

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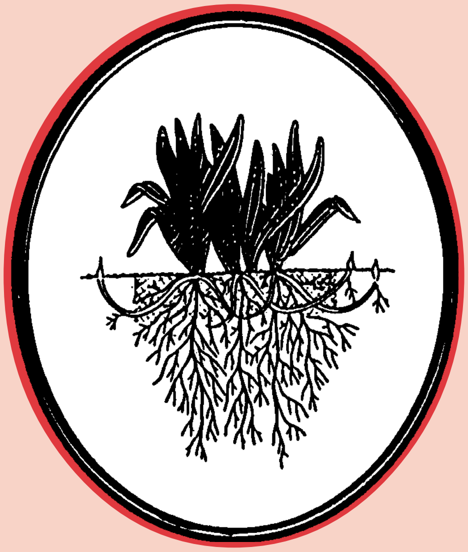
Table 1. Commercial Turf Products in the United States

Organism	Strain	Trade Name	Status
Trichoderma harzianum	1295-22	Turf Shield (BioTrek)	Registered 1996
Gliocladium catenulatum	J1446	Primastop	Registration Application 5/97
Pseudomonas aureofaciens	Tx-1	SpotLess	Registered 1999
Streptomyces lydicus	WYEC 108	Actinovate	Registration Application 10/00
Bacillus subtilis	GB03	Companion	EUP Application 12/01
Bacillus licheniformis	SB3086	GR 710-140	Registration Application 06/02

Cornell Turfgrass and Landscape Management Field Day



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- Tours of Cornell Research Center, Cornell Plantations and Downtown Ithaca
- Education tent
- Demonstrations
- Trade show

For Turf Professionals

- Annual bluegrass weevil research
- Low or nonchemical management of golf greens
- Overseeding high traffic areas
- Wetting agent evaluation
- Microbial and organic product evaluations
- Turfgrasses for high use sports turf
- Moss control in putting greens
- Pest management and water quality
- Turfgrass weed control
- Weed suppressive fescues
- Velvet bentgrass management
- Shaded tee management
- Soil test calibration studies

Of Ornamental Interest

at the Research Center

- Promising maples for urban use
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- Koelreuteria selection
- Weed suppressive ground covers
- Compost and disease suppression
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June 17, 2003

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CORNELL Turfgrass

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CUTT

A Healthy Ecosystem

Studies have demonstrated that more effective control of dollar spot is achieved when higher populations of inoculants are introduced or when higher populations are maintained between application intervals.

Biological Control of Turfgrass Diseases

Application, Efficacy and Commercialization

New technology for applying microbial inoculants to turfgrasses was introduced in the United States in 1999 with the registration of the BioJect® Fermentation and Injection System to deliver *Pseudomonas aureofaciens* strain Tx-1 for control of dollar spot. This system is also used to deliver inoculants in other agricultural settings. Much of the rationale for such a device is that it provides a means of making daily or continuous applications, thus facilitating the maintenance of high populations of the introduced inoculant.

Numerous studies have demonstrated that more effective control of dollar spot on creeping bentgrass is achieved when higher populations of inoculants are introduced or when higher populations are maintained between application intervals. For example, *Pseudomonas aureofaciens* strain Tx-1 is more effective in controlling dollar spot when applied at a level of 10^7 cells/ml than when applied at a level of 10^5 cells/ml. Repeated applications of this strain at densities of 10^6 cells/ml allow it to become well established in turfgrass systems and to overwinter 1-2 cm below the turfgrass surface. Other inoculants behave similarly. For example, *T. harzianum* strain 1295-22 was more effective in controlling dollar spot, brown patch, and Pythium root rot when applied at cell densities $>10^7$ conidia/ml than when applied at lower concentrations. In field studies, populations persisted at levels $>10^5$ cfu/g dry wt soil following applications of granular or spray formulations of strain 1295-2. Similar observations have been made with *Stenotrophomonas maltophilia* strain C3 for control of leaf spot, *Typhula phacorrhiza* for control of Typhula blight. Immediately following the application of most inoculants, populations begin to decline. Although populations of *E. cloacae* could be introduced into golf putting greens at levels between 10^7 and 10^9 cfu/g soil, populations declined to 10^4 to 10^5 cfu/g 13 wk after application but overwintered at extremely low populations.

Suppression of summer patch of KBG was more effective when *S. maltophilia* strain 21C6 or *Serratia marcescens* strain 9M5 were applied 1-4 wk after planting than when applied at the time of sowing. Greater suppression was observed with both strains when applied at cell densities of 10^{10} cfu/ml than when applied at 10^8 cells/ml. Thirty five weeks after inoculation, populations declined to between 10^4 and 10^5 cfu/g soil.

Aside from application frequency, the time of day at which inoculants are applied may influence efficacy. In a study by Craft *et al* the timing (day vs. night) and frequency (daily vs weekly) of application of microbial inoculants was studied in field trials to determine their impacts on the efficacy of control of dollar spot. Over a two-year period the efficacy of all microbial inoculants was unaffected by applica-

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