Evaluation of Golf Putting Green Management Systems with Reduced Chemical Pesticide Inputs: 2005 Report[1]

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2005 Overview

This season represented some significant alterations in cultural and pest management programs. Cultural programs differed only slightly in fertility and cultivation regimes. Mowing height was 0.140”(3.5mm) for all greens. Soil tests have indicated adequate amounts macro and micro-nutrients therefore, alternative culture greens were fertilized with N and iron only supplied as ammonium sulfate and chelated iron. In an effort to acidify the rootzone supporting the velvet bentgrass greens we applied ammonium thiosulfate and chelated iron. The standard culture greens received an array of complete fertilizer products that provide more balanced nutrition.

IPM and bio-based reduced risk pest management programs utilized the EIQ formula for pesticide selection. This provides an indication of the relative environmental compatibility of the products. Typically this confined our product selection to those deemed “reduced risk” or “bio-fungicides” by the EPA However, lowest labeled rate applications of propiconizole (Banner) were made when fungal diseases became epidemic. These low rate applications are considered reduced risk based on our EIQ calculations.

The foundation treatment in our Reduced Risk program was the bi-weekly application of Polyoxin-D (Endorse) and potassium salt of phosphorous acid (Alude. These products are classified as bio-fungicides and the Alude served as a significant source of potassium. Studies have shown that phosphite products do not act as P fertilizers. Both Endorse and Alude were generously donated by Cleary Chemical Company.

"To address dollar spot epidemics, historically we utilized regular applications of EcoGuard from Novozymes." However, this season we made two early season preventative applications of the naturally derived boscalid (Emerald) from BASF. Research from Michigan and New Jersey suggest early season applications could reduce inoculum levels thereby providing season long reduction in dollar spot.

In 2005, there was a severe decline of the velvet bentgrass greens, especially #10. We felt that a combination of traffic stress, direct heat stress and excessive N fertilization caused the catastrophic failure and forced us on a temporary green for several weeks in July and August. Several samples from the turf were sent to our team member Rich Buckley at the Rutgers Diagnostic Lab and came back as abiotic problems.

INTRODUCTION

This is the fifth year of a study assessing the feasibility and performance of golf course putting green turf comparing traditional management techniques with an IPM approach utilizing population-based pest management and to a system that utilizes biologically-based controls and reduced risk chemistry.

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[1] This information was also reported to the funders: the NE IPM Center (USDA) and the United States Golf Association (USGA).

The work, initially funded by the USGA, was initiated on the Green Course at the Bethpage State Park, Long Island, New York in 2001. The Green Course is one of five public courses at the Park and accommodates approximately 50,000 rounds of golf annually. The greens are made of push-up native soil and have been heavily sand top-dressed for the last six years, and are typical of a high-use public course in a northern metropolitan community. A more detailed discussion of methodology and results from 2001 through 2003 can be found at http://usgatero.msu.edu/, and the 2004 report at http://nysipm.cornell.edu/reports/ann_rpt/AR05/comm.asp.

RESEARCH 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 and currently available chemical pesticides in New York State may be used. (typical of the pest management conducted at the other four courses in the park)

IPM: Cultural and biological approaches to prevent and minimize pest problems were emphasized, but any legal practice or pesticide could be used when based on pest population and pressure from current and historical scouting records.

Bio-Based Reduced Risk (formerly non-chemical treatment): Cultural and biological approaches to prevent and minimize pest problems were emphasized. Reduced risk chemical pesticides and biopesticides were used to prevent turf loss and product selection was strictly confined to those with low EIQ values.

Cultural Management

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

Alternative: Modified cultural practices; selected to reflect the most progressive practices that maximize turfgrass performance and minimize turf stress.

The experimental design resulted in six management systems. Each green served as a replicate, with all 18 greens of the Bethpage Green Course used to accommodate three replications of the 6 management systems. After the first season (2001), the greens in the alternative culture, nonchemical (now "reduced risk") system were regrassed with velvet bentgrass (SR 7200) sod. In 2004, the "non-chemical" treatments were modified to "reduced risk" in recognition of the challenges in maintaining the integrity of the non-chemical treatments.

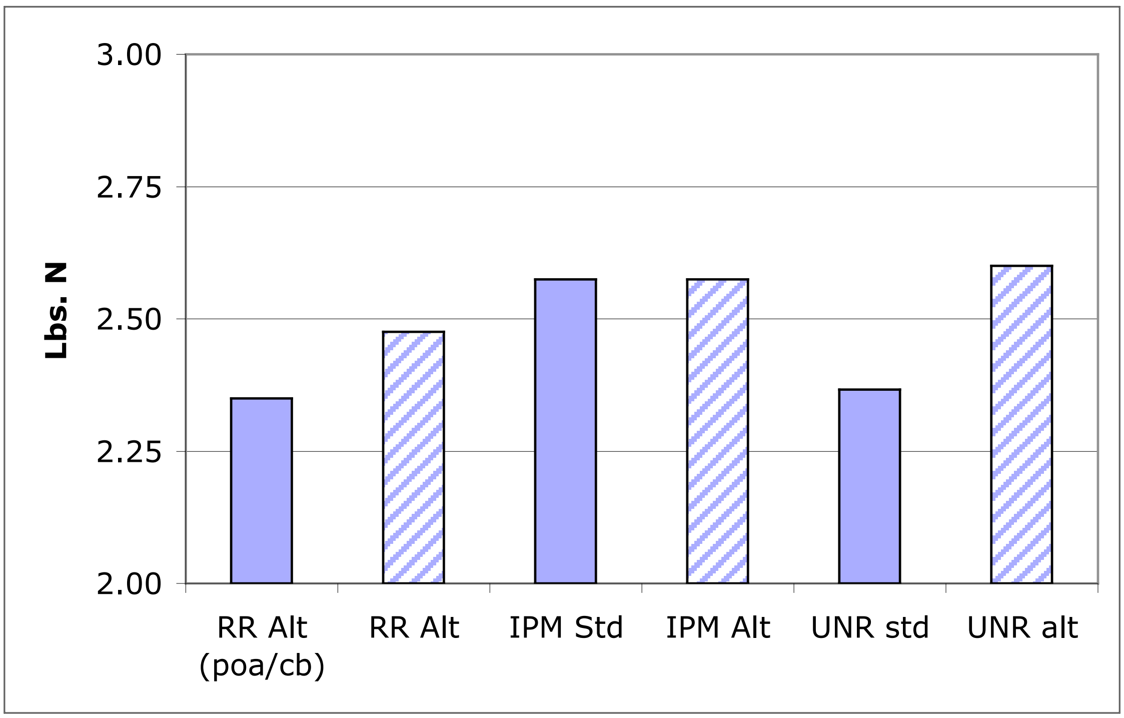
After three years of attempting to manage 70-yr. old mixed stands of bentgrass and annual bluegrass without synthetic pesticides in the Northeastern U.S. climate, we conceded that nonchemical management (management without any EPA-classified I, II, or III chemical pesticides) was not sustainable with current technology. Therefore, we decided that a more viable interim approach was to avail the project of tools designed to select very low risk products, even if the treatments were no longer technically "non-chemical".

In 2004 we introduced a significant change in the project by using the "Environmental Impact Quotient" (EIQ) (Kovach et al. 1992), to select the low-impact pest management products and practices in the IPM and reduced risk treatments. The EIQ model provides information on pesticides that will have the least harmful effects on non-target organisms, applicators and golfers. The superintendent chooses the lowest risk product amongst the legal products expected to be efficacious under the specific circumstances encountered. In 2004 and 2005 preemptive strategies were used to prevent severe quality loss in the reduced-risk treatments, including the use of reduced risk pesticides such as Endorse and Alude from Cleary Chemical Co.

Fertility

Soil tests have indicated adequate amounts macro and micro-nutrients. Therefore, alternative culture greens were fertilized with N and iron, supplied as ammonium sulfate and chelated iron. In an effort to acidify the rootzone supporting the velvet bentgrass greens we applied ammonium thiosulfate and chelated iron. The standard culture greens received an array of complete fertilizer products that provide more balanced nutrition. Total nitrogen applied is shown in figure 1.

Figure 1. Total nitrogen applied, 2005



Data Collection and Analysis

Turfgrass quality ratings are collected bi-weekly during the growing season on a scale of 1 to 9, where 1= poor quality, 9=excellent quality and 6 is considered acceptable quality. Ball roll measurements are recorded bi-weekly during the season with a USGA Stimpmeter. Three balls are rolled in two directions on a relatively level green area and six measurements are averaged.

Soil samples were collected in May at a 10cm depth and analyzed by Brookside Laboratories, Brookside, OH using Mehlich-3 extraction. Tissue samples were collected in May and July and analyzed for nutrient content using wet digestion.

Root samples were collected to a 10cm depth in July. Samples were cleaned free of soil and ashed to ash-free weight.

RESULTS AND DISCUSSION

Turf Quality

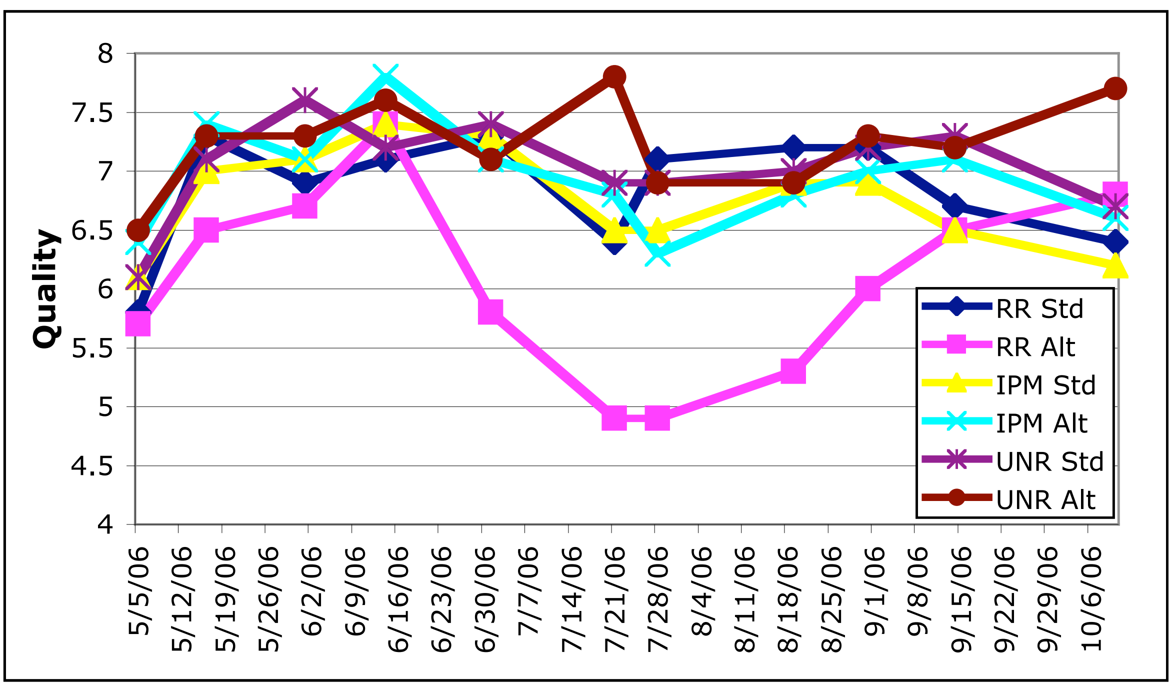
In 2005, significant differences among treatments for visual quality were rare (Figure 2, Tables 1-4). When there were significant differences it was obvious that the poor quality of the velvet bentgrass greens asserted a strong influence on mean treatment values. Still, all treatments, lest the velvet bentgrass and one early season rating on the reduced risk poa/bentgrass greens maintained acceptable quality ($\geq$6) throughout the season

The velvet bentgrass greens were the poorest quality of any of the greens in 2005 and each season seem to struggle through the warm summer months. In addition, we continue to see increased annual bluegrass invasion in each surface that will require an herbicide application or complete re-grassing.

There is a dearth of information on the cultural management of velvet bentgrass under modern conditions. Most information is more than two decades old and suggests that velvets perform best under low-fertility and on acid soils. Little is known about the relative traffic tolerance of velvet bentgrass, especially recovery from wear.

Our fertility levels appear to be low and in the range of what might be required, however it is possible we are still too high. Therefore in 2006 we will apply 50% of the fertility to the velvets as is supplied to the annual bluegrass dominated greens. Our concern is that we may be exceeding the traffic tolerance of velvet bentgrass at Bethpage and this exacerbates heat and other environmental stress.

Figure 2. Turfgrass Quality, 2005



RR=reduced risk pest mgt, IPM=IPM pest mgt, UNR=unrestricted pest mgt.
Std=Standard culture; Alt=Alternative culture
*Turfgrass quality ratings on a scale of 1-9 where 1= poorest quality, 9= highest quality and 6= acceptable quality.

Table 1. Main and interactive effects on turf quality for cultural and pest management treatments, 2005

Treatment	5-May	16-May	1-Jun	14-Jun	1-Jul	21-Jul	28-Jul	19-Aug	31-Aug	14-Sep	10-Oct
Pest Mngt.	NS	NS	NS	NS	NS	0.0014	NS	NS	NS	NS	0.0069
Cultural	NS	NS	NS	NS	0.0158	NS	0.0254	NS	NS	NS	NS
Pest Mngt. x Cultural	NS	NS	NS	NS	NS	0.0111	0.0263	NS	NS	NS	NS

Table 2. Main effect on turf quality means for cultural management systems, 2005

Treatment	5-May	16-May	1-Jun	14-Jun	1-Jul	21-Jul	28-Jul	19-Aug	31-Aug	14-Sep	10-Oct
Cultural (ALT)	6.2	7.1	7.0	7.6	6.7	6.5	6.0	6.4	6.8	7.2	6.6
Cultural (STAND)	6.0	7.1	7.2	7.3	7.3	6.6	6.8	7.0	7.1	6.7	6.4
LSD (0.05)	NS	NS	NS	NS	0.5	NS	0.7	NS	NS	NS	NS

Table 3. Main effect on turf quality means for pest management systems

Treatment	5-May	16-May	1-Jun	14-Jun	1-Jul	21-Jul	28-Jul	19-Aug	31-Aug	14-Sep	10-Oct
Pest Mngt. (UNR)	6.3	7.2	7.4	7.4	7.3	7.3	6.9	6.9	7.3	7.0	7.0
Pest Mngt. (IPM)	6.3	7.2	7.1	7.6	7.2	6.7	6.4	6.8	7.0	7.2	6.4
Pest Mngt. (RR)	5.8	6.9	6.8	7.2	6.6	5.6	6.0	6.2	6.6	6.6	6.2
LSD (0.05)	NS	NS	NS	NS	0.6	0.8	0.8	NS	NS	NS	0.5

Table 4. Interactive effect on turf quality means for culture and pest management

Treatment	5-May	16-May	1-Jun	14-Jun	1-Jul	21-Jul	28-Jul	19-Aug	31-Aug	14-Sep	10-Oct
RR Std	5.8	7.3	6.9	7.1	7.3	6.4	7.1	7.2	7.2	6.7	6.4
RR Alt	5.7	6.5	6.7	7.4	5.8	4.9	4.9	5.3	6.0	6.5	6.8
IPM Std	6.1	7.0	7.1	7.4	7.3	6.5	6.5	6.9	6.9	6.5	6.2
IPM Alt	6.4	7.4	7.1	7.8	7.1	6.8	6.3	6.8	7.0	7.1	6.6
UNR Std	6.1	7.1	7.6	7.2	7.4	6.9	6.9	7.0	7.2	7.3	6.7
UNR Alt	6.5	7.3	7.3	7.6	7.1	7.8	6.9	6.9	7.3	7.2	7.7
LSD (0.05)	NS	NS	NS	NS	0.9	1.1	1.2	NS	NS	NS	NS

Ball Roll

There were no significant effects of any treatments on ball roll (tables 5-7), however we are significantly below our target values for standard culture of at least 9 ft. Ball roll exhibited a seasonal trend with greatest distances achieved in spring and fall and smaller distances in summer. This is consistent with previous research on the seasonality of ball roll measures.

Mowing heights are a limiting factor to improving green speed. Clearly we will need to reduce mowing heights on the standard culture greens to get the green speed into the nine-foot range. In addition, while we are already at low fertility (i.e., less than 3 lbs of actual N per 1000 square feet), we will need to increase vertical mowing and topdressing to maintain speeds in the alternative culture greens to compensate for the high mowing heights.

Table 5. Main and interactive effects of culture and pest management treatment on ball roll, 2005

TREATMENT	16-May	1-Jun	28-Jul	14-Sep	10-Oct
Chemical	NS	NS	NS	NS	NS
Cultural	NS	NS	NS	NS	NS
Chemical x Cultural	NS	NS	NS	NS	NS

Table 6. Main effects of cultural treatment on mean ball roll distances, 2005

TREATMENT	16-May	1-Jun	28-Jul	14-Sep	10-Oct
Cultural (ALT)	8.4	8.5	7.4	8.6	8.4
Cultural (STAND)	8.4	8.3	7.4	8.7	8.4
LSD (0.05)	NS	NS	NS	NS	NS

Table 7. Interactive effects of treatments on mean ball roll distances, 2005

Treatment	10-Jun	1-Jun	28-Jul	14-Sep	10-Oct
RR Std	8.3	7.9	7.4	8.7	8.4
RR Alt	8.6	8.7	7.4	8.7	8.5
IPM Std	8.5	8.3	7.4	8.6	8.4
IPM Alt	8.2	8.6	7.3	8.6	8.3
UNR Std	8.4	8.6	7.3	8.7	7.8
UNR Alt	8.4	8.3	7.4	8.6	8.4
LSD (0.05)	NS	NS	NS	NS	NS

Tissue and Soil Nutrient Analyses

Tissue was analyzed for nutrient content in May (Table 8). Although we did not have data on N content of the tissue, it appeared from the data on the other nutrients that N content was acceptable. Ca, Mg, P and Na levels were adequate and the K content of the tissue was normal. It is somewhat surprising to see such variability in tissue K, which ranges from a low of 1.19% to a high of 2.47%. The unrestricted pesticide management program had a mean of 2.1%, which was statistically greater than the 1.7% mean value for the reduced-risk treatment. Both values were within sufficiency ranges for tissue K and could reflect the K supplied via the Alude treatments.

The Mn content of the tissue was normal. There was more Mn in the reduced-risk than in the unrestricted or the IPM treatments, and there was more Mn in the alternate culture than in the standard culture treatment. Surprisingly, the soil Mn was greatest in the unrestricted pesticide treatment. The Fe content of the tissue was normal. Even though soil Fe was affected by pest and cultural management, these differences were not apparent in the tissue Fe content.

Table 8. Tissue nutrient content for samples collected from Bethpage State Park Green Course in May 2005.

Green	Pesticide	Cultural	Ca	Mg	K	Na	P	Mn	Fe
	Treatment				%			ppm	
1	UNR	STAND	0.33	0.2	2.33	0.04	0.46	66	294
2	RR	STAND	0.34	0.18	1.97	0.04	0.41	81	453
3	IPM	STAND	0.31	0.15	1.69	0.04	0.34	72	469
4	RR	STAND	0.17	0.1	1.28	0.04	0.27	55	1001
5	IPM	STAND	0.36	0.18	2.05	0.04	0.44	73	369
6	UNR	STAND	0.42	0.17	1.9	0.04	0.42	89	1496
7	RR	ALT (V)	0.4	0.16	1.19	0.03	0.3	250	340
8	IPM	ALT	0.36	0.21	2.33	0.04	0.5	77	548
9	UNR	ALT	0.36	0.2	2.08	0.04	0.48	79	476
10	RR	ALT (V)	0.23	0.15	1.49	0.03	0.39	219	1112
11	IPM	ALT	0.26	0.15	1.92	0.04	0.37	60	409
12	UNR	ALT	0.32	0.2	2.16	0.05	0.46	73	252
13	UNR	ALT	0.38	0.19	2.11	0.04	0.44	97	312
14	IPM	ALT	0.25	0.15	1.42	0.03	0.37	143	2367
15	RR	ALT (V)	0.25	0.16	1.61	0.04	0.4	258	1054
16	RR	STAND	0.25	0.16	2.47	0.04	0.47	75	313
17	UNR	STAND	0.33	0.19	2.07	0.04	0.43	71	226
18	IPM	STAND	0.44	0.22	2.29	0.04	0.5	92	358

Tissues were sampled again in July (Tables 9-11). Potassium in these samples were all within a generally accepted sufficiency level of 1.5-3.0%. Also, the P levels were adequate and if anything, were somewhat higher than are usual. A typical range is 0.4-0.6%. The tissue content of Ca and Mg were normal, but Ca was at the low end of the range (0.2-1.2%). All other nutrients were considered in the normal range.

Table 9. Tissue nutrient content for samples collected from Bethpage State Park Green Course in July 29, 2005

Green	Chemical	Cultural	K	P	Ca	Mg	Fe	Mn	Na	Al	B
				%					ppm		
1	UNR	STAND	2.41	0.63	0.34	0.22	203	91	681	62	11.4
2	RR	STAND	1.76	0.52	0.28	0.17	708	178	622	332	8.2
3	IPM	STAND	2.06	0.54	0.34	0.19	668	104	823	324	9.3
4	RR	STAND	2.20	0.56	0.30	0.18	435	116	633	213	6.7
5	IPM	STAND	2.47	0.59	0.32	0.21	382	103	760	123	7.4
6	UNR	STAND	2.30	0.63	0.29	0.19	267	91	650	116	7.7
7	RR	ALT (V)	2.33	0.61	0.19	0.18	257	401	616	78	5.5
8	IPM	ALT	2.53	0.66	0.31	0.19	395	134	1063	142	7.4
9	UNR	ALT	2.45	0.65	0.29	0.20	285	101	943	70	8.5
10	RR	ALT (V)	2.22	0.67	0.27	0.18	307	465	697	64	4.6
11	IPM	ALT	2.38	0.60	0.31	0.19	418	148	729	139	6.5
12	UNR	ALT	2.20	0.60	0.31	0.21	229	79	678	66	7.4
13	UNR	ALT	2.24	0.65	0.36	0.22	189	87	700	44	7.0
14	IPM	ALT	2.22	0.64	0.35	0.21	323	119	795	110	5.3
15	RR	ALT (V)	1.96	0.59	0.18	0.15	656	352	675	136	4.7
16	RR	STAND	2.32	0.57	0.30	0.18	392	102	716	163	6.2
17	UNR	STAND	2.38	0.64	0.33	0.21	243	101	687	63	8.3
18	IPM	STAND	2.35	0.61	0.31	0.20	338	137	638	94	5.2

There are treatment effects on nutrient content of all nutrients except for K. (tables 10-11). There is an interesting relationship between tissue Al and corresponding Fe and P in the tissue. More Al is associated with more Fe but less P. One might expect that a soil acidification program could cause this type of response, because Fe and Al are more soluble at lower pH, but soluble P generally decreases at lower pH.

In addition to the acidifying fertilizer we applied significant amounts of P in the Alude treatment however it does not appear that the P was being incorporated into the plant but rather must have had a direct effect on the pathogens.

Table 10. Differences in mean tissue nutrient content as a result of pest management treatments to greens at Bethpage Green Course. Samples collected 29 July 2005.

Chemical	K	P	Ca	Mg	Fe	Mn	Na	Al	B
		%					ppm		
Unr	2.33	0.63	0.32	0.21	236	92	723	70	8.4
RedRisk	2.13	0.59	0.25	0.17	459	269	660	164	6.0
IPM	2.34	0.61	0.33	0.20	420	124	801	155	6.9
LSD	**NS**	**0.04**	**0.04**	**0.02**	**174**	**38**	**133**	**83**	**1.7**

There are some slight effects of the cultural treatments on tissue nutrient content (Table 11), but not as dramatic as in the pest management treatments.

Table 11. Differences in mean tissue nutrient content as a result of cultural treatments to greens at Bethpage Green Course. Samples collected 29 July 2005.

Cultural	K	P	Ca	Mg	Fe	Mn	Na	Al	B
		%					ppm		
Alternative	2.28	0.63	0.29	0.19	340	210	766	94	6.3
Standard	2.25	0.59	0.31	0.19	404	114	690	165	7.8
LSD	**NS**	**0.032**	**NS**	**NS**	**NS**	**31**	**NS**	**68**	**1.4**

Soil nutrients were also analyzed in May (Table 12). The Mehlich 3 CEC values were normal for a sandy soil with relatively high organic matter content and perhaps some clay. The pH on all greens was at optimum levels for grass growth. The alternative culture greens had a pH of 6.1, and the standard culture pH was statistically higher at 6.4. This may have been a result of iron sulfate applications to the alternative culture greens; however, the standard culture greens tested higher in soil Fe.

The soil organic matter was relatively high, but this provides a higher CEC, slow release of N, P, and S, and excellent water-holding capacity.

Sulfur, Ca, Mg, Na and K levels were normal. However, phosphorus was extremely high and fertilizer applications of P were probably unnecessary. The P levels may be high due to Phosphonate fungicide use.

The micronutrient levels were fine. Iron was greatest in the reduced-risk and IPM treatments, while Mn was greatest in the unrestricted treatment, and Al was greatest in the reduced-risk treatment. Additionally, Fe was greater in the standard management than in alternative management, but Al was higher in alternative management than in standard.

Table 12. Soil nutrient content for samples collected from Bethpage State Park Green Course in May 2005

	Treatment		CEC	pH	OM	S	P	Ca	Mg	K	Na	Fe	Mn	Cu	Zn	Al
			cmol		%	ppm						ppm				
1	UNR	STAND	11.6	6.6	4.2	54	262	1611	237	80	22	333	25	7	29	398
2	RR	STAND	10.5	6.7	3.8	45	303	1486	224	65	24	408	21	6	28	312
3	IPM	STAND	9.0	6.1	3.5	36	270	1122	177	57	23	332	22	6	25	295
4	RR	STAND	8.9	6.2	4.0	35	287	1154	165	65	21	406	20	5	26	292
5	IPM	STAND	11.6	6.3	4.3	34	316	1549	218	63	19	338	18	9	34	381
6	UNR	STAND	9.6	6.4	4.3	34	212	1281	199	51	22	272	28	5	19	329
7	RR	ALT (V)	11.5	6.2	4.2	54	347	1477	216	81	23	296	18	9	31	701
8	IPM	ALT	12.7	6	4.3	35	345	1571	234	68	20	367	16	8	33	390
9	UNR	ALT	9.9	6.7	3.7	36	273	1396	206	62	21	314	24	7	29	346
10	RR	ALT (V)	12.1	5.9	4.3	52	310	1419	216	86	27	289	19	6	25	650
11	IPM	ALT	9.3	6	3.7	34	264	1152	159	73	22	352	20	6	27	305
12	UNR	ALT	9.8	5.9	4.2	34	198	1161	172	65	23	268	24	4	22	255
13	UNR	ALT	9.5	6.3	3.5	35	213	1233	182	80	21	256	22	5	24	326
14	IPM	ALT	9.9	6.1	4.1	34	241	1260	176	60	25	307	20	6	30	283
15	RR	ALT (V)	10.0	6.1	3.7	60	280	1236	197	77	27	332	20	6	22	661
16	RR	STAND	11.1	6.2	4.2	37	271	1437	212	70	20	339	17	6	28	337
17	UNR	STAND	13.6	6.5	5.5	47	403	1857	271	81	30	375	24	13	40	506
18	IPM	STAND	13.9	6.3	4.0	42	417	1833	270	77	23	403	19	12	44	440

Rooting

As we have seen over the first several years of the study there are few significant differences among the treatments relative to rooting (Tables 13-16). This was slightly surprising given the velvet bentgrass should have demonstrated significant greater rooting than the annual bluegrass dominated surfaces in the other treatments. However, the velvet greens suffered severe dieback in 2005 that could explain the lack of rooting differences.

Table 13. Main and interactive effects of culture and pest management treatment on ash-free root weight (measured to 10 cm depth). Sampled Sept 14 2005.

TREATMENT	10cm root wt. (mg)
Pest Mngt	NS
Cultural	NS
Chemical x Cultural	NS

Table 14. Main effects of cultural treatment on mean ash-free root weight (measured to 10 cm depth). Sampled Sept 14 2005.

TREATMENT	10cm root wt (mg)
Cultural (ALT)	54
Cultural (STAND)	47
LSD (0.05)	NS

Table 15. Main effects of pest management treatment on mean ash-free root weight (measured to 10 cm depth). Sampled Sept 14 2005.

TREATMENT	10cm root wt. (mg)
Pest Mngt (UNR)	58
Pest Mngt (IPM)	63
Pest Mngt (RR)	72
LSD (0.05)	NS

Table 16. Interactive effects treatment on mean ash-free root weight (measured to 10 cm depth). Sampled Sept 14 2005.

Treatment	10cm root wt (mg)
RR Std	66
RR Alt (velvet)	75
IPM Std	61
IPM Alt	69
UNR Std	55
UNR Alt	62
LSD (0.05)	NS

Pest Incidence and Pesticide Use

The majority of pesticide applications are for disease management, especially dollar spot and brown patch. Figure 3 shows the predominant target of pesticide application. In general we continue to see a decline in overall weed and insect incidence on the Green Course putting greens. Very few greens have required pre-emergence herbicide treatments for crabgrass and goosegrass. In addition, except for a few sporadic outbreaks of cutworms, there were no significant insect problems on the putting greens.

There was a significant reduction in the number of pesticide applications made to the reduced risk velvet bentgrass treatments when compared to the annual bluegrass dominated greens (Table17). Pesticides were considered "reduced risk" if classified as such by the EPA. They included Polyoxin D zinc salt (Endorse), mono and di-potassium salts of phosphorus acid (Alude) and boscalid (Emerald).

Figure 3 Target of Pesticide Applications

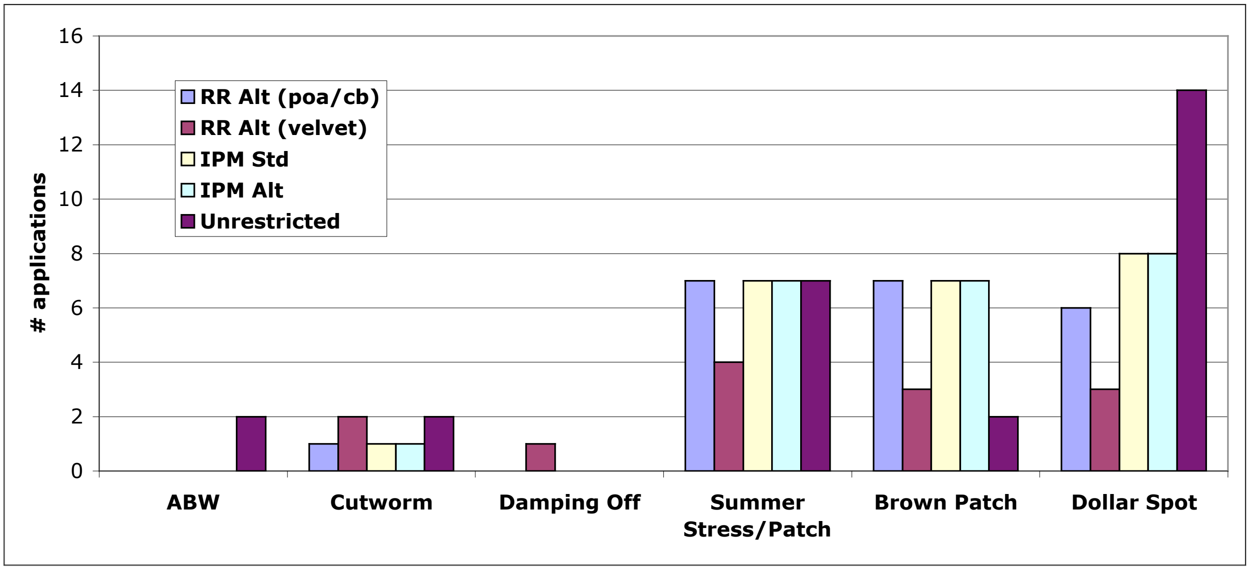


Table 17. Number of Pesticide Applications on Reduced Risk Greens in 2005

	Poa/creeping bent	Velvets
Chemical Insecticide	1	2
Chemical Herbicide	0	0
Chemical Fungicide	5	5
SubTOTAL	**6**	**7**
Reduced Risk Insecticide	0	0
Reduced Risk Fungicide	8.7	3
SubTOTAL	**8.7**	**3**
TOTAL	**14.7**	**10**

The number of pesticide applications to IPM and unrestricted greens are shown in table 18. The IPM greens received 56% fewer traditional chemical fungicides than the unrestricted greens. Both the IPM and unrestricted treatments received 16 fungicide applications, but in the IPM treatments over half were reduced risk products. The IPM greens received 75% fewer insecticides than the unrestricted greens, and no herbicides were required on any greens. Although numbers of pesticide applications are easily compared, they reveal nothing about the qualitative effect of these pesticides. A more meaningful evaluation of the significance of the reductions and changes in pesticide use is gained by comparing the environmental impact (EIQ) (see section below).

Table 18. Number of Pesticide Applications on Unrestricted and IPM Greens in 2005

Chemical	Unrestricted	IPM Standard (%reduction)		IPM Alt. (%reduction)	
Insecticide	4	1	75%	1	75%
Herbicide	0.1	0.1	0%	0.1	0%
Fungicide	14	6	57%	6	57%
SubTOTAL	**18.1**	**7.1**	**61%**	**7.1**	**61%**
Reduced Risk					
Insecticide	0	0	0%	0	0%
Fungicide	1	10	(900%)	10	(900%)
Bio Fungicide	0	0	0%	0	0%
SubTOTAL	**1**	**10**	**(900%)**	**10**	**(900%)**
TOTAL APPLICATIONS	**19.1**	**17**	**10%**	**17**	**10%**

Environmental Impact

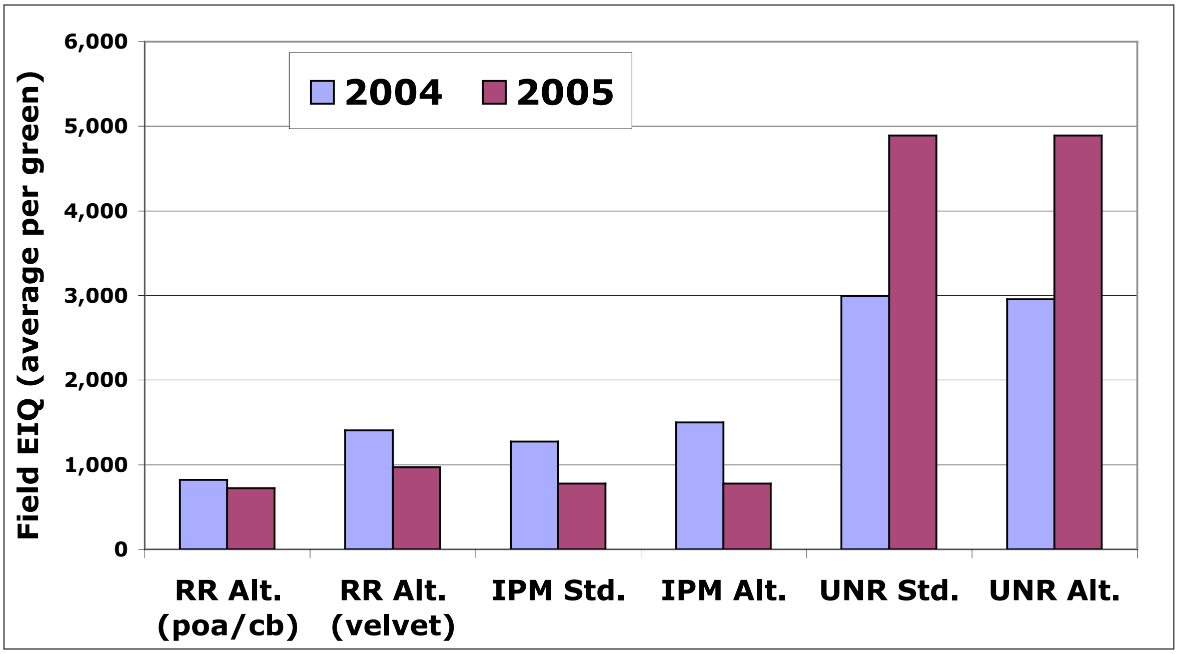
Comparing the number of pesticide applications is a fairly arbitrary method for assessing pesticide use when a variety of products are being used, and does not account for the potential environmental effect. However, few alternative tools for assessing and comparing environmental effects are available.

In 2004 and 2005 we used the Environmental Impact Quotient (EIQ) (Kovach et al.,1992) for both selecting low impact products, and to assess the cumulative impact of all products applied during the season in each of the six management systems. The EIQ uses 13 criteria including acute and chronic human toxicity, soil and leaf persistence, toxicity to non-target organisms, and leaching and runoff potential to determine worker, consumer/user, and ecological impact—which are combined into one final quotient number. The model balances factors such as toxicity to fish with the probability for the pesticide to leach or runoff the initial application site. The final quotient, or "EIQ number" is produced for all pesticides assessed, and is multiplied by the actual rate of use to give a "field EIQ".

The field EIQ was calculated for each treatment, and 2004 and 2005 totals are shown (Figure 4). In both years, the EIQ of unrestricted treatments had significantly higher field EIQs than both the IPM and reduced risk treatments. In 2005, the IPM and RR greens had numerically lower EIQs than 2004, whereas the UNR EIQs were higher suggesting significantly greater pest pressure in 2005.

We must use caution when interpreting the EIQ results. We suggest there were no meaningful differences among IPM and RR treatments in 2004 and 2005. However, there are clear differences among IPM, RR and the unrestricted treatment. The EIQ has proved to be an excellent resource for our Project Manager to select products that offer control at or close to the level of traditional synthetic pesticides and with greater environmental compatibility.

Figure 4. Environmental Impact of Pesticide Applications, expressed as Field EIQ



Labor

Over the last few years we have seen a converging of labor hours among treatments, as seen in 2005 (Fig. 5). However, in the early phases of the project we had a clear distinction among labor hours for alternative and standard culture, as seen in 2002 (Fig. 6). Alternative culture treatments always had greater labor hours with significantly different mowing and cultivation regimes. However, over time as treatments have become more homogeneous the labor differences have dissolved.

Figure 5. Labor hours expended, extrapolated to 18 greens, 2005

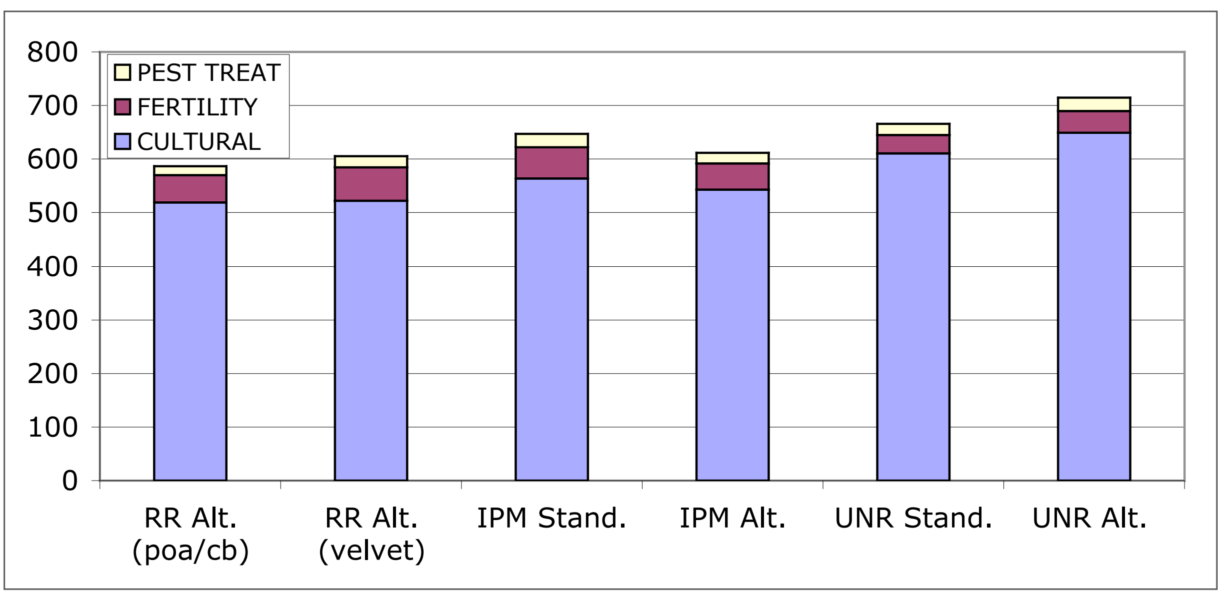
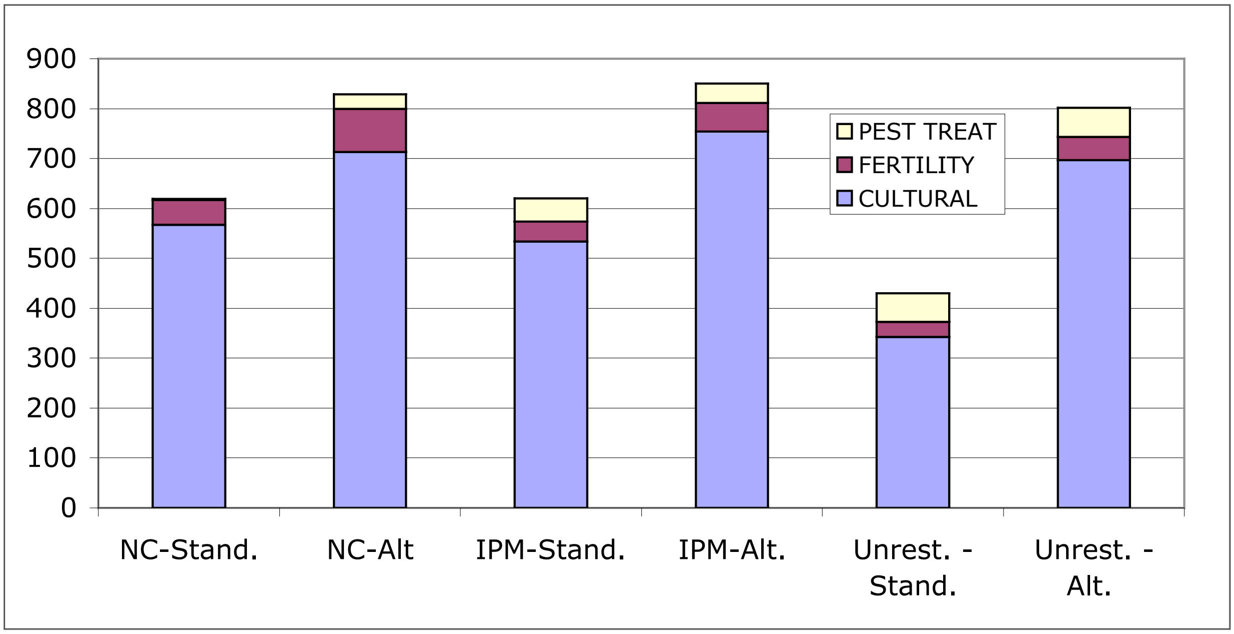


Figure 6. Labor hours expended, extrapolated to 18 greens, 2002



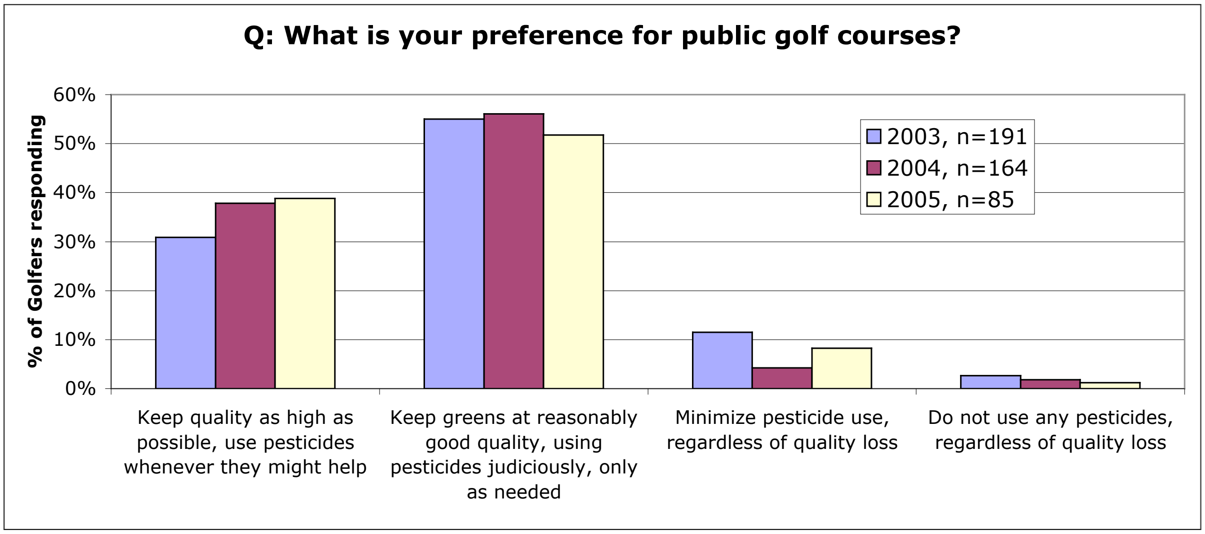
Golfer Satisfaction Survey

Golfers were surveyed annually from 2003-2005 to assess their perceptions of the visual and performance quality of greens managed under the various pest management and cultural treatments. In all years, the golfer ratings for the greens from all treatments averaged "good" to "very good" for overall quality and tracking (ability of a putt to hold a line), with the exception of the IPM alternative culture treatment in 2003 having a lower rating for tracking.

In addition, all green speed ratings averaged "good speed" (as compared to "too fast" or "too slow"). Therefore, we conclude that golfers accepted the quality of greens as managed in all of our treatments in years 3-5, with the exception of times that turf was lost or greens were closed.

Golfers were also queried on their opinion of pesticide use on golf courses. In all years, the majority chose an IPM approach, as shown for 2005 (figure 7).

Fig. 7 Golfer preferences on pesticide use, 2005



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. To date we have given over 50 presentations and written 15 reports and articles, reaching several thousand golf course superintendents and environmental advocates. Discussion of this project has opened new dialog in many arenas where interested parties were previously adversarial.

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