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(Approximately 250 words)

PROJECT SUMMARY

This project will provide long-term information on the costs and turfgrass quality associated with golf course turf managed with few or no chemical pesticides. Many golf courses in New York State and other areas of the U. S. are being compelled, or are choosing, to reduce or eliminate the use of chemical pesticides. Turfgrass managers need better information on how cultural practices and alternative pest management strategies can be combined to maintain acceptable, playable golf course turf. Furthermore, those advocating pesticide-restrictive policies are often unaware of the costs of implementing the policies and the resulting impacts on turfgrass quality.

Our project was established in 2001 and was funded through 2004 by the U.S. Golf Association. It explores total management systems, as practiced by turf managers, rather than focusing on individual technologies and isolated practices. We are requesting an additional three years of funding to continue this project and establish a long-term research site. Two cultural and three pest management systems are being compared in a factorial design, utilizing all 18 greens of a high-use public golf course. The site is a living laboratory, research and demonstration site and results have already provided a great deal of information on low- and non-chemical turfgrass management. This project addresses important scientific, environmental and social aspects of golf, and compares them in ways that are useful to golf managers as well as the general public. Our project's research is long-term and dynamic by nature, and three more years will provide critical and comprehensive additional information.

According to the Paperwork Reduction Act of 1995, an agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0524-0039. The time required to complete this information collection is estimated to average .50 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

PROJECT DESCRIPTION

A. PROBLEM, BACKGROUND, AND JUSTIFICATION

Background

Golf courses throughout the United States and Canada are being challenged to reduce or eliminate the use of chemical pesticides. In New York State, many public golf courses have been affected by legislation that phases-out and/or eliminates chemical pesticide use. Such laws have been passed for municipal properties in Suffolk, Westchester and Albany Counties, and the City of Buffalo. In addition, at least 20 laws that would restrict pesticide use on golf courses in other areas of the state are currently under consideration. Those advocating pesticide-restrictive laws and policies are often unaware of the costs of implementing the policies and the resulting impacts on golf turf performance. Furthermore, the knowledge and tools to implement such policies are not currently available to golf turf managers.

Golf courses are important green space in urban and suburban communities. According to the U.S. Golf Foundation <<http://www.ngf.org/>>, there are 18,643 golf courses in the United States and up to 36 million people play golf annually. Over 3,000 courses are located in the Northeast region, with New York ranking as the fifth highest golf state nationally with 860 courses. Golf courses provide recreational area for golfing, jogging and walking and also serve as wildlife habitat. Courses commonly abut residential property, and are frequently situated near wells, wetlands, streams and other water sources. For these reasons, community residents are often concerned about the pest management practices being used.

The 2004 New York State Turfgrass Survey (Ropel et al., 2004) indicated that golf courses spend more than \$23 million dollars annually on pesticides with 74% spent directly on fungicides. When factored together with labor expenditures for pesticide application, pest management costs exceed \$40 million annually. When asked about significant problems they are facing today, 65% of golf course managers rated disease management as their highest concern. Furthermore, when asked about significant future problems, government regulations and loss of chemicals were the two most frequent answers.

Golf turf managers who want, or are required, to minimize their reliance on chemical technology need information on how to maintain acceptable, playable golf course turf. Unfortunately, there is a dearth of information available on individual practices and technologies to reduce pesticide use, and especially on how these alternative cultural and pest management technologies integrate and work together in a system. For example, Plumley et al. (1992) found that increasing the height of annual bluegrass putting greens from 3.2mm to 4 mm reduced incidence of summer patch (*Magnaporthe poae*) by 40%, and Huang et al. (2000) showed the favorable influence of increased mowing heights on plant energy dynamics that results in healthier plants. However, very few managers have implemented this practice because of its negative effect on ball roll distance—an important putting green performance indicator. Yet it may be possible to maintain acceptable ball roll distance, if increased mowing height is counteracted by a suite of cultural practices such as increased mowing frequency, aggressive topdressing and rolling.

More recently, new strategies have been discovered for reducing the stress of mowing by allowing the turf to rest. Howieson and Christians (2003) showed how reducing mowing frequency from seven days per week to five days per week improved plant health. In fact, a second study by Howieson and Christians (2004) indicated that mowing once at a low height was less stressful than double-cutting in the same mowing event at a higher height. This type of research will be vital to integrate into the alternative culture treatments of our proposed work and determine real-world efficacy of the research. Additional research by Rossi (2004) has shown that mower type also influences turfgrass stress response. In that study, double-cutting three days per week and single-cutting four days per week with floating head hand mowers reduced basal crown rot anthracnose and improved turfgrass quality while maintaining ball roll distances as compared to single or multiple cuttings with fixed head hand mowers. These types of cultural practices that reduce stress on turfgrass plants are key to reducing disease occurrence and severity in a putting green environment.

In addition to the mowing information, several alternative cultural practices have been developed that will allow for enhanced plant health and reduced disease infestation. For example, Han and Guertal (2001) demonstrated the benefit of using fans to create a surface wind speed of 3 miles per hour to minimize leaf wetness. This research also identified that when allowed to run in the evening, fans reduced soil temperatures by as much as 5°C in the top 2 cm. This approach has not been investigated on an existing golf course with high populations of annual bluegrass. We hypothesize that overall disease occurrence and severity will be reduced, based on Xu et al. (2003) who showed that heat stress tolerance was improved when evening soil temperatures were reduced prior to daytime heat stress. In fact plants were able to tolerate daytime temperatures in excess of 35°C when nighttime soil temperatures were reduced.

These types of cultural innovations while proven under field laboratory conditions or in growth chambers need to be ground-truthed to demonstrate their ability to be integrated into modern turfgrass management programs. The proposed project provides that proving-ground. We can ensure successful evaluation, because a unique relationship has been established with the Bethpage State Park—our cooperators are now accustomed to operating the golf course in a research mode. Also, the park contains five contiguous golf courses, which protects them from possible negative financial repercussions of conducting research at a real-world, revenue-generating facility.

Project Foundation and History

In 2001 we initiated a project that implements and tests these types of combinations by exploring total management systems, as practiced by turf managers, rather than focusing on individual technologies and isolated practices. The project, funded for three years by the United States Golf Association (USGA), was conducted on all 18 greens of the Green Course at Bethpage State Park, Long Island, NY. A fourth year (2004) was funded with carryover funds, regional USGA funds, and many in-kind and materials donations that exceeded \$125,000 in products and services. For example, the Green Course was given a \$50,000 microbial fermentation device, the BioJect. In addition to the unit, more than \$20,000 of supplies and technical support was donated to determine performance of the approach in our project. The Green Course accommodates approximately 50,000 rounds of golf annually and is typical of a

high-use public golf facility in the northeast. We have managed greens under three distinct pest management strategies (conventional, IPM and non-chemical¹).

These regimes are being evaluated for quality, cost, pesticide use and perception by golfers. Because the research is being conducted under real-world conditions at a high-use public course, the results are realistic and easy to demonstrate to the public as well as to golf course superintendents. In fact, our project has already become a focal point for those seeking information on low-chemical golf course management. Results to date have provided a great deal of information on low- and non-chemical turfgrass management—but we are just beginning to reap the benefits of all the time and resources that have been invested thus far. The research should continue on this site in order to evaluate new strategies and long-term impacts. Additionally, the high profile nature of the project to date has attracted other researchers and private companies that are interested in evaluating their technology under high stress conditions. NE IPM is ideally suited to fund the next phase of this project, because we address so many of the program's priority areas. It would be a shame to forfeit the biological and cooperative history that has been created on this course.

We have chosen to work on putting greens because they are the most difficult and pesticide-intensive areas to manage. Studies (GCSAA, 2003) have shown that while putting greens make up less than 5% of the playable area they receive more than 70% of the pest management treatments. From the perspective of the game of golf, two thirds of all shots played during a round of golf involve the putting green—thereby making greens the most critical areas for the success of a golf course.

As discussed above, fungicides account for 74% of pesticide expenditures on golf courses. Major disease problems such as dollar spot, anthracnose and summer patch are currently being evaluated for response to alternative cultural and chemical strategies. Dollar spot is a significant disease of golf course turf throughout the country, and is documented as the primary pest and target of pesticide use at Bethpage State Park (Grant and Rossi, 2004—appendix A). Horvath et al. (2002) have identified several biotypes of dollar spot in Michigan that have become resistant to several classes of chemical fungicides. They have begun exploring the development of biological control of these resistant strains with *Pseudomonas* spp. Additionally, the Novozymes Co. has developed *Bacillus licheniformis* for use in golf turf that has not seen widespread implementation but could offer significant benefits for managing resistance.

Summer patch has increased in severity on annual bluegrass areas at Bethpage over the last four years and research from Vincelli (2004) suggests that use of phosphorous acid-based fertilizers increase plant defenses and thereby could reduce incidence of summer patch. In one year of testing this approach at Bethpage, we have seen some positive results of shifting our management focus toward a more nutritionally-based approach. Lastly, basal crown rot anthracnose has emerged as the number one disease on golf course greens in the Northeast U.S. (Inguagiato et al., 2004). There are no effective curative control programs and several studies have identified fungicide-resistant strains (Uddin and Soika, 2003). To date we have seen only minor infestations

¹ The nonchemical treatments were modified to "Reduced-risk" in the fourth year of the project, as described later in the Approach and Procedures section.

in our project, but new cultural management strategies developed by our colleagues in adjacent states will be implemented in the coming years to further minimize the potential for this devastating disease.

Diseases are the most common and destructive pests of greens, but all pests are addressed in our project because we are taking a systems approach. Our results will apply directly to golf courses throughout the Northeast region, and the rest of the cool season grass zone in the United States, Canada and Europe. The project's focus on developing alternative strategies as well as a strong emphasis on reduced-risk approaches to golf turf management opens an important dialogue with the golf course industry. This industry has previously been reluctant to embrace IPM practices because of a perceived significant increase in labor needs and reductions in turf quality. This project will indirectly but explicitly enhance the environmental compatibility of golf turf management programs. We will demonstrate ways for golf course superintendents to be better environmental stewards, and to reduce risks of pesticide exposure to golf course workers, golfers, and community residents. We will also reduce the risk of pest damage by including IPM monitoring and diagnostic techniques.

Our effort is well respected within the research turfgrass community, the industry and by non-scientific policymakers. For example, a Long Island county with a municipal pesticide ban has been monitoring our project's progress. Through educational sessions, and further discussions with us, the advisory committee has shifted their policy from one that granted arbitrary exemptions for pesticide use on golf courses to one that has a sound, scientific, IPM base, using criteria such as thresholds, history and expected weather. The two original PDs have already been invited to speak about this project to thousands of people in the United States, Canada and Europe. Most recently we have been invited to provide the keynote address at the International Turfgrass Society meeting in July 2005 in Wales. We have a unique opportunity with this project to provide scientifically-based information that will likely have a significant impact on future policy for pesticide use on golf courses in the region, nation and internationally.

We have successfully implemented a large-scale comprehensive research project that addresses agronomic, societal and environmental issues associated with golf in the United States. This type of research has never before been conducted on modern golf course greens. We have been able to conduct this work at Bethpage for a variety of unique and important reasons.

- The Park Director (Dave Catalano), Golf Course Superintendent (Craig Currier), Green Course Supervisor (Andy Wilson) and IPM Specialist (Kathie Wegman) are highly dedicated to making the project succeed.
- Bethpage State Park houses five golf courses. Any golfer who may be dissatisfied with the Green Course, due to conditions resulting from our research project, can select an alternate course--without significant revenue losses to the park.
- The two original PDs for this project have made the substantial commitment to each physically be at Bethpage 1-3 times monthly, and to always be available to Bethpage staff by phone and email. On our proposed work, the addition of four new university collaborators, who are geographically closer to the park, will further strengthen this support.
- In addition to the USGA's investment for the first four years of this project, we garnered over \$400,000 of donations of materials and in-kind labor to actualize its implementation.

As home of the 2002 and 2009 U.S. Open, and the first truly public host facility, Bethpage has a high profile in the public's eye. The Park is ideally poised to both host and publicize our research, and show the public that their demands for low-impact, high-quality golf are being addressed. Our special situation is highlighted by the fact that our colleagues in Ontario, Canada have attempted to replicate this project, but have been unsuccessful in finding a willing golf course host. Ideally the 18 greens in this project would be designated as a permanent research site. Realistically, the project can only continue as long as there are committed researchers, site cooperators, and funders. The first two parties are on board, and we hope that NE IPM will also see the tremendous value in continuing the project.

Priorities

Our project directly addresses many priorities for both golf course and community IPM. Priorities set by a Northeast stakeholder group for golf in 2001; the Northeast IPM Center Community IPM Work Group in 2003; and the Golf Course Superintendents Association of America's Environmental Institute for Golf 2004 IPM Task Force Priorities are listed below, followed by the way in which our project addresses the priority.

Golf Course (see <<http://northeastipm.org/partners/priorities/turf2001.html>>)

Research

- Priority: Documentation of IPM impacts (economics, environmental, water quality)
 Our project: Documents both economic and environmental impacts
- Priority: Alternatives to current pesticides including new (non-pesticide) IPM techniques
 Our project: Innovates, tests and demonstrates non-pesticide tactics for management of diseases, insects and weeds on golf course greens
- Priority: Documentation of costs incurred (damage and cost of control) for specific pests
 Our project: Tracks costs of all cultural and pest management techniques, for all pests. Pest incidence, severity and damage are also quantified.
- Priority: Development and demonstrations of systems approaches to IPM
 Our project: We develop, demonstrate and compare golf course management systems (nonchemical, IPM and conventional). Our project is a prime example of a systems-based approach, and has never been done before on golf course turf.

Extension

- Priority: Educate and communicate with others:
 -information about the benefits of golf turf IPM for public policy makers, golfers, course owners / superintendents and employers.
- Our project: We are producing information on what can be expected from reduced and non-chemical greens management. We have begun to disseminate the information and will have many more opportunities if we are granted new funds to continue the project. Our golfer surveys will provide information important to golf course superintendents and policy makers regarding quality expectations and thresholds.

- Nonchemical poa/creeping bentgrass greens were marginally acceptable or below acceptable quality for at least one month each year.
- Dollar spot has been the predominant pest problem, but incidence and severity were reduced in 2002 as compared to 2001. Its pest status has further declined under our non-chemical and IPM treatment regimes in 2003 and 2004.
- Rhizoctonia incidence was higher in 2002 and 2003 than 2001.
- Cutworms either favor velvet bentgrass, or the damage appears more severe than on poa/creeping bentgrass greens.
- In 2002, the alternative culture greens generally performed better than the standard culture in all pest management treatments. Less pesticide was also required to maintain alternative greens under both the IPM and non-chemical strategies.
- Annual weather variations impact pest occurrence and severity, and the ability to successfully manage greens with few or no pesticides.
- We have not yet been able to maintain poa/creeping bentgrass greens at an acceptable quality level, without chemical pesticides.
- The majority of golfers surveyed indicated they prefer an IPM approach as compared to conventional or nonchemical.
- A reduced-risk insecticide, spinosad, has effectively managed black cutworm infestations.
- New reduced-risk fungicides with active ingredients such as polyoxin-D zinc salts, boscalid, and phosphites, significantly reduced disease occurrence and severity. Some are allowed under the National Organic Standards.
- Several biological controls, including *Pseudomonas aureofaciens* and *Bacillus licheniformis*, significantly reduced disease occurrence and severity.

What will we gain with an additional three years?

Future benefits of this project include:

- Seeing long-term changes in turfgrass, soil, microbial and pest communities.
- Managing greens and tracking success under a wide variety of weather conditions, as they vary from year to year.
- Incorporation of new pest management products and practices, and fine-tuning of previously adopted strategies.
- Aggressively shifting management program to encourage the success of velvet bentgrass and minimize annual bluegrass ingress by adopting new research practices being developed by colleagues in adjacent states.
- Golf course superintendents, who chose or are compelled to manage with limited pesticide inputs, will become better informed of their options.
- Golf course superintendents, golfers, policy makers, and environmental and health advocates will greatly increase their comprehension of quality and economic expectations for golf course greens managed with few or no chemical pesticides. They will have tangible, comparative information for decision making.
- The project identifies areas needing further research within the constraints of each management system, and provides researchers a venue for “ground-truthing” of their technologies. For example, after hosting visits with each co-PD, we will devise strategies for integrating the technologies they have shown to be effective under research conditions.

- Results of this systems-based approach will be communicated to the audiences cited via public meetings, extension publications, research presentations and articles in scientific journals and the popular press.
- The proven success of the PDs in communicating the results of this project holds NEIPM in good stead for enhancing the profile of the regional IPM efforts from grass roots environmental advocates through policy-makers as well as golfers who benefit from reduced risk approaches to golf turf management.

Our project's research is long-term and dynamic by nature, and three more years will provide critical and comprehensive additional information. The soil, grass, pest and microbial ecologies of greens managed under each system are evolving and changing over time. As the greens mature, they better represent the outcome of long-term management strategies. At the same time, we are continually improving the management systems by incorporating appropriate new products and practices as we learn from previous results and newly-researched possibilities come to light. We adjust our turfgrass culture and pest management as we monitor the response of the greens and the pest populations. Continuation of the project will also attract additional interest from industry, which will further spur innovation and develop new products and practices focusing on improving the environmental compatibility of golf turf management systems.

Because of the high-profile nature of the project and the intensive communication strategies of the PDs, many in the industry are able to follow the results and relate our progress to what might be possible in their own situations. For example, our establishment of a new turfgrass species, velvet bentgrass, has attracted significant interest from golf course superintendents. This interest has already increased demand for that grass and caused seed companies and sod growers to expand production. At the same time, new research by Murphy (unpublished) and Boesch and Mitkowski (2003) is being conducted with velvet bentgrass that will be useful for our project and overall chemical pesticide reduction. Two of these authors (Murphy and Mitkowski) have joined our project in this proposal as co-PDs. All of our management strategies build on previous results, so that new knowledge continually enhances our ability to produce quality playing surfaces with few or no chemical pesticides. In addition to building our knowledge base with further research, the next three years become a critical time for sharing information and demonstrating results with golf course managers, environmental and health advocates, policy makers, and the general public.

A field tour, held in August 2003 at Bethpage, was attended by 60 golf course professionals and environmental advocates. Participants were able to see results of this project first-hand, and discuss the challenges and possibilities for managing putting greens under various management systems. Thoughtful discussions ensued about how we could further refine our systems, and how superintendents could incorporate aspects of the work on their own courses. Superintendents and advocates were able to see each other's interests more clearly, and discuss them. In this way, Bethpage Green has become a living laboratory, research and demonstration site. Continuation of the project will vastly increase our technical knowledge and also provides a scientific basis for these necessary discussions on the environmental, economic and social aspects of golf.

B. OBJECTIVES

The goal of this project is to provide long-term information on the costs and turfgrass quality associated with golf course turf managed with few or no chemical pesticides.

Objective 1. Produce aesthetically and functionally acceptable golf turf under six unique management systems. There are 3 pest management strategies (unrestricted current standard, IPM, nonchemical) and 2 sets of cultural management practices (standard and alternative).

Objective 2. Evaluate and compare the aesthetic and functional turfgrass quality, pest occurrence, and pesticide impact in each management system.

Objective 3. Analyze the economics of each system, including golfer satisfaction.

Objective 4. Publicize results to golf course managers, policy makers, golfers, environmental and health advocates and the general public.

C. APPROACH AND PROCEDURES

Management Systems

The proposed work would extend a large-scale research and demonstration project that began in 2001 on the 18 putting greens of the Green Course at Bethpage State Park, Long island, NY. When the project was first conceived, we wanted to test how well greens would fare when managed without chemical pesticides (mimicking a law in an adjacent county), and with reduced reliance on chemical pesticides (IPM). Therefore, we established three pest management treatments: conventional (unrestricted), IPM and nonchemical. However, we felt that the best chance for the low-chemical strategies to succeed would be if cultural practices were modified to reduce stress on the turfgrass plants. To test this hypothesis, while providing fair comparisons with how golf courses are currently managed, we maintained half of the greens under current cultural practices, and half with stress-reducing alternative practices. This 3 x 2 factorial design resulted in six unique management systems, with three greens (replicates) in each treatment regime. The two cultural and three pest management treatments are described below.

Cultural Management

Current Standard: Cultural practices normally employed on the Green Course, such as mowing height and frequency, topdressing, and irrigation practices (table 1).

Alternative: Modified Bethpage cultural practices (table 1), selected to reduce turfgrass stress, and minimize pest problems, while striving to maintain acceptable performance standards (e.g., quality ratings above 6 on the NTEP rating scale and ball roll distance > 2.5 meters).

Table 1. Cultural Management Practices

Practice	Cultural Management*	
	Standard	Alternative
Mowing Ht. Range (bench settings; mowing performed with triplex units)	3.3 mm (0.130") normally, lower to 2.8 mm (0.110) for tournament preparation	3.3 mm (0.130") normally, raise if turf is stressed—up to 4.8 mm (0.188")
Mowing Frequency	1x/day, 7 days/week	1x/day, 5 days/week
Roller	Groove	Solid
Irrigation	automatic 3-4:00 AM	manually activated 4:30-6:30 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. Approx. 60-70% of N supplied via organic sources, notably Sustane. Overall, 25% more N than standard cult.
Topdressing	Every 2-3 weeks	Weekly, no brushing. Overall, 25% more sand than standards.
Rolling	1x per week	Up to 3x per week (if needed for ball roll)
Vertical Mowing	Every 2 weeks	Occasionally
Spike and Hydro-ject	Occasional	Every 3 weeks, May - Sept.
Clean up Pass	4x per week	2x per week

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

Pest Management

Unrestricted: All legal and currently available chemical pesticides in New York State may be used to manage pests, both preventatively and curatively. Pest management, as practiced on the Black Course (Bethpage's championship course), is followed. Prophylactic treatments, such as snow mold preventative fungicides may be used.

IPM: Least-toxic approaches, as defined by factors such as water quality impact, effects on non-target organisms and toxicity to humans, are emphasized. Higher-risk treatments are used when necessary to maintain expected performance (e.g. quality ratings above 6 on the NTEP rating scale and ball roll distance >2.5 meters). Biological and cultural methods for pest management are used when possible. 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. In this system, acceptable turfgrass performance is not

intentionally sacrificed. Therefore, it is sometimes necessary to select a more toxic product or method in order to avert significant turfgrass damage or loss of turf.

Non-chemical (or reduced-risk): Biological and cultural methods for pest management are emphasized. Ideally, pesticides registered in class I, II, or III by the EPA are not used. This mimics conditions currently legislated for some municipally-owned golf courses in Suffolk County and other areas of New York. However, we concede that emergency pesticide applications were needed in recent years. Therefore, this treatment now allows for the use of reduced-risk chemical pesticides when deemed necessary to avoid loss of turf. Non-chemical pest management options include the use of biostimulants, increased fertility, microbial inoculants, incorporation of disease-suppressive composts, and entomopathogenic nematodes and fungi. Severe damage or loss of turf may occur under some conditions and the cost of reestablishing the areas through overseeding and sodding are included in the economic analysis of the management programs.

The management systems were modified over the four years of the project, in response to challenges in maintaining playable putting surfaces. The current systems, which we propose to continue, are best described by explaining why the modifications were made. For the first year and half, the six management systems were as follows, with three greens in each system.

Table 2. Management Systems

PEST MANAGEMENT	CULTURAL PRACTICES	
	Current Standard	Alternative
Unrestricted	I	II
IPM	III	IV (will be renovated to velvet bentgrass in 2005)
Non-chemical ²	V *discontinued for lack of quality in 2002	VI-a (converted to velvet bentgrass, Nov. 2001) VI-b (poa/creeping bentgrass) *was treatment V until July 2002

We were unable to maintain acceptable quality on any of the six nonchemical greens in the first year of the project, and several greens died by September. In strategizing for improvement, we concluded that a radical change would be necessary and converted the grass cover on the three alternative culture greens from the traditional poa (annual bluegrass) and creeping bentgrass mixture, to velvet bentgrass—a highly disease resistant (yet seldom used) species. Quality of the nonchemical greens was improved in the second year, with good performance from the velvet bentgrass. However, halfway through the second year an emergency chemical fungicide application was necessitated to preserve the standard culture nonchemical greens (poa/creeping bentgrass). We then conceded that we were unable to maintain acceptable conditions in system V, and we could not guarantee the survival of those greens. Therefore, those three greens are now being managed with alternative cultural practices (now system VI-b)--providing a comparison of

² We allowed unmanageable problems to take their full course (including loss of turf) in Systems V & VI in the first year. Subsequently, we reserved and exercised the prerogative of making an emergency treatment to keep turf playable in system V in 2002 and 2003. In 2004, the treatment was further modified to “Reduced-risk” as described.

traditional poa/creeping bentgrass greens, and velvet bentgrass greens, under nonchemical pest management. In 2004, this treatment was further modified to “Reduced-risk” because of ongoing difficulties in maintaining acceptable quality without the use of chemical pesticides. This treatment includes increased use of beneficial microbial organisms, and the occasional use of reduced-risk chemical pesticides when deemed necessary to avoid unacceptable loss of quality or turfgrass cover.

To further enhance both the reduced-risk and IPM approaches, in 2004 we began using the Environmental Impact Quotient (EIQ) (Kovach et. al, 1992) to select “least toxic” pesticides among efficacious products. Currently we are analyzing our 2004 treatments to determine the total EIQ value of each of our six systems. EIQ totals provide a means for assessing and comparing actual environmental impact of full management systems, such as we are testing. Previously, we have only been able to compare numbers of applications. In other work, outside of this project, we are working to modify the EIQ to better address the impacts of turfgrass applications. This modified EIQ should be ready for use in the 2005 season.

Chemical pesticides are the main tools used for pest management in the unrestricted treatments. During the initial four years, between 14 and 21 applications were made annually, mainly targeted at fungal diseases. Pesticides are only applied in the IPM treatments when action thresholds are reached, or when site history and current weather conditions warrant intervention, and when nonchemical treatments are not practical. IPM management resulted in 29-61% fewer applications during the past four years. A variety of cultural and biological pest management strategies are used in the nonchemical treatments. Cultural practices are mainly those that reduce overall stress on plants and thereby reduce disease occurrence and severity (described in table 1). However, midnight mowing to reduce cutworm populations and manual removal of weeds are further examples of cultural practices specifically conducted to manage pests. We will continue to use biological pest control products that have successfully been used previously. These include *bacillus licheniformis* and *Pseudomonas aureofaciens*. The cultural and biological strategies used on the nonchemical greens are also used on the IPM greens whenever feasible.

New practices planned for 2005 include decreasing the frequency of mowing, use of the biological control *Bacillus subtilis* (Companion) for summer patch management, and product selection based on a new, modified EIQ. In the spring of 2005, we plan to convert the three alternative culture IPM greens to velvet bentgrass. Although, we have often been unable to maintain acceptable playing quality on the nonchemical creeping bentgrass greens over the last four years, we are anxious to see if we can obtain consistently high quality conditions on velvet bentgrass greens when a minimal amount of pesticide inputs (IPM) are allowed. Further products and practices will be added based on the advice and consensus of the newly expanded PD team.

Performance Management Evaluation

Putting greens systems will be evaluated throughout the growing season for aesthetic and functional performance, pest occurrence, species population dynamics, tissue and soil nutrient content, organic matter dynamics and rooting. The assessments will be performed by the onsite IPM specialist (IPMS), the golf course supervisor, or the PDs.

Daily visual inspections (four times per week).

The onsite IPMS walks each green, inspecting all areas from ≤ 1 meter distance. Irregular areas are closely examined for signs and symptoms of disease-causing organisms, agronomic stress and insect pests. The location of all symptoms are mapped and quantified.

If a disease is suspected, turf is examined microscopically by the IPMS. If a positive identification is not obtained, a sample will be sent for identification to the Turfgrass Diagnostic Laboratory at Rutgers University. Additional samples may be sent to the University of Rhode Island.

If insect pests are suspected, the IPMS looks for signs of feeding damage and the insects themselves. Additional insect monitoring is used as appropriate, such as pheromone trapping for cutworm adults and oriental beetles, mowing box inspections for annual bluegrass weevil adults, and soap flushes for cutworm caterpillars and armyworms.

If no causal organism is found to be associated with the observed malady and agronomic stresses are suspected, the IPMS seeks specific indications by examining the grass plants, thatch and soil; previous scouting records; and records of previous cultural and pest management practices at that location.

Signs and symptoms are quantified as the percentage of the green where the pest is a) detected, or b) approaching threshold, or c) over threshold. The following thresholds are used:

DISEASE	ACTION THRESHOLD
Anthraxnose	detection
Dollar spot	2 spots/m ² (5 spots/25 ft ²)
Fairy ring	If hydrophobic
Pythium root rot	detection
Rhizoctonia	2 patches/green
Snow mold	10 patches/green
Summer patch	2 patches/green

“Percent area affected” is recorded for symptoms of pests without a threshold, and general symptoms such as thinning.

Weekly quality and pest assessment**Pest monitoring**

Irritant sampling—Insects are sampled from three randomly selected individual square meter areas on each green, using a soap-based irritant as described by Vittum, *et al.* (1999). All pest, beneficial, and incidental insects will be counted by species and life stage, if possible. Unknown insects are collected for later identification.

Pine litter floatation—In the spring, pine litter is sampled weekly and submerged in water to extract overwintering annual bluegrass weevil adults (Vittum, *et al.*, 1999), to estimate insect abundance and expected time of migration from overwintering areas.

Cutworm traps—Pheromone traps for monitoring adult cutworm flights are used as necessary.

Weed mapping—Weeds will be identified and mapped on all greens each week, with the exception of *poa annua* which will be quantified monthly (see below).

Monthly assessments

Functional & aesthetic factors

Overall putting green visual quality--Assessment is rated on a scale from 1-9 based on the NTEP ratings with 1= dead turf, 9= ideal turf and 6= acceptable turf.

Ball roll distance--Measured with a Stimpmeter at the same time of day in an area representative of the putting green. Three rolls are conducted in two directions to determine average distance.

Turfgrass Tissue nutrient analysis--Monitored monthly by collecting clippings and submitting to the Cornell Nutrient Analysis Lab or a private laboratory. These analyses are used to develop nutritional history, determine correlations with pest and stress incidence, and establish a precise nutrient management program.

Surface species population dynamics --Vegetative assessments of the putting greens are conducted across the entire surface. In addition, annual bluegrass populations are monitored in specific locations on each putting green with the point quadrat method.

Bimonthly assessments

Rooting--Monitored by extracting 5 cm cores to a depth of 25 cm, removing the soil, oven drying and recording dry weights at 7.5 cm increments.

Organic matter--Dynamics in the top 3 cm are monitored by establishing a baseline prior to initiation of treatments using the weight loss upon ignition method.

Economic Analysis

The costs of labor and materials will be quantified for each management regime, and extrapolated to estimate the economics for an 18-hole golf course.

Golfer Satisfaction Survey

Golfer satisfaction surveys were conducted twice in the original project, and will be conducted annually in the additional three years being requested. Golfer assessments of the quality of individual greens allow us to calibrate our measurements to the golfer's perceptions. These surveys indicate which management systems would be accepted by golfers, and are an important element in addressing the social aspects of golf and the environment.

Outreach Activities

We will host a field day at Bethpage in 2007, to share our next three years of results with golf course personnel, researchers, extension educators, and environmental and health advocates. We will also conduct an educational tour targeted at legislators and other policy makers in the summer of 2006. Press releases, and articles for trade journals and the popular press, as well as a scientific article will be written.

D. COOPERATION AND INSTITUTIONAL UNITS INVOLVED

The project is a partnership among the New York State IPM Program, the Department of Horticultural Sciences at Cornell University (NY), Rutgers University (NJ), the University of Rhode Island and the Bethpage State Park (NY). New York is the lead state.

New York (Cornell) will be primarily responsible for project design, direction and decisions; data collection, entry and analysis; conducting golfer satisfaction surveys; and project reporting. Cornell PDs will provide expertise in cultural and nutrient management of *poa annua* and creeping bentgrass turf, IPM practices, and biological control of insects. Two PDs (Grant and Rossi) will visit the field site 1-3 times monthly during each growing season, and one PD (Peck) will visit 2-3 times annually.

New Jersey (Rutgers) will provide expertise on disease diagnosis, biological control of diseases, and velvet bentgrass management. NJ is primarily responsible for diagnosis of disease samples. Rutgers PDs will visit the field site 2-3 times during each growing season.

Rhode Island (University of RI) will provide expertise on disease diagnosis, cultural and biological control of diseases, diseases of velvet bentgrass, and identification of plant parasitic nematodes. RI will be secondarily responsible for diagnosis of disease samples, when diagnostic confirmation is needed, or nematode identification is required. The RI PD will visit the field site 2-3 times during each growing season.

E. IMPLEMENTATION AND EVALUATION PLANS

Incorporation of tactics into golf course management projects

Our project is research of the most applied kind, and demonstrates practices and systems at the same time we are testing them. Therefore, the project inherently includes both research and extension. After hosting visits with each co-PD we will devise strategies for integrating the technologies they have shown to be effective under research conditions. This will offer the collaborators an opportunity to “ground-truth” their technologies. The project is designed in a systems approach, so we consider and implement all aspects of course maintenance. We have selected putting greens, the most difficult management areas, and we are working on a high-use public course. Therefore, successful practices for reducing pesticide reliance in these areas will have been subjected to the toughest tests of golf course maintenance. Practices that prove economically feasible will be immediately implementable. In addition, the high profile nature of the project and of the Bethpage facility, along with the intensive communication strategies of the PDs, allow the industry to follow the results and relate progress to what might possible in their own situations.

Evaluation Plan

Our project evaluation will include several indicators.

Pesticide use: We aim to reduce pesticide in the IPM treatments, with the goal of a 50% reduction as compared to the conventional treatments. Number of pesticide applications

will be an indicator measured. Nonchemical velvet greens will be managed without any chemical pesticides, unless an emergency application is necessitated.

Pesticide impact: EIQ values will be quantified to determine the environmental impact of each of the six systems tested. This measure will be superior to the simple tabulation of pesticide applications. However, tracking pesticide applications will still be a useful indicator, and one that is easily grasped by practitioners.

Turfgrass Quality: Ideally, greens in all management systems will maintain acceptable quality throughout the season, and will not differ significantly from each other. Putting green quality will be assessed by visual ratings and ball roll distance, as described earlier.

Pest occurrence and severity: We aim to hold pest occurrence and severity levels in the IPM and nonchemical treatments equal or lower than their conventional counterparts. We will monitor and record the area of each green that is over threshold for individual pests, four times per week.

Economics: We aim to hold costs in the IPM and nonchemical treatments equal or lower than their conventional counterparts. However, the actual cost of all labor and material inputs will be recorded and compared by management system.

Golfer Satisfaction: Golfers will be surveyed annually to determine their preferences and acceptance of the greens quality resulting from the six management systems. In continuity with the surveys of the previous two years, approximately 200 golfers will be asked to rate visual and putting quality of each green, green speed and their acceptance of the condition of these factors at the survey time.

Timeline

2005

- Spring: Resurface three alternative culture IPM greens with velvet bentgrass.
Resume implementation of all management regimes and data collection.
- Summer: Continue implementation of all management regimes and data collection.
Conduct golfer satisfaction survey.
- Fall: Continue implementation of all management regimes and data collection.
- Winter: Review and analyze data.
Write trade journal article.

2006

- Spring: Continue implementation of all management regimes and data collection.
Present results and lead discussion at National IPM Symposium.
- Summer: Continue implementation of all management regimes and data collection.
Conduct golfer satisfaction survey.
Conduct tour for legislators and other policy makers.
- Fall: Continue implementation of all management regimes and data collection.
- Winter: Review and analyze data.

Write trade journal article.

2007

- Spring: Continue implementation of all management regimes and data collection. Present results and lead discussion at Regional NE IPM Symposium.
- Summer: Continue implementation of all management regimes and data collection. Conduct golfer satisfaction survey. Host field day for golf professionals and environmental advocates.
- Fall: Continue implementation of all management regimes and data collection.
- Winter: Review and analyze data. Present results at NE IPM Meeting. Write trade journal article. Write scientific article.

REFERENCES

- Boesch, B. and N. Mitkowski. 2003. Cultivar development and management of velvet bentgrass (*Agrostis canina*). Proceedings of the 72nd University of Rhode Island Turfgrass Field Day. GCSAA. 2003. Member Survey of Products. Golf Course Superintendents Association of America, Lawrence, KS. pp. 57-59.
- Grant, J.A. and F.S. Rossi. 2004. Evaluation of reduced chemical management systems for putting green turf. *USGA Turfgrass and Environmental Research Online*. Vol. 3(4):1-13. <http://usgatero.msu.edu/>
- Han, D. Y. and E.A. Guertal. 2001. Fan and syringing effects on bentgrass putting greens. *2001 American Society of Agronomy Annual Meeting Abstracts*.
- Horvath, B. J., Kravchenko, A. N., and J.M. Vargas. 2002. Geostatistical analysis of dollar spot: Towards a new understanding. *Phytopathology*. Vol. 92, No. 6.
- Howieson, M. and N.E. Christians. 2004. Physiological responses of creeping bentgrass to mowing. *2004 Iowa Turfgrass Research Report*. 2004, p. 47.
- Howieson, M. and N.E. Christians. 2003. Changes in carbohydrate metabolism in response to mowing. *2003 Iowa Turfgrass Research Report*. July 2003, p. 45-47.
- Huang, B., X. Liu, J. Fry, and M. Kenna. 2000. Burning the candle at both ends: High temperatures and low cutting heights lead to a dead end! *USGA Green Section Record*. 38 (3):15-16. (http://www.usga.org/green/record/00/may_june/burning_the_candle.html)
- Inguagiato, J. C., Murphy, J. A., Lawson, T. J., Crouch, J. A. and B.B. Clarke. 2004. Anthracnose as influenced by nitrogen, growth regulators, pre-emergence herbicides, and verticutting. *Proceedings of the Thirteenth Annual Rutgers Turfgrass Symposium*. 2004, p. 46-47.
- Kovach, J., C. Petzoldt, J. Degni, and J. Tette. 1992. A Method to Measure the Environmental Impact of Pesticides. New York Agricultural Experiment Station Bulletin #139. Cornell University, Ithaca, NY, 8pp. Updated version available at <http://www.nysipm.cornell.edu/publications/EIQ.html>

- Plumley, K.A., B.B. Clarke, B.I. Hillman and T.E. Bunting. 1992. The effect of mowing height on the distribution of *Magnaporthe poae* in the soil profile and the development of a DNA probe for the detection of the pathogen. *Phytopathology*, 82 (10).
- Ropel, S.C., B.L. Smith and C.A. Howard. 2004. New York Turfgrass Survey. New York Agricultural Statistics Service, Albany, NY. 80 pp.
- Rossi, F.S. and M.C. Thurn. 2004. Effect of mower type and frequency on putting green performance. *Cornell University Turfgrass Times*, Vol. 15: 4-6.
- Uddin, W. and M.D. Soika. 2003. Effects of turfgrass cultural management practices on severity of anthracnose basal rot in mixed-annual bluegrass and creeping bentgrass greens. *Phytopathology*. Vol. 93, No. 6.
- Vincelli, Paul. 2004. Resistance to phosphite fungicide. *Hole Notes*. Vol. 35, No. 6
- Vittum, P.J., M.G. Villani and H. Tashiro. 1999. *Turfgrass Insects of the United States and Canada*, second edition. Cornell University Press, Ithaca, NY.
- Xu, Q., Huang, B., and Z. Wang. 2003. Differential effects of lower day and night soil temperatures on shoot and root growth of creeping bentgrass. *HortScience*. Vol. 38, No. 3.



Turfgrass and Environmental Research Online

...Using Science to Benefit Golf



Drs. Frank Rossi and Jennifer Grant investigated the use of integrated pest management and non-chemical management systems compared to conventional chemical pest control on putting greens located at Bethpage State Park. IPM resulted in fewer pesticide applications than conventional chemical pest control and similar putting green quality for most of the study period.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 290 projects at a cost of \$25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of *using science to benefit golf*.

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Evaluation of Reduced Chemical Management Systems for Putting Green Turf

Jennifer A. Grant and Frank S. Rossi

SUMMARY

Research was conducted at Bethpage State Park by Cornell University researchers to evaluate the aesthetic and functional performance of golf putting greens managed under various cultural and pest management systems. Findings include:

- IPM greens received 27-46% fewer pesticide applications than the unrestricted pest management (current standard) greens.
- Velvet bentgrass greens outperformed poa/creeping bentgrass greens when managed without chemical pesticides for most of 2002, and parts of 2003.
- Nonchemical poa/creeping bentgrass greens were marginally acceptable or below acceptable quality during the most stressful months of each year-much of July, August, and sometimes early September.
- Dollar spot was the predominant pest problem in all years, but incidence and severity were reduced in the second and third year.
- Rhizoctonia incidence was higher in 2002 and 2003 than 2001.
- Cutworms either favor velvet bentgrass, or the damage appears more severe than on poa/creeping bentgrass greens.
- In 2002, the alternative culture greens generally performed better than the standard culture in all pest management treatments. Less pesticide was also required to maintain alternative greens under both the IPM and non-chemical strategies. However, this did not occur in other years.
- The non-chemical standard culture greens received an emergency chemical fungicide application in 2002, and two to three in 2003.
- Project results have been conveyed to several thousand golf course personnel, environmental advocates, and policy makers.
- The project is influencing golf course practices and policies in the U.S., Canada and beyond.

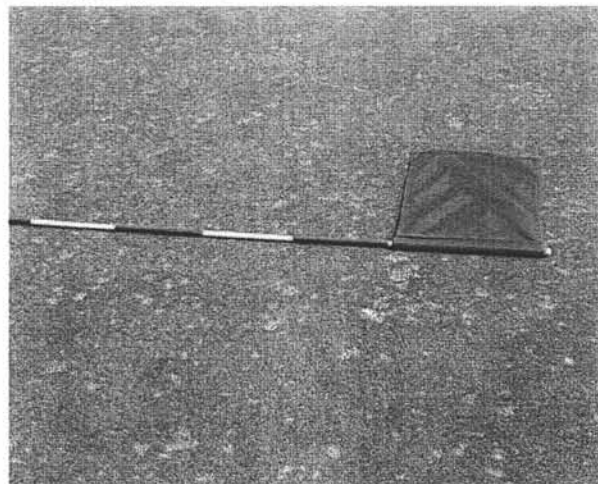
Communities around the world are increasingly demanding that golf courses be managed with few or no pesticides. Yet managers faced with operating their facilities under constraints on

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the use of chemical technology need information on how to maintain acceptable 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. For these reasons, we designed a project to provide information on the feasibility and performance of putting green turf managed using Integrated Pest Management (IPM) systems or no chemical pesticides.

Our objective was 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 explored total management systems, as practiced by turf managers, rather than focusing on individual technologies and isolated practices. The work was conducted at the Bethpage State Park on the Green Course, Farmingdale, NY. This course accommodates approximately 50,000 rounds of golf annually, has push-up soil greens that have been heavily sand topdressed for the last six years, and is typical of a high-use public course in the New York city metropolitan area.



Throughout the study, dollar spot was the primary pest problem in all treatments and was the target of the majority of the pesticide applications.

METHODOLOGY

Management Practices

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

Pest Management

Unrestricted: All legal chemical pesticides in New York State were available for pest management (i.e. practices similar to the a medium budget public golf facility in the Northeast US). Preventative control of pests was a significant aspect of weed, insect, and disease management.

IPM: Pest management practices were determined by the specific needs of individual greens. Actions were based on scouting information, action thresholds (when feasible) and site history. Cultural and biological approaches to prevent and minimize pest problems were emphasized, but any legal practice or pesticide was available. When pesticides were deemed necessary, the least-toxic and most effective products were selected based on potential risk factors such



In 2002, the Toro Company and Raven Industries (South Dakota) donated an injection sprayer that could apply small quantities of materials which greatly aided treating the IPM-managed greens.

as water quality impact, effects on non-target organisms, and toxicity to humans.

In this system, acceptable turfgrass performance was not intentionally sacrificed. Therefore, it was 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 turfgrass damage or loss of turf. Prophylactic chemical treatments were used only when justified by significant site history of problems, pending weather conditions, limitations of labor force, and lack of curative strategies that were acceptable in the risk assessment process.

Non-chemical: As in the IPM treatments, cultural and biological approaches to prevent and minimize pest problems were emphasized and decisions were based on the specific needs of individual greens. However, no pesticides registered in EPA class I (danger), II (warning), or III (caution) were allowed. The nonchemical treatment criteria were based on current restrictions for 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: The cultural practices in place at Bethpage were modified in an effort 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 increased fertility, double-cutting, and rolling were implemented if necessary to maintain these performance standards.

The experimental design resulted in six management systems as shown in Table 1. Each green served as a replicate, and we used all 18 greens of the Bethpage Green Course to accommodate three replications of the six management systems. System I was typical management for

Pest Management	Cultural Practices	
	Standard	Alternative
Unrestricted	I	II
IPM	III	IV
Nonchemical	V	VI (velvet)

Table 1. The design of the experiment using two cultural practices and three pest management strategies resulted in six treatment combinations, or management systems.

the Green Course--a quality, high-use public golf course. Systems III and V were 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 each year to respond to turfgrass performance and weather conditions.

After the first season, the greens in system VI were resodded with nine-month-old velvet bentgrass (SR 7200). Halfway through the second year, we conceded that we were unable to maintain acceptable conditions in system V, and we could not guarantee the survival of those greens. Therefore, those three greens are now being managed with alternative cultural practices providing a comparison of traditional *Poa*/creeping bentgrass greens and velvet bentgrass greens with nonchemical pest management.

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

2001

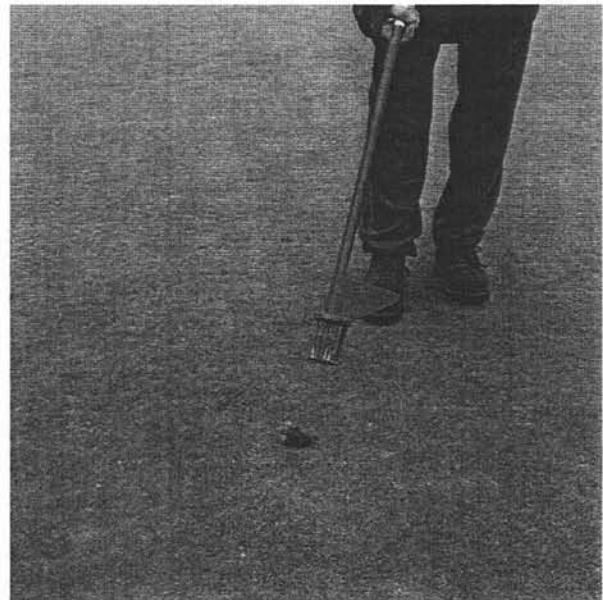
- o Rolling greens in the morning to reduce incidence and severity of dollar spot
- o Increased fertility to aid recovery from dollar spot injury
- o Application of entomopathogenic nematodes (*Heterorhabditis bacteriophora*) against annual bluegrass weevil larvae and cutworm caterpillars
- o Manual removal of weeds
- o Green closure to reduce traffic and allow for

renovation (four nonchemical greens, three of which were closed for over one month)

- o A winter compost cover of AgreSoil (biosolid-based compost) to reduce snow mold incidence and severity

2002

- o Tree removal around four nonchemical and one IPM green to increase sunlight and air circulation
- o Renovation with velvet bentgrass
- o Increased fertility to aid recovery from dollar spot injury, increased use of ammonium sulfate, and use of Sustane fertilizer
- o Regular applications of a biological fungicide, *Trichoderma harzianum* (TurfMate)
- o Manual removal of weeds.
- o Green closure to reduce traffic and allow for recovery (one green for three weeks)
- o A winter compost cover of NutriBrew (brewery-based compost)
- o Occasional applications of compost tea (Earthworks)
- o Phosphite product (Nutrigo) for prevention and alleviation of summer stress and decline
- o Standard fertility supplied with kelp-based materials from Plant Food Company



Throughout the study, weeds were removed manually from IPM and non-chemical greens

Cultural Management*		
<u>Practice</u>	<u>Standard</u>	<u>Alternative</u>
Mowing Height (bench settings; mowing with triplex units)	2.8 - 3.6 mm (0.110 to 0.140") 2003 = 3.3 mm (0.130")	3.8 - 4.8 mm (0.175" to 0.188") velvet always at 0.130" 2003 = 3.3 mm (0.130")
Mowing Frequency	1x/day, 7 days/week	2x/day, 5 days/week 1x/day, 2 days/week
Rolling	Groove (except 2003)	Solid
Irrigation	automatic 3-4:00 AM	manually activated 4:30-6:30 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. Approx. 60-70% of N supplied via organic sources, notably Sustane
Topdressing	Every 2-3 weeks	Weekly, no brushing
Rolling	1x per week**	Up to 3x per 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 per week	2x per week (3x in 2003)
<p>* Practices adjusted in attempt to attain >2.6 m (8 ft) ball roll distance. ** Practice seldom or never done in 2003 because of labor constraints.</p>		

Table 2. Standard and alternative cultural practices utilized on the Green Course's putting greens at Bethpage State Park.

2003

- o Increased fertility to aid recovery from dollar spot injury, increased use of ammonium sulfate, and use of Sustane fertilizer
- o Regular applications of a biological fungicide, *Bacillus licheniformis* (EcoGuard)
- o Manual removal of weeds
- o Green closure to remove traffic and allow for recovery (2 greens, 3-5 weeks each)
- o Phosphite product (Allude) for prevention and alleviation of summer stress and decline
- o Reduced risk fungicide, polyoxin-D (Endorse), derived from fermented *Streptomyces cacaoi*, for brown patch control
- o Reduced risk insecticide, spinosad (Conserve), produced by a soil-dwelling bacterium (*Saccharopolyspora spinosa*), for cutworm control

Performance and Pest Evaluations

Putting greens systems were evaluated throughout each growing season for aesthetic and functional performance, pest occurrence, species population dynamics, and tissue and soil nutrient content. Greens were inspected three to six times per week for signs and symptoms of disease-causing organisms, agronomic stress, insect pests, and weeds. Occurrence was mapped and quantified. In the second and third year, most diseases were recorded by "percent area of the green over threshold", according to action thresholds agreed upon by both researchers and golf course personnel (Table 3). Additional insect monitoring techniques such as irritant sampling (soap flushes),

Disease	Action Threshold
Anthrachnose	Detection
Dollar spot	2 spots/m ²
Fairy ring	If hydrophobic
Pythium root rot	Detection
Rhizoctonia	2 patches/green
Snow mold	10 patches/green
Summer patch	2 patches/green

Table 3. Disease thresholds that were used to rate putting green performance

cutworm pheromone traps, pine litter floatation and soil core examination were used at appropriate times to detect and quantify insect populations.

Visual quality of putting greens was assessed periodically using the NTEP rating system (1-9, with 1= dead turf, 6= acceptable turf and 9= ideal turf). Ball roll distance was also measured periodically with a Stimpmeter (six rolls at designated permanent location on green, three times in two directions) for adjustment of treatment practices. In addition, annual bluegrass populations were monitored approximately once a month throughout the project using the point quadrat method.

Economic Analysis and Golfer Satisfaction

To address the practical implications of our work, we are assessing the feasibility of each management system. Costs of labor and materials for each management regime were recorded for an economic analysis. To assess golfer acceptance, nearly 200 golfers were surveyed in the fall of 2003 for their perceptions of putting green quality and their opinions on pesticide use.

RESULTS**General Observations**

Putting greens are involved in at least 75% of the shots in a round of golf and are therefore an integral aspect of the game. High quality expectations and low pest thresholds for these areas present a formidable challenge when reducing pesticide inputs. In most cases we were able to maintain quality of IPM greens while drastically reducing insecticide and herbicide use, and to a lesser extent fungicides (Tables 4 and 5). Diseases and heavy traffic were responsible for low quality and sometimes death of nonchemical greens. Variable and severe environmental conditions explain much of the difficulty in managing diseases, whereas weeds and insects are not as clearly climatically influenced.

Pests and Pest Management

Throughout the study, dollar spot was the

primary pest problem in all treatments and was the target of the majority of pesticide applications. This disease severely reduced visual quality and performance of nonchemical greens and was responsible for the closure of four greens during the first year. The three standard culture non-chemical greens received an emergency chemical fungicide application in early August of the second season to mitigate dollar spot, and received two to three emergency applications per green in the third season to control dollar spot and other diseases.

It should be noted that regardless of pesticide use, some unrestricted and IPM greens had more days with some portion of the green over threshold for dollar spot than did the nonchemical greens (Fig. 1). This does not relate to how widespread problems were on each green, but does demonstrate that some turf areas escape control

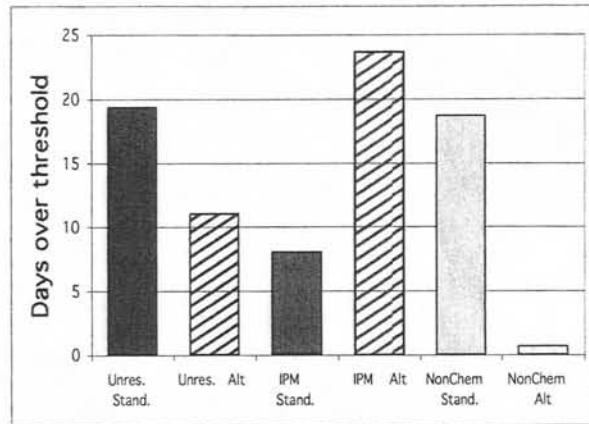


Figure 1. Dollar spot occurrence over threshold in 2003 for different management strategies.

even with full chemical availability.

Anthracoese was also problematic mainly in the first year and on greens cut at lower heights, but was usually considered to have stemmed from

<u>Year</u>	<u>Unrestricted</u>	<u>IPM--Standard</u> (% reduction)	<u>IPM--Alternative</u> (% 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%)
2003 <i>Chemical pesticides applications only (not including reduced risk and biological pesticides)</i>			
Insecticides	2.0	1.0 (-50%)	1.0 (-50%)
Herbicides	1.0	0 (-100%)	0 (-100%)
Fungicides	11.2	8.7 (-22%)	8.0 (-19%)
Total	14.2	9.7 (-32%)	9.0 (-36%)
<i>Reduced risk product and biological control applications</i>			
Reduced Risk Insecticides	0	0	0.7
Reduced Risk Fungicides	2.0	4.0	5.0
Bio Fungicide	0	9.0	9.0

Table 4. Mean number of pesticide applications in Unrestricted and IPM pest management systems

	<u>Standard</u>	<u>Alternative</u> (velvets)
Chemical Insecticide	0	0
Chemical Herbicide	0	0
Chemical Fungicide	2.7	0.3
Total	2.7	0.3
Reduced Risk Insecticide	0	1.3
Reduced Risk Fungicide	7.0	3.3
Total	7.0	4.7
Bio Fungicide	13.7	4.3

Table 5. Mean number of pesticide applications in nonchemical management systems in 2003

turfgrass stress rather than acting as a primary pathogenic agent. Anthracnose was diagnosed on the velvet bentgrass greens in 2002 and 2003 in areas near bunkers where sand was deposited on the green followed by clean up passes.

Rhizoctonia (brown patch) was a minor problem in the first year, problematic on two greens in 2002, and flourished in the third year of the study when hot, humid conditions persisted into evening hours and favored pathogen development. The reduced risk fungicide, Endorse, was applied regularly in effort to stem the tide of brown patch on IPM and nonchemical greens and up to four chemical fungicides were applied to the unrestricted greens for brown patch control.

Fairy ring became a prevalent and sometimes severe problem on the nonchemical greens and some of the IPM greens in 2002, and continued into 2003. We associated its occurrence with greens that had been covered with compost the previous winter, and the velvet bentgrass sod that arrived with a significant thatch layer. The disease was often severe enough to create hydrophobic conditions and was managed with wetting agents, hydrojecting, and fungicides on the IPM greens. Diseases other than those discussed were occasionally detected, but were not the target of pesticide applications and did not result in loss of turf.

Insects of significance were black cutworms and annual bluegrass weevils (ABW). In

2001, an application of a biological insecticide (*Heterorhabditis bacteriophora* nematodes) was targeted at 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 naturally occurring *H. bacteriophora* nematode-infected ABW have been detected at low levels in all years. The heaviest populations of ABW were observed in the collars and other higher-cut turf. We were fortunate that no damage occurred on the greens. However, if an entire course were managed without pesticides, ABW management could be a significant challenge in the northeast. In 2003, the reduced risk insecticide

Conserve was used successfully for cutworm management on IPM and nonchemical greens.

Weed concerns in all years were dominated by crabgrass and goosegrass in the *Poa*/creeping bentgrass greens, and *Poa annua* was considered a weed in the velvet bentgrass greens. In 2002, goosegrass incidence was much higher in the standard cultural treatments as opposed to the alternative treatments (Fig. 2). However, differences were not significant due to

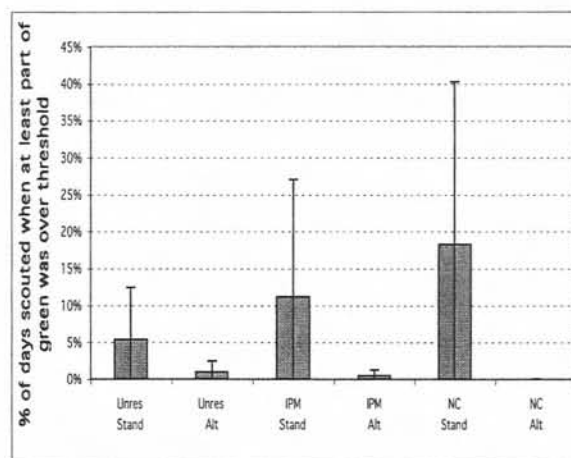


Figure 2. In 2002, goosegrass incidence was much higher in the standard cultural treatments compared to the alternative treatments.

high variation among greens, and this trend was only seen in the nonchemical treatments in 2003.

Throughout the study, weeds were removed manually from IPM and non-chemical greens, and were treated by one annual herbicide treatment to all unrestricted greens. Some IPM greens were also treated with herbicides: four in 2001, two in 2002, but none in 2003. Note that both greens requiring treatment in 2002 were in the standard cultural treatment. Weed populations in the nonchemical *Poa*/creeping bentgrass greens

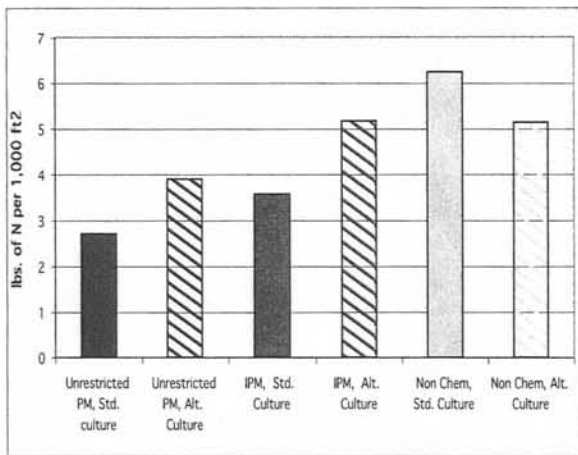


Figure 3. The unrestricted pest management, standard culture greens received the least amount of nitrogen (2.7 lbs./1,000 ft²).

have been increasing, and requiring more time to weed. In addition, the collar of one of these greens was treated with an herbicide in 2003 to reduce pressure of goose and crabgrass invasion.

The number of chemical pesticide applications is summarized in Tables 4 and 5. In all years, most pesticide applications that were avoided on IPM greens occurred early in the season before dollar spot was widely established. The three nonchemical, standard culture greens received one emergency fungicide application in 2002, and two to three per green in 2003.

No chemical pesticides were used on the velvet bentgrass greens, except that in 2003 one velvet green received a an application of Alliette for suspected Pythium root rot and all received one or two reduced risk insecticide applications.

Pest Management			
Culture	Unrestricted	IPM	Nonchemical
Standard	2.4	2.4	1.3
Alternative	2.3	2.2	2.3

Table 6. Mean ball roll distances (meters) in 2003

Fertility

The unrestricted pest management, standard culture greens received the least amount of nitrogen (2.7 lbs./1,000 ft²) (Fig. 3). The alternative culture treatments received more N than their standard counterparts in the unrestricted and IPM treatments. However, in the nonchemical treatments, alternative culture greens received less N. This is partly due to different nutrient requirements for velvet bentgrass, and because the standard culture nonchemical greens received extra nutrients in an attempt to compensate for pest damage and poor turfgrass health and to promote recovery.

Visual and Performance Quality

In 2001, the quality of all greens was below acceptable in the early season but recovered by June. Quality of all non-chemical greens was unacceptable as of late August to early September, resulting in closed or very low quality greens for the remainder of the season. Quality of five of the six IPM greens equaled that of the

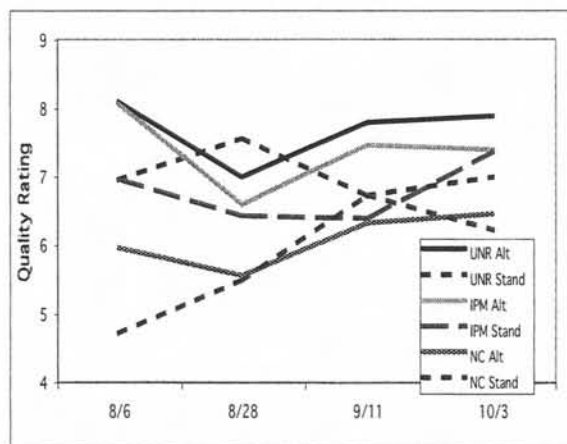


Figure 4. In 2002, all IPM and unrestricted treatments maintained acceptable quality throughout the season.

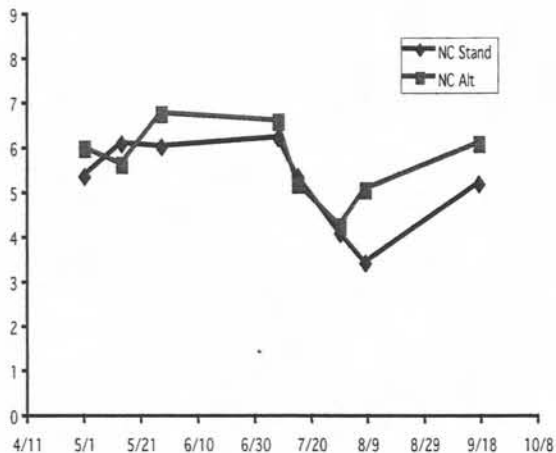


Figure 5. In 2003 all nonchemical greens were below acceptable quality for much of July and August.

unrestricted treatments throughout the season.

In 2002, all IPM and unrestricted treatments maintained acceptable quality throughout the season (Fig. 4). The quality of non-chemical standard greens was better than 2001, but still very low in August. The velvet greens were unacceptable in August, but recovered and were acceptable for the rest of the season. In all treatments, quality of the alternative culture greens was usually higher than their standard culture counterparts.

In 2003 all nonchemical greens were below acceptable quality for much of July and August (Fig. 5), and one velvet green was closed for a month. IPM and unrestricted greens were similar in quality for most of the season (Fig. 6), but the IPM greens fared worse in 2003 and were sometimes slightly below acceptable quality in both May and August, and two greens were unacceptable in September.

Throughout the study we struggled to achieve ball roll values of >2.4 meters (Table 6), but measurements were surprisingly low. Even the standard culture, unrestricted pest management systems that mimic normal Bethpage practices often did not produce the targeted ball roll distances. Obviously the use of triplex mowing may be a factor. However, we were still unable to achieve desired distances with topdressing and use of a growth regulator (Primo) on a regular

basis. Ball roll distances were slightly lower in the alternative culture unrestricted and IPM greens, but not as much as might be expected based on N input. This raises an interesting question regarding nitrogen use and ball roll. Distances were moderately low for the nonchemical velvet bentgrass greens and very low for the *Poa*/creeping bentgrass nonchemical greens.

Labor

Increased labor needs are an obvious component of both IPM and non-chemical management. Basic scouting requires two to three hours per 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.

Labor use in 2002 is presented in Figure 7. The majority of labor hours on the golf course are spent on cultural management, and alternative

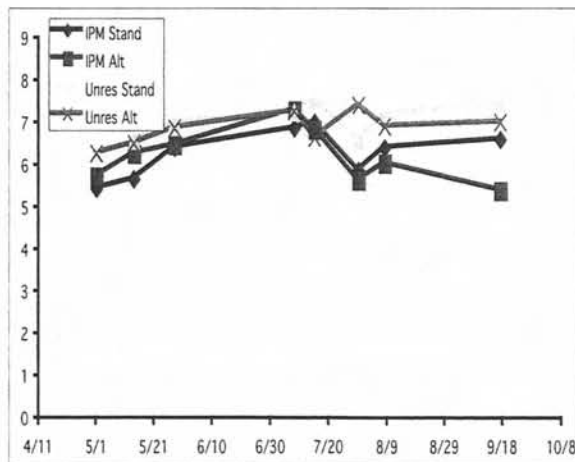


Figure 6. IPM and unrestricted greens were similar in quality for most of the 2003 season.

cultural management always took more time than standard culture. Labor time spent on pest management decreased with lower pesticide usage. However, this is a small portion of the overall labor hours. As might be expected, the unrestricted pest management standard culture system was the most efficient in terms of labor hours.

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. It was very difficult for Bethpage Green Course staff to carry out the practices mandated by the various management systems in this experiment with first tee times as early as 5:04 a.m. A few tasks were made more labor intensive by the nature of the experiment (e.g. mowing at two 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 non-chemical systems on an 18-hole course.

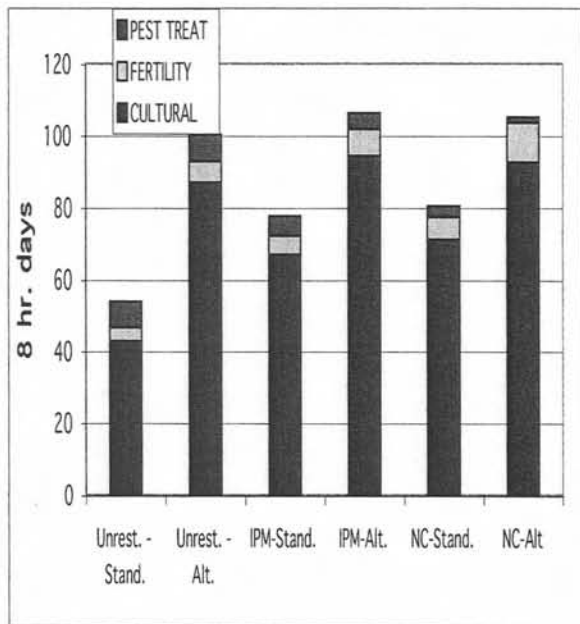


Figure 7. The majority of labor hours on the golf course are spent on cultural management, and alternative cultural management always took more time than standard culture.

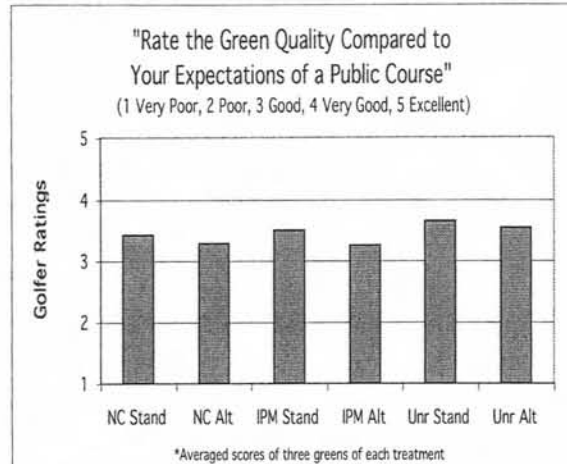


Figure 8. Scores showed no differences by treatment in golfer perception of the visual quality of greens.

Golfer Satisfaction Survey

Scores showed no differences by treatment in golfer perception of the visual quality of greens (Fig. 8) and the green speed (Fig. 9), and golfers rated all green speeds as "just right" or slightly fast. Golfers did perceive a difference in tracking quality of greens and rated the IPM alternative greens lower than other treatments (Fig. 10). Slow healing of some IPM greens after aerification likely caused these low ratings. When asked how they felt about pesticide use on public golf courses, the majority of golfers surveyed chose the IPM answer: "Keep greens at reasonably good quality, using pesticides judiciously, only as needed" (Fig. 11). Only 14% of golfers wanted pesticide use reduced if it meant a reduction in quality.

Outreach and Impact

Results from this study have been publicized in a number of formal and informal settings, in addition to reporting to the USGA. At a public field day in August 2003, 60 people toured the Green Course and learned about the alternative and IPM practices and products employed in the project. To date we have given 40 presentations and written 15 reports and articles, reaching several thousand golf course superintendents and environmental advocates in the U.S., Canada and beyond.

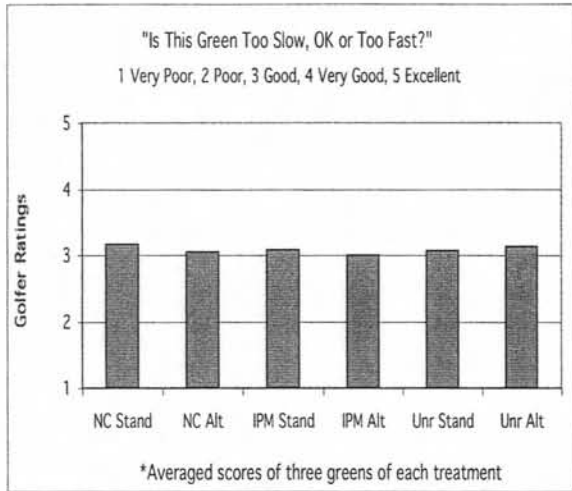


Figure 9. Golfers did not perceive differences in green speed between greens that received different management strategies.

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 non-chemical 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 in 2002. This might suggest that two management strategies are superior to those currently practiced on many public golf courses. However, differences based on culture were less pronounced in the first and third year. It is likely that the wet weather conditions in 2003 outweighed any positive effect of alternative cultural management practices. In 2003, we utilized more of these biological and reduced-risk pesticides, but had less labor.

Greens that were covered with compost in winter greened up more rapidly in spring and produced significantly more clippings than the non-composted treatments. Compost applications like-

ly increased the population of beneficial microbes in IPM and nonchemical greens and may have contributed to reduced dollar spot incidence. However, the winter compost covers left layers in the soil profile and were associated with damaging fairy ring infestations and a high incidence of brown patch. Increased fertility from the compost in the early season resulted in healthy turf with high density and rapid growth that prohibited 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 low to mid 2-meter range. We decided not to use compost covers in the winter of 2003-2004, but the overall benefit of compost covers may be greater in areas with more intense and consistence snow mold pressure.

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 2.4 meters. Soil tests indicated a significant lack of potassium, although tissue tests did not reveal the deficiency.

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 2002 and

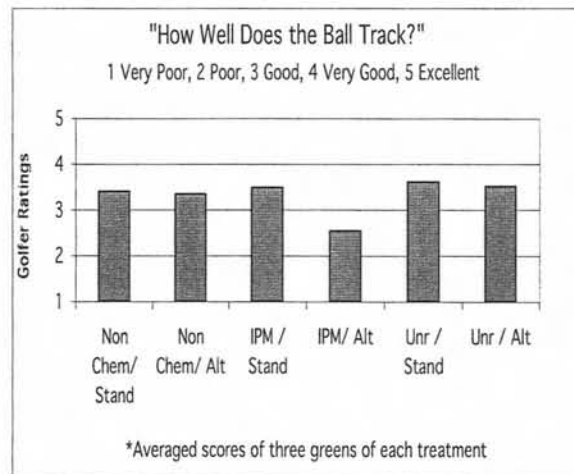


Figure 10. Golfers did perceive a difference in tracking quality of greens and rated the IPM alternative greens lower than other treatments.

2003 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 (150 kg per hectare) 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.

Phosphite products (Nutrigrow in 2002 and Allude in 2003) were donated by Cleary Chemical to mitigate summer decline symptoms. We do not know if the observed benefits of these products are because of nutritional effects on plants and/or direct impacts on pathogens that might be associated with summer decline such as Pythium root rot. Fertility on the velvet bentgrass was high in both 2002 and 2003, yet surfaces still appeared to be off-color and thin for much of the season, especially in July and August. The poor quality in 2003 may have been related to persistent, excessively wet conditions and a significant thatch layer. The major disease has been fairy ring which left depressions that affected ball roll.

While there had been concern for the overall recuperative ability 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/or



When asked how they felt about pesticide use on public golf courses, the majority of golfers surveyed chose the IPM answer: "Keep greens at reasonably good quality, using pesticides judiciously, only as needed."

more susceptible to their damage, and healed slowly from ball marks.

Early in the project it was clear that pesticide use in the IPM systems could have been further reduced if it were easier for the superintendent to quickly respond to rising pest levels. A large spray tank makes small spot treatments difficult and inefficient. Furthermore, sprayers at Bethpage are shared among courses and thus not always available on short notice. These factors

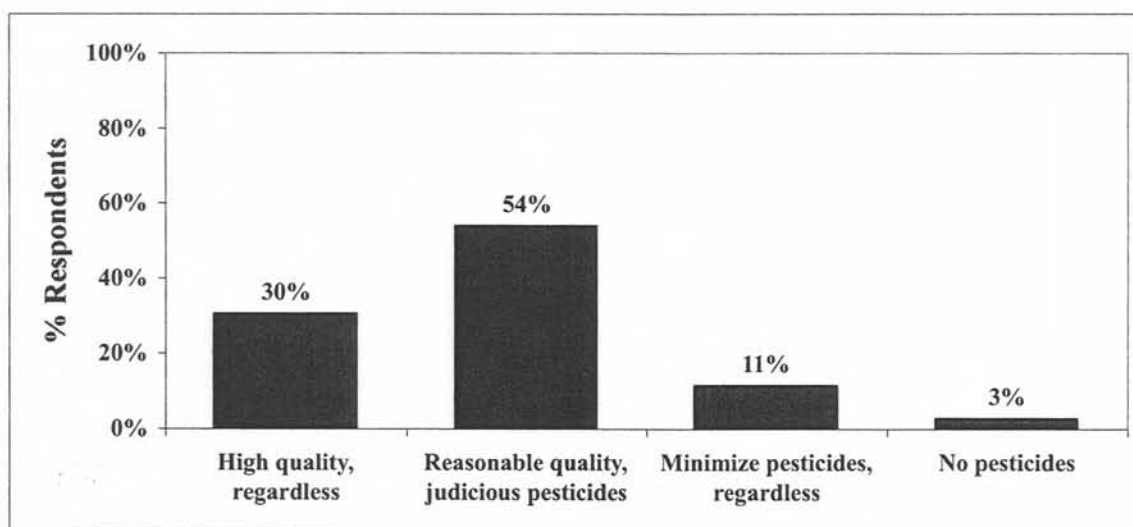


Figure 11. Only 14% of golfers wanted pesticide use reduced if it meant a reduction in quality.

encouraged the superintendent to include IPM greens when spraying the unrestricted greens. An injection sprayer was donated to the project to help overcome these issues.

We are still analyzing the full economic implications of each management regime. However, it is clear that a minimum of one or two extra employees would be required for a course to implement IPM and nonchemical management strategies. Golfers in our satisfaction survey were accepting of the greens quality in all treatments. However, we surveyed in October, and need to repeat the survey in the stressful months of July or August. In our study, it has been necessary to close some nonchemical greens each year. These conditions on a solitary golf course would undoubtedly be unacceptable and would result in loss of revenues.

The range of results over the three years of the study reflect the variation of environmental conditions. In a wet year like 2003, cultural and biological methods for disease suppression are less effective. In the Northeast, *Poa*/creeping bentgrass greens are highly susceptible to disease and stress pressure in July and August. Management with few chemical pesticides continues to be a challenge during these summer months. We believe that pesticide use can be significantly reduced in some years without compromising quality. However, research is still needed to develop tools and knowledge to deliver consistent and reliable results with few or no chemical pesticides.

Lastly, it should be noted that this project has already filled a significant role of informing turfgrass managers, environmental advocates and policy makers about golf course management with fewer pesticides. Discussion of this project has opened new dialog in many arenas where interested parties were previously adversarial. An example of the positive impact is that Suffolk County (which borders Bethpage State Park) reassessed their pesticide restrictions and revised their policy to one which is more scientifically based.

The Suffolk County-owned golf courses had been banned from using chemical pesticides, with the potential to obtain up to three application

exemptions per year. Through extensive discussions of this project and of basic principles of IPM, the diverse committee guiding implementation of the law decided to amend the law. The committee adopted an IPM approach that now allows pesticide use when specific criteria are met including: research-based thresholds, local tolerance levels for pests and pest damage, site history, forecasted weather, and available management options.

Interest in reduced and nonchemical management of golf courses in North America has been mounting in recent years. Communities throughout the U.S. and Canada are learning from our results.

Acknowledgements

We would like to thank the USGA, Bethpage State Park, Raven Industries, Toro, the Sustane Corporation, Novozyme, BioWorks, AgreSource, BASF, Tee to Green Sod, Commodity Specialists, Cleary's Chemical, Storr Tractor, Plant Food Company, Maxwell Turf Supply Company, Tamson Yeh and Nassau County Cooperative Extension and Long Island Golf Course Superintendent Association for their generous support of this project.

KEY PERSONNEL

Jennifer Grant will be responsible for overall project oversight and reporting. She will visit the project site on a regular basis (1-2 times per month during the growing season), consult with co-PDs and cooperators and make decisions on management practices and inputs--especially those concerning pest management.

Grant has over 15 years of IPM and turfgrass management experience. Her specialty is extending and researching low-impact pest management practices for turfgrass. Her work in New York State has included researching biological control of scarab grubs with entomopathogenic nematodes; designing IPM programs for golf course, institutional and residential turfgrass; and conducting training sessions and diagnostic courses for golf course superintendents and staff, IPM scouts, lawn care professionals and school grounds managers. Grant has conducted applied research on golf course scouting; biological control of turfgrass insects and diseases; and scarab grub monitoring in turf. Her current research projects investigate non-chemical golf course maintenance, alternative management of school grounds, and the effects of organic topdressing on athletic fields.

Frank Rossi will visit the project site on a regular basis (1-2 times per month during the growing season), consult with co-PDs and cooperators and make decisions on management practices and inputs--especially those concerning cultural management. Rossi has over 20 years of experience in turfgrass management and ecology. He conducts research and outreach education programs in the areas of environmental quality, integrated pest management, turfgrass ecology, stress physiology, and the effects of organic and micronutrient products on turfgrass quality.

Richard Buckley will be primarily responsible for laboratory diagnosis of turfgrass samples from the research site that are suspected of having disease or cultural problems, and will provide disease diagnosis training for the onsite IPM specialist. He will also be part of the team determining specific practices for pest and turfgrass management for each treatment, and will visit the project site 2-3 times annually. Buckley has 13 years of experience as Rutgers' plant laboratory diagnostician, and has expertise in disease and insect pest problems in turf and ornamentals, plant problem solving, and pest management techniques.

Bruce Clarke's primary responsibility will be consultation on disease prevention and management strategies. He will be part of the team determining specific practices for pest and turfgrass management for each treatment, and will visit the project site 2-3 times annually. Clarke is an authority on root-infecting fungi associated with patch diseases of turf, and is also well known for his work on the development of integrated disease control strategies to reduce pesticide usage. His research focuses on the identification and control of abiotic and biotic diseases associated with cool season turfgrasses.

Nathaniel Mitkowski's primary responsibility will be consultation on disease prevention and management strategies. He will be part of the team determining specific practices for pest and turfgrass management for each treatment, and will visit the project site 2-3 times annually. Mitkowski will provide laboratory diagnosis of turfgrass samples from the research site when his expertise is required. He will also provide disease diagnosis training for the onsite IPM specialist.

Mitkowski's research focuses is on stress-related diseases of golf course turf, including *Leptosphaerulina* as a primary turfgrass pathogen in the Northeast, the characterization of bacterial wilt of *Poa annua*, and investigation of factors influencing nematode populations on golf course putting greens. In addition, he examines the effects of multiple cultural management strategies on the quality of velvet bentgrass turf and is screening a limited collection of velvet germplasm for dollar spot resistance. Velvet bentgrass—a low maintenance grass with reduced management needs and high disease resistance—is pivotal to the proposed work in this project.

James Murphy's primary responsibility will be consultation on cultural and weed management of *poa annua*, creeping bentgrass and velvet bentgrass putting green turf. He will also be part of the team determining specific practices for pest and turfgrass management for each treatment, and will visit the project site 2-3 times annually. Murphy has 20 years of experience in turfgrass management. His areas of study include evaluation of turfgrass germplasm and best management practices to improve plant stress tolerance and promote environmental stewardship; mowing management effects on turf quality; evaluation of wetting agent and fertilizer efficacy; determination of the soil zone influenced by the creation of soil macropores with high pressure water injection; and evaluation of polyacrylamide gel in relation to soil moisture and nutrient retention and the implications to plant stress.

Daniel Peck's primary responsibility will be consultation on insect management. He will be part of the team determining specific practices for pest and turfgrass management for each treatment, and will visit the project site 2-3 times annually. His research focuses on the biology and management of major turfgrass pests; the influence of the soil environment on the behavior and ecology of subterranean insects and their natural enemies; discovery and exploitation of scarab pheromones, and the effect of control tactics on nontarget microarthropod communities. His work on the ecology and management of annual bluegrass weevils will be especially pertinent to the project.

Bethpage State Park Personnel

The Bethpage Green Course supervisor (Andy Wilson) will be responsible for implementing and recording all management practices. The IPM Specialist (Kathie Wegman) will be responsible for collection and recording of pest and turfgrass performance data, and initial diagnosis of pest and turfgrass problems.