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

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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 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.

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

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.

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

	Cultural Practices	
Pest Management	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 tratment 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 (Nutrigro) 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*	
Practice	**Standard**	**Alternative**
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)

* 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.

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

Disease	Action Threshold
Anthracnose	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

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 nonchemical 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 even with full chemical availability.

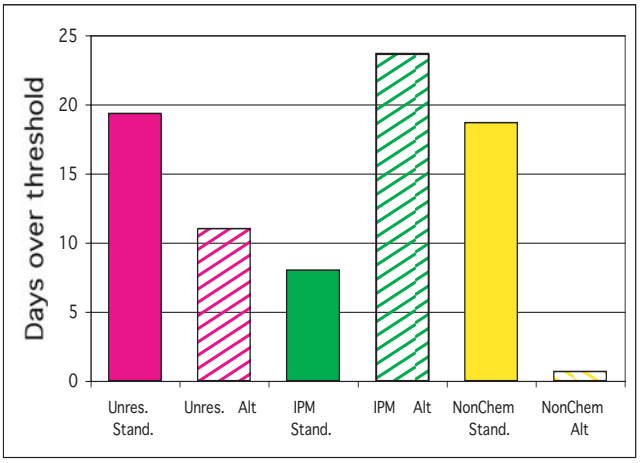

Figure 1. Dollar spot occurence over threshold in 2003 for different management strategies.

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

Year	Unrestricted	IPM--Standard (% reduction)		IPM--Alternative (% 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	***Chemical pesticides applications only*** *(not including reduced risk and biological pesticides)*				
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%)**
	Reduced risk product and biological control applications				
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

	Standard	Alternative (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

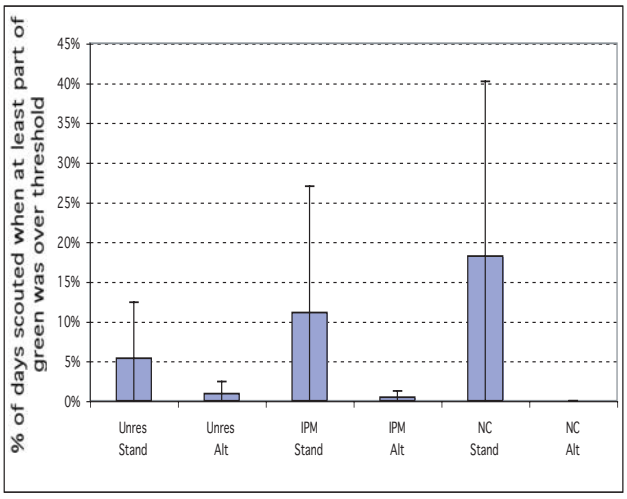

Figure 2. In 2002, goosegrass incidence was much higher in the standard cultural treatments compared to the alternative treatments.

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

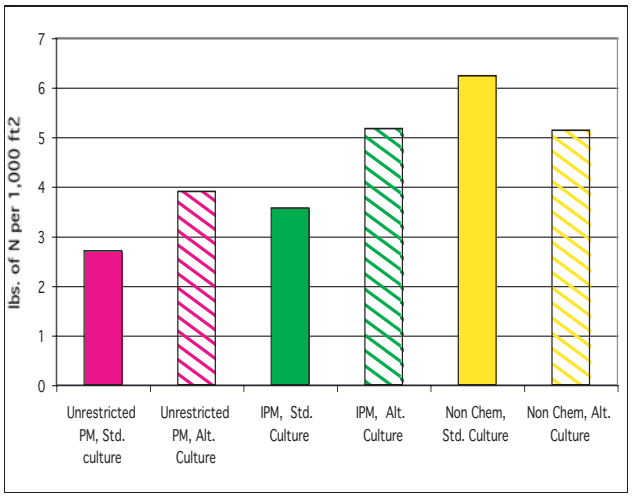

Figure 3. The unrestricted pest management, standard culture greens received the least amount of nitrogen (2.7 lbs./1,000 ft^2).

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 ft^2) (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

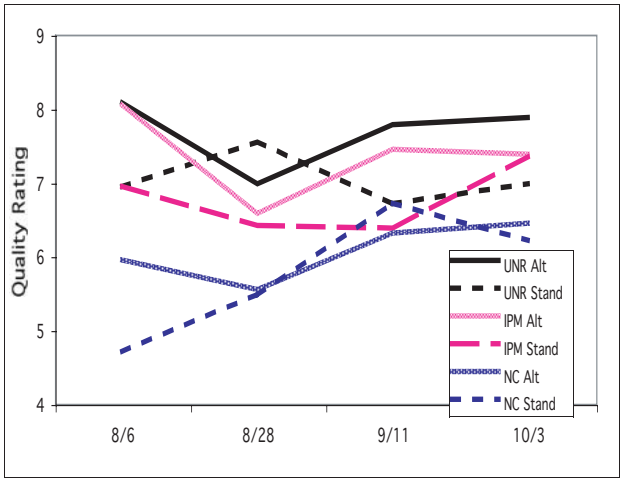

Figure 4. In 2002, all IPM and unrestricted treatments maintained acceptable quality throughout the season.

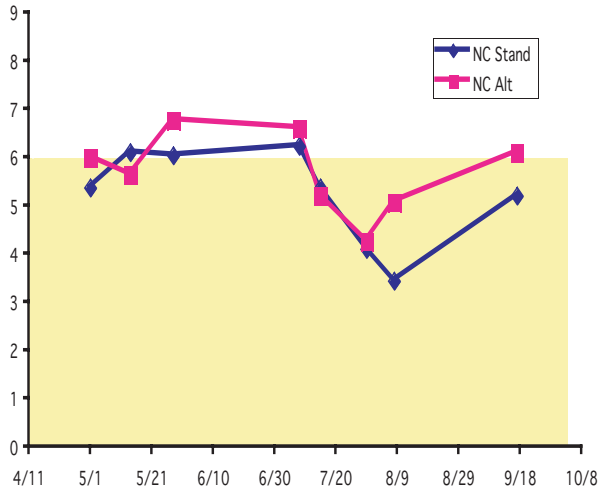

Figure 5. In 2003 all nonchemical greens were below acceptable quality for much of July and August.

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

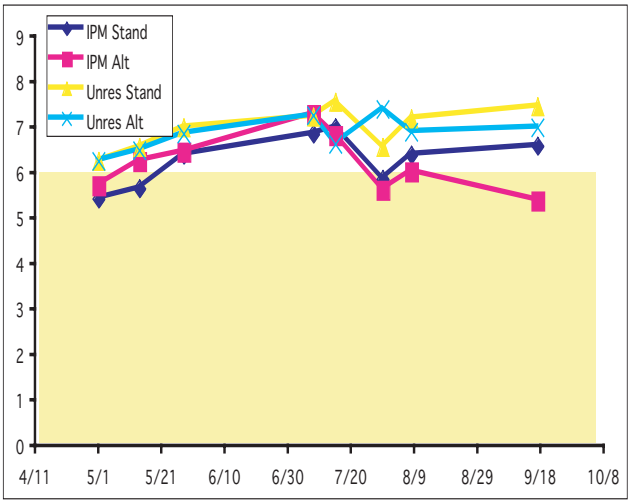

Figure 6. IPM and unrestricted greens were similar in quality for most of the 2003 season.

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.

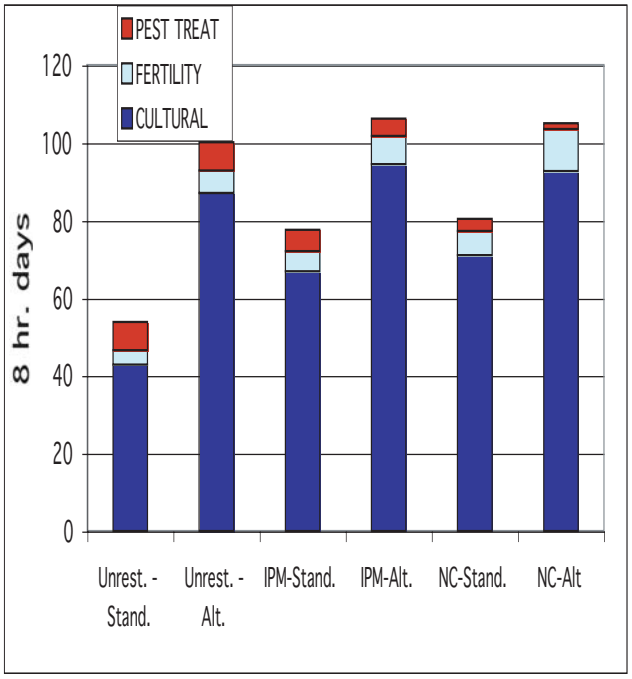

Figure 7. The majority of labor hours on the golf course are spent on cultural management, and alternative cultural management always took more time than standard culture.

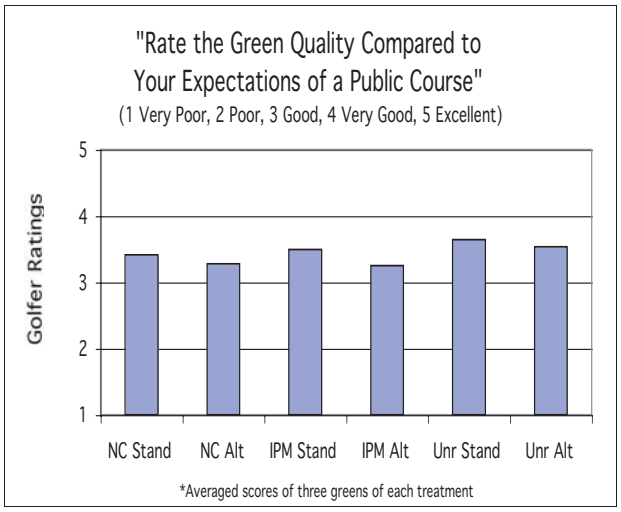

Figure 8. Scores showed no differences by treatment in golfer perception of the visual quality of greens.

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.

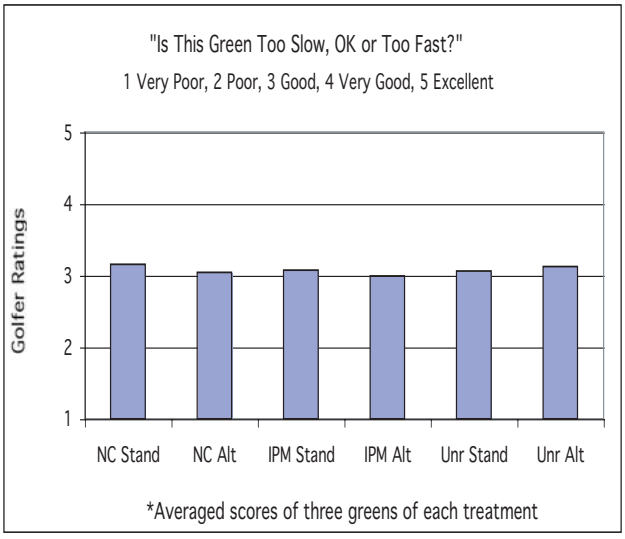

Figure 9. Golfers did not perceive differences in green speed between greens that received different management strategies.

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 likely 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

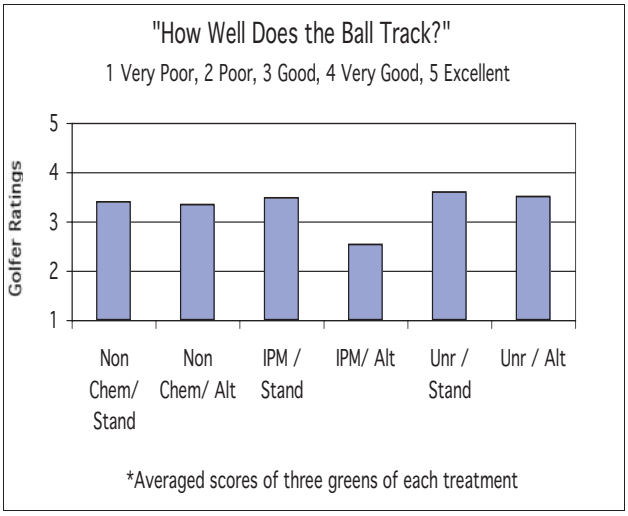

Figure 10. Golfers did perceive a difference in tracking quality of greens and rated the IPM alternative greens lower than other treatments.

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

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."

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

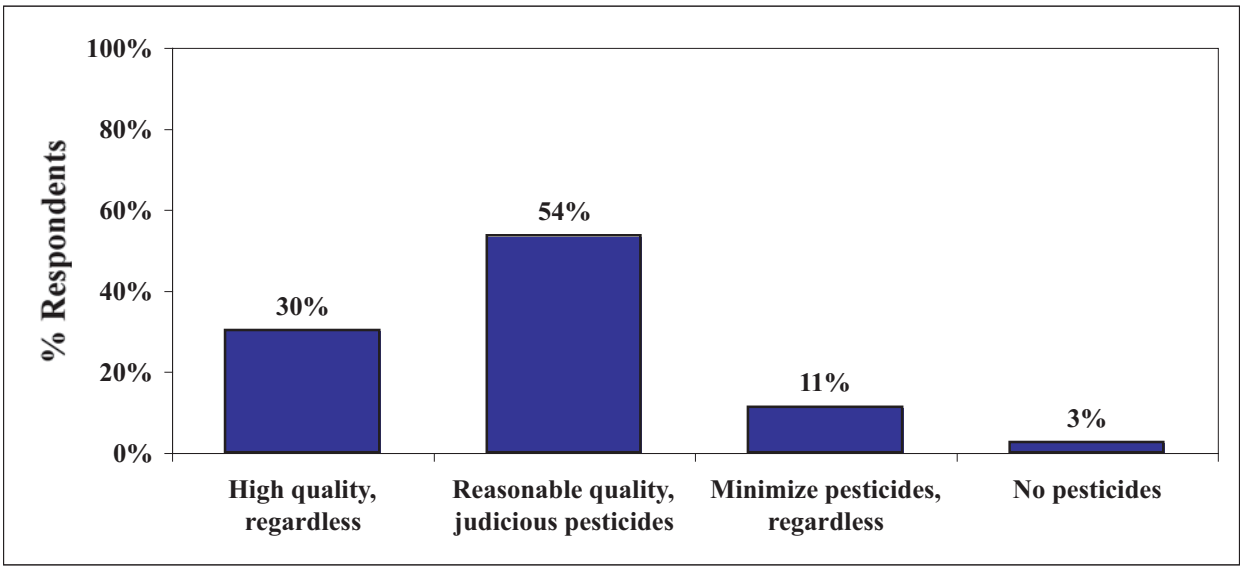

Figure 11. Only 14% of golfers wanted pesticide use reduced if it meant a reduction in quality.

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.

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