1999 ANNUAL RESEARCH REPORT

THE PENNSYLVANIA STATE UNIVERSITY

CENTER FOR TURFGRASS SCIENCE

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Evaluation of the Agronomic and Sports Turf Quality of a Modular Turf System Installed over Black Top

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The desire to provide a safer playing surface and still allow numerous and varied events in a stadium has led to the development of portable fields. As these systems become a viable option, a stadium can hold non-sporting events on pavement or artificial turf. When natural turf is desired, the portable field is installed over the artificial turf as individual modules.

In this study we wanted to evaluate the agronomic and playing surface quality of the modular turf system GrassTiles™. We wanted to compare tiles installed over blacktop with tiles installed over a traditional sand-based root-zone.

Materials and Methods

On September 2, 1997, Hummer Sport Turf Inc. of Lancaster, PA delivered fifteen turfgrass modules (tiles) to the Joseph Valentine Turfgrass Research Center, University Park, PA. The tiles are shown in Fig. 1 – 3. Each 7' x 7' x 2.25" tile was grown in a container. The soil mix in the container consisted of a USGA specified sand:peat mix. In addition to the sand and peat, various rates of DuPont Shredded Carpet filaments were incorporated into the root-zone mix prior to turfgrass establishment.

Fig. 1. Removing tile from container.

Fig. 2. Area prepared for tile installation.

Fig. 3. Tile being installed over sand base.

The amount of DuPont Shredded Carpet in each treatment tile is shown in Table 1. The PVOH treatment is a chemical developed by DuPont and included in the root-zone in an attempt to increase the rate of turfgrass recovery after stress. Each treatment was replicated three times for a total of 15 treatment tiles.

Table 1. List of treatments for Experiment 1.

Treatment	Rate of Fibers
	--(% weight)--
Control	0%
DuPont Shredded Carpet	1%
DuPont Shredded Carpet	1% with P.V.O.H.
DuPont Shredded Carpet	3%
DuPont Shredded Carpet	5%

The tiles were installed over blacktop with an approximately 0.25 inch drainage mat between the blacktop and the tile root-zone. The experiment was given basic maintenance including mowing, watering, and fertilization. The experiment was given no special attention.

On Sept. 3, 1997 we began to impose wear on the treatments tiles. Wear was applied with a Brinkman Wear Machine (Cockerham and Brinkman, 1989). The wear machine was pulled with a Steiner model 420 tractor equipped with a dual turf tire package in order to minimize wear due to the tractor tires. The machine was driven over the tiles using five passes three times per week. Cockerham and Brinkman (1989) estimate that two passes with their wear machine is equivalent to a NFL game at the 40-yard line between the hash marks. Wear ended for the season on Nov. 18, 1997. In 1998 wear began on April 15 and ended Aug. 17. Typically, wear was applied regardless of weather conditions.

Data Collection

Soil Physical Properties

Soil bulk density - The soil physical properties measured in this experiment include, soil bulk density and soil water content.

Soil bulk density data were derived from measurements of soil total density and volumetric water content taken with a Troxler 3400-B series surface moisture/density gauge.

Playing Surface Quality

Surface Hardness- Surface hardness was measured using a Clegg impact soil tester (CIT) equipped with a 2.25 kg hammer (Rogers and Waddington, 1989). The average of six hardness measurements on each subplot was used to represent the hardness value of the subplot.

Traction- Linear traction measurements were taken using PENNFOOT (McNitt et al., 1996, 1997) configured with a loading weight of 121.8 kg and a high-top molded shoe. The traction values reported are the average of three traction measurements recorded on each subplot.

Turfgrass Density- Turfgrass density was rated visually, and density was recorded on a scale of zero to five using half units. Zero represents a plot with no turfgrass present and five represents 100% turfgrass cover and no visible root-zone mix. A rating of 3.0 represents an acceptable turfgrass density in the center of a high school football field. The visual rating took into account both percent turfgrass cover and density of tillers.

Divoting- At the end of the study, divot size was measured on each treatment sub-plot. Divots were created using a weighted pendulum attached to the three-point hitch of a tractor. At the end of the pendulum the head of a golf club pitching wedge was attached. The height of the wedge, relative to the treatment surface was controlled with an adjustable metal pad. The pad can be set at different heights and when the three-point hitch is lowered the pad rests on the soil surface. During these experiments the depth was set to 15 mm.

The pendulum was released from a horizontal position. The pendulum is weighted with a 76 kg lead weight. After the pitching wedge cuts through the soil surface, the maximum length and width of each divot was measured.

EXPERIMENT 2 – GROW-IN

On May 10, 1998, Hummer Sport Turf Inc. of Lancaster, PA delivered twelve turfgrass modules (tiles) to the Joseph Valentine Turfgrass Research Center, University Park, PA. The tiles were the same as those described in Experiment 1 and shown in Fig. 1 – 3. The soil mix in the container consisted of a USGA specified sand:peat mix. In addition to the sand and peat, various rates of DuPont Shredded Carpet filaments were incorporated into the root-zone mix prior to turfgrass establishment.

The amount of DuPont Shredded Carpet in each treatment tile is shown in Table 2. Each treatment was replicated three times for a total of 12 treatment tiles. The tiles were arranged in a randomized complete block design. The tiles were installed over eight inches of a 90% sand 10% peat (v:v) USGA specified root-zone. This mix was underlain by six inches of USGA specified drainage gravel that included corrugated PVC drainpipe. The experiment was given basic maintenance including mowing, watering, and fertilization.

Table 2. List of treatments for Experiment 2.

Treatment	Rate of Fibers
	--(% weight)--
Control	0%
DuPont Shredded Carpet	3%
DuPont Shredded Carpet	3% with P.V.O.H.
DuPont Shredded Carpet	5%

On June 1, 1998 we split the block with two levels of wear. The two levels were no wear and wear equaling 7.5 NFL games per weak. Wear was applied with a Brinkman Wear Machine (Cockerham and Brinkman, 1989). The wear machine was pulled with a Steiner model 420 tractor equipped with a dual turf tire package in order to minimize wear due to the tractor tires. The machine was driven over the high wear subplots with five passes three times per week. Wear ended for the season on Oct. 15, 1998. Typically, wear was applied regardless of weather conditions.

Data Collection

Soil physical property and surface playing quality data was collected on two rating dates (July 3, 1998 and Oct. 14, 1998).

Data collection followed the procedures described in Experiment 1. Divot data was collected on Oct. 15, 1998.

Rating Dates and Statistical Analysis

The turfgrass density rating and the means of the three soil bulk densities, three soil water contents, three traction, six surface hardness measurements, and three divot sizes were analyzed using the analysis of variance and Fisher's Least Significant Difference (lsd) test at the 0.05 level. A lsd was not calculated when the F ratio was not significant at the 0.05 level.

RESULTS

EXPERIMENT 1

Soil Bulk Density

The results for the soil bulk density values are listed in Table 3. The control, DuPont Shredded Carpet 1% and 1% with PVOH had soil bulk densities that were not different on either rating date. The DuPont Shredded Carpet 3% had a lower soil bulk density than the control or the 1%

treatments on both rating dates. The DuPont Shredded Carpet 5% had a soil bulk density value that was lower than all other treatments on both rating dates.

Table 3. Mean soil bulk density values for treatments in Experiment 1.

Treatment	Nov. 14, 1997	July 3, 1998
	(g/cc)	
Control	1.22	1.37
DuPont Shredded Carpet 1%	1.21	1.35
DuPont Shredded Carpet 1% with P.V.O.H.	1.21	1.35
DuPont Shredded Carpet 3%	1.12	1.21
DuPont Shredded Carpet 5%	1.09	1.15
lsd (0.05)	0.11	0.04

Soil bulk density values increased for all treatments as wear increased. The DuPont Shredded Carpet 3% and 5% had lower soil bulk density values than the other treatments on both rating dates. The difference between soil bulk density values for these treatments was greater on the second rating date, indicating that the differences between treatment bulk density values increased with increasing wear. Low soil bulk density typically translates into lower resistance to root penetration and greater rooting.

Soil Water Content

Soil water content differences due to treatments are shown in Table 4. There were no significant differences between soil water contents caused by treatments on either rating date. The difference in soil water contents between rating dates should be noted. During the Nov. 14, 1997 rating date all surface playing quality measurements were taken while the soil water content was high. On the July 3, 1998 rating date the playing quality measurements were taken while the soil water was very low. Thus the playing quality measurements reflect a variety of playing condition extremes.

Table 4. Mean soil water content for treatments in Experiment 1.

Treatment	Nov. 14, 1997	July 3, 1998
	(% by vol.)	
Control	28.8	9.2
DuPont Shredded Carpet 1%	29.4	9.8
DuPont Shredded Carpet 1% with P.V.O.H.	29.7	11.2
DuPont Shredded Carpet 3%	27.1	9.0
DuPont Shredded Carpet 5%	27.3	10.7
lsd (0.05)	NS	NS

Surface Hardness

Playing surface hardness (impact attenuation) differences due to treatments are shown in Table 5. We measured no significant surface hardness differences between the control and either DuPont Shredded Carpet 1% treatments.

Table 5. Mean surface hardness values for treatments in Experiment 1.

Treatment	Nov. 14, 1997	July 3, 1998
	(Gmax)	
Control	75.8	100.6
DuPont Shredded Carpet 1%	73.9	114.5
DuPont Shredded Carpet 1% with P.V.O.H.	75.3	109.4
DuPont Shredded Carpet 3%	67.4	86.5
DuPont Shredded Carpet 5%	61.5	86.7
lsd (0.05)	5.6	13.0

As the rate of Shredded Carpet increased the playing surface hardness values decreased significantly. On the Nov. 14, 1997 rating date the DuPont Shredded Carpet 5% treatment had playing surface hardness values lower than all other treatments. The DuPont Shredded Carpet 3% treatment had surface hardness values lower than the DuPont Shredded Carpet 1% treatments and the control.

As wear progressed, the surface hardness values of all treatments increased. A portion of the increase measured on the July 3, 1998 rating date can also be attributed to the low soil water contents of treatments on that day. Prior studies have consistently shown a negative correlation between soil water content and surface hardness (Rogers and Waddington, 1990; McNitt and Landschoot, 1998).

On the July 3, 1998 rating date the DuPont Shredded Carpet 3% and 5% treatments had significantly lower surface hardness values than all other treatments. This was after the tiles had been exposed to wear levels equivalent to 150 NFL games and the soil was allowed to dry considerably. These tiles, installed over blacktop and exposed to 150 NFL games with no aeration and moderate maintenance, had a playing surface hardness equivalent to or lower than most natural soil athletic field under similar soil moisture conditions.

Traction

The traction differences due to treatments are shown in Table 6. On the Nov. 14, 1997 rating date the control measured higher in traction than all treatments except DuPont Shredded Carpet 1%. On the July 3, 1998 rating date there where no significant traction differences between treatments.

Table 5. Mean traction values for treatments in Experiment 1.

Treatment	Nov. 14, 1997	July 3, 1998
	(Newtons)	
Control	1419	1405
DuPont Shredded Carpet 1%	1360	1459
DuPont Shredded Carpet 1% with P.V.O.H.	1396	1378
DuPont Shredded Carpet 3%	1336	1373
DuPont Shredded Carpet 5%	1356	1349
lsd (0.05)	48	81

Traction differences between treatments were generally small. This indicates that the addition of the DuPont Shredded Carpet does not increase or decrease traction. These results coupled with the results of other studies (McNitt et al., 1997) show no evidence of an increased tripping hazard due to the addition of Shredded Carpet.

Turfgrass Quality

The turfgrass quality ratings for treatments are shown in Table 7. There were no significant turfgrass quality differences between treatments on either rating date. The third column in the table shows the amount of recovery observed two weeks after wear treatments had stopped. While the DuPont Shredded Carpet 1% with PVOH had the highest recovery rating, the difference was not statistically significant compared to the other treatments.

Table 7. Turfgrass Visual Ratings (5 = most dense, 0 = least dense) in Experiment 1.

Treatment	Nov. 14, 1997	July 3, 1998	Recovery
	(5 - 0)		
Control	4.2	2.6	0.1
DuPont Shredded Carpet 1%	3.8	2.9	0.2
DuPont Shredded Carpet 1% with P.V.O.H.	4.1	2.9	0.7
DuPont Shredded Carpet 3%	4.0	3.0	0.5
DuPont Shredded Carpet 5%	3.9	3.1	0.5
lsd (0.05)	NS	NS	NS

The important thing to note in the data in Table 7 is that all treatments showed high quality turf on the Nov. 14, 1997 rating date after the equivalent of over 70 NFL games. Even after 150 NFL games all the treatments were at or very close to an acceptable rating of 3.0. This data demonstrates that this modular system can more than adequately sustain quality turfgrass under extreme wear conditions with only a 2.25 inch root-zone depth.

Divoting

The divot testing was performed once at the end of the study due to the destructive nature of the test. The divot dimensions for treatments are listed in Table 8.

Table 8. Divot width and length for treatments in Experiment 1.

Treatment	Width	Length
	-------------(cm)-------------	
Control	9.4	27.2
DuPont Shredded Carpet 1%	8.1	13.2
DuPont Shredded Carpet 1% with P.V.O.H.	8.1	14.7
DuPont Shredded Carpet 3%	7.9	11.9
DuPont Shredded Carpet 5%	7.4	10.7
lsd (0.05)	0.8	5.6

The control had divots that were larger than any treatment containing DuPont Shredded Carpet. The divot length for the control was essentially double in size compared to treatments containing Shredded Carpet. The divot width is controlled to some degree by the width of the club head and less dramatic differences were measured in this dimension. A trend was evident, with increasing concentrations of Shredded Carpet resulting in smaller divot width. These differences were not statistically significant between varying rates of Shredded Carpet but the control had divot widths larger than any other treatments.

These results are in general agreement with the results found by McNitt et al. 1996, where the addition of DuPont Shredded Carpet reduced divot size by half compared to the control.

EXPERIMENT 2 – GROW-IN

Soil Bulk Density

The results for the soil bulk density values are listed in Table 9. All treatments containing DuPont Shredded Carpet measured lower in soil bulk density than the control. This was the case for both the no wear and high wear subplots. DuPont Shredded Carpet 5% measured lower in soil bulk density than any other treatment under all wear levels on both rating dates. The DuPont Shredded Carpet 3% with PVOH had a higher bulk density than the DuPont Shredded Carpet 3% on both rating dates after wear was applied and on the second rating date under the no wear treatments.

Table 9. Mean soil bulk density values for treatments in Experiment 2.

Treatment	No Wear	High Wear	No Wear	High Wear
	---------------(g/cubic cm)--------------			
Control	1.25	1.55	1.21	1.30
DuPont Shredded Carpet 3%	1.08	1.32	1.08	1.13
DuPont Shredded Carpet 3% with P.V.O.H.	1.13	1.37	1.07	1.18
DuPont Shredded Carpet 5%	1.04	1.25	1.03	1.08
lsd (0.05)	.03	.03	.03	.03

As the rate of DuPont Shredded Carpet increased the soil bulk density decreased. These results are similar to the results for Experiment 1 and show that when exposed to wear there is little gained in soil bulk density reduction from placing the tiles over 8 inches of sand. There is a much greater reduction in soil bulk density by the addition of at least 3% DuPont Shredded Carpet by weight.

Soil water content

Soil water content differences due to treatments are shown in Table 10. The treatments containing DuPont Shredded Carpet contained less water than the control on the first rating date, over both wear levels. While the differences are small they are significant and show a difference between growing in the tiles and placing them over blacktop. In the overlay study (Experiment 1), there was no differences in water contents due to treatments. When the tiles were placed over 8 inches of sand (Experiment 2), the tiles held a few percent less water if they contained the DuPont Shredded Carpet. This may be due to the lower soil bulk density creating greater aeration porosity in the treatments containing DuPont Shredded Carpet. By the second rating date, after more wear was applied there was no difference in soil water content due to treatments.

Table 10. Mean soil water content values for treatments in Experiment 2.

Treatment	No Wear	High Wear	No Wear	High Wear
	----------------(% by vol.)---------------			
Control	14.8	14.8	6.2	7.3
DuPont Shredded Carpet 3%	12.7	12.7	7.1	7.7
DuPont Shredded Carpet 3% with P.V.O.H.	12.9	12.4	7.0	7.9
DuPont Shredded Carpet 5%	11.8	11.8	7.0	7.6
lsd (0.05)	1.3	1.3	NS	NS

Surface hardness

Surface hardness differences due to wear are listed in Table 11. On the first rating date under the no wear level, no surface hardness differences between treatments were measured. On the high wear level plots the DuPont Shredded Carpet 5% treatment had lower surface hardness values than all other treatments. There was no significant difference between the control and the DuPont Shredded Carpet 3% or 3% with PVOH.

Table 11. Mean surface hardness values for treatments in Experiment 2.

Treatment	No Wear	High Wear	No Wear	High Wear
	(g/cc)			
Control	65.7	86.9	74.2	85.6
DuPont Shredded Carpet 3%	64.3	85.0	74.3	83.7
DuPont Shredded Carpet 3% with P.V.O.H.	66.2	84.6	74.7	80.0
DuPont Shredded Carpet 5%	63.1	78.9	70.3	69.8
lsd (0.05)	NS	3.0	4.2	4.2

On the second rating date, after approximately 37.5 NFL games of wear, the DuPont Shredded Carpet 5% treatment had lower surface hardness values than all other treatments. The DuPont Shredded Carpet 3% with PVOH also had a lower surface hardness value than the control. Under the no wear level few differences were measured. The DuPont Shredded Carpet 5% treatment had a statistically lower surface hardness value than the DuPont Shredded Carpet 3% with PVOH. This difference is relatively small and of little practical significance.

Comparing the values obtained when the tiles are installed over 8 inches of sand versus over blacktop, we see that the tiles over blacktop did have slightly higher surface hardness values after 150 NFL games. For instance the DuPont Shredded Carpet 3% treatment had a surface hardness value of 86.5 over blacktop and 83.7 over sand, while the DuPont Shredded Carpet 5% treatment had a surface hardness value of 86.7 over blacktop and 69.8 over sand. After 75 NFL games, the tiles installed over blacktop had surface hardness values lower than newly installed artificial turf (typically mid seventies) and after 150 games and under dry soil moisture condition the tiles installed over blacktop had surface hardness values that would be considered in the normal range for a natural turfgrass playing field that was low in soil moisture (mid eighties).

Traction

Traction differences due to treatments are shown in Table 12. There were few differences measured. On the October 14, 1998 rating date, the DuPont Shredded Carpet 5% treatment had a statistically higher traction value than the control under the no wear level. There is little evidence to suggest a significant change in traction due to the presence of DuPont Shredded Carpet.

Table 12. Mean linear traction values for treatments in Experiment 2.

Treatment	No Wear	High Wear	No Wear	High Wear
	--------(Newtons)--------			
Control	1495	1343	1433	1370
DuPont Shredded Carpet 3%	1465	1290	1460	1370
DuPont Shredded Carpet 3% with P.V.O.H.	1465	1314	1440	1400
DuPont Shredded Carpet 5%	1414	1349	1486	1405
lsd (0.05)	NS	NS	35.8	NS

Turfgrass Quality

The turfgrass quality data for treatments in Experiment 2 are listed in Table 13. There were few significant differences in quality between treatments. On the October 14, 1998 rating date both 3% treatments had higher turfgrass quality than either the control or the DuPont Shredded Carpet 5% treatment.

Table 13. Turfgrass Visual Ratings (5 = most dense, 0 = least dense) for treatments in Experiment 2.

Treatment	No Wear	High Wear	No Wear	High Wear
	--------(5 - 0)--------			
Control	5	3.1	5	2.0
DuPont Shredded Carpet 3%	5	3.1	5	2.5
DuPont Shredded Carpet 3% with P.V.O.H.	5	2.8	5	2.3
DuPont Shredded Carpet 5%	5	3.3	5	2.0
lsd (0.05)		NS		0.3

While the tiles performed well in Experiment 2, the turfgrass quality ratings at the end of the study were lower than those at the end of Experiment 1. Both experiments received only moderate maintenance. I believe that Experiment 2 received inadequate water at times, which reduced the turfgrass quality. We observed that the grow-in study (Experiment 2) required more water than the overlay study (Experiment 1). Had Experiment 2 received more water, the turfgrass quality results may have been different. Nevertheless, these results indicate the ease of growing a quality playing surface using just the tiles and a drain pad over a hard surface. To our surprise the tiles installed over the blacktop required equal or at times less maintenance than the tiles installed over 8 inches of a USGA specified sand.

Divoting

The divot testing was done once at the end of the study due to the destructive nature of the test. The divot lengths for treatments in Experiment 2 are listed in Table 14.

For the high wear level subplots, the control had divots that were larger than any treatment containing DuPont Shredded Carpet. The divot length for the control averaged 50% greater in length than the other treatments. Under the no wear level, the control had divot lengths greater than the DuPont Shredded Carpet 3% treatment on the July 3, 1998 rating date.

These results are in general agreement with the results from Experiment 1 and those found by McNitt et al. 1996, where the addition of DuPont Shredded Carpet, at a 3% rate, reduced divot size by half compared to the control.

Table 14. Divot length for treatments in Experiment 2.

Treatment	No Wear	High Wear	No Wear	High Wear
	(cm)			
Control	6.6	16.0	9.2	11.4
DuPont Shredded Carpet 3%	5.4	10.2	8.6	8.5
DuPont Shredded Carpet 3% with P.V.O.H.	6.2	9.2	8.4	7.6
DuPont Shredded Carpet 5%	6.2	8.9	9.2	7.1
lsd (0.05)	1.1	1.1	NS	2.5

Summary

These results demonstrate that the modular system containing DuPont Shredded Carpet reduces soil bulk density, reduces surface hardness, and reduces divoting, while maintaining equivalent traction characteristics. This study compared tiles installed over blacktop with tiles installed over an eight-inch root-zone. We did not find major differences in soil physical characteristics or playing surface quality between the two installation procedures. This study demonstrates that with proper maintenance, the tile system, containing at least 3% DuPont Shredded Carpet, can provide a quality playing surface using either of the two installation procedures.

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The Effects of Crumb Rubber on the Density and Surface Hardness of Perennial Ryegrass

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Funding Sources: Niche Recycling

Introduction

Applications of crumb rubber to turfgrass sites has been identified as a positive practice which can increase wear tolerance of turf under wear stress. Rogers et al. (1998) reported that crumb rubber topdressings increased turf cover and had other positive effects on a Kentucky bluegrass-perennial ryegrass turf which was subjected to simulate traffic.

The objective of this study was to evaluate the crumb rubber provided by Niche Recycling as a material for topdressing turfgrass sites to increase turfgrass wear tolerance.

Materials and Methods

The experimental site was a perennial ryegrass (var. SR4200) grown on a Hagerstown silt-loam soil at the Valentine Turfgrass Research Center in University Park, PA. The site was mowed at 0.5 inches three times per week and clippings were returned. The plots received 3 lbs of nitrogen per 1,000 sq ft in 1998. The turf was irrigated as needed to provide adequate growth. The experimental area did not receive any pesticide applications or cultivation treatments.

The crumb rubber used (supplied by Niche Recycling) had a bulk density of 32 lbs/cubic ft. Treatments (1/8, 1/4, 3/8 inches deep) were individually weighed and applied by hand. The plots were not mowed for a few days following crumb rubber applications. Plots were 4 by 6 ft and arranged in a randomized complete block design with three replications. Applications were made on July 6 and September 4, 1998.

Traffic simulation was done using a Brinkman Wear Simulator (Figure 1). The Brinkman simulates traffic by using dual rollers with welded bolts (to mimic cleats) protruding from the rollers surfaces. The rollers turn at different speeds to create a shearing action to cause wear to the turf. Theoretically, two passes with the Brinkman simulates the traffic of one NFL football game inside of the hash marks at the 40 yard line, although it does not take divoting into consideration. Five passes were made on the plots every Monday and Friday to simulate five games per week.

Visual turf density ratings and Clegg impact measurements were made on September 4, 30, and November 23. The September ratings were 58 and 84 days after the first application of crumb rubber. The November 23 rating was 54 days after the second application of crumb rubber.

Visual density ratings were done on a scale of 1 to 10, with 10 being full turf coverage and 1 being bare ground. Surface hardness characteristics were measured with a Clegg Impact Hammer. The Clegg consists of a missile which is dropped through a guide tube and measures the maximum deceleration (Gmax) of the missile upon impacting the surface.

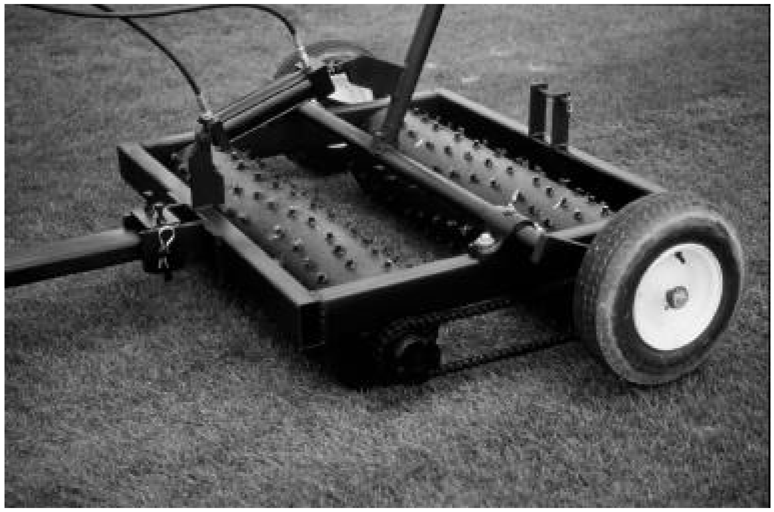

Figure 1. Brinkman Wear Simulator

The higher the Gmax value, the higher the surface hardness. Five drops of the hammer were done on each plot on each rating date.

All data was subjected to analysis of variance procedures. Treatment means were separated on each rating date using the Least Significant Difference test with p = 0.05.

Results and Discussion

Visual densities were the lowest for the rating dates 54 and 58 days after the first and second crumb rubber applications, respectively (Table 1). There were no statistical differences between treatments on any of the three rating dates.

Table 1. Turfgrass densities for a perennial ryegrass turf treated with crumb rubber.

Treatment	Depth (in)	9/4/98	9/30/98	11/23/98
Crumb Rubber	0.125	6.2 a*	8.0 a	6.8 a
Crumb Rubber	0.250	6.5 a	8.8 a	7.3 a
Crumb Rubber	0.375	6.5 a	8.7 a	6.7 a
Untreated Control	0.00	5.8 a	8.2 a	6.3 a

*Treatments within the same column followed by the same letter are not statistically different according to the Least Significant Difference test with p = 0.05.

There were statistical differences on the September 4 and November 23 ratings dates for surface hardness (Table 2). On September 4, the 0.125 and 0.25 inch treatments had significantly higher surface hardness values as compared to the untreated controlled. The 0.375 inch treatment also had significantly high surface hardness values as compared to the control on the November 23 rating.

Table 2. Clegg impact values (Gmax) of a perennial ryegrass turf treated with crumb rubber.

Treatment	Depth (in)	9/4/98	9/30/98	11/23/98
Crumb Rubber	0.125	88.5 a*	78.3 a	87.1 a
Crumb Rubber	0.250	83.4 ab	83.3 a	83.8 a
Crumb Rubber	0.375	75.9 bc	78.7 a	83.6 a
Untreated Control	0.00	72.2 c	74.1 a	70.7 b

*Treatments within the same column followed by the same letter are not statistically different according to the Least Significant Difference test with p = 0.05.

A possible reason for not seeing any differences between treatments may be that the crumb rubber is too coarse or may not have been worked in to a position that can provide crown protection. Rogers et al. observed that the size of the crumb rubber and the time for the crumb rubber to become effective is very important in crumb rubber performance. The crumb rubber provided by Niche recycling was very coarse as compared to the crumb rubber that is commercially available (Figure 2). The crumb rubber used in this study may become more effective in the following season.

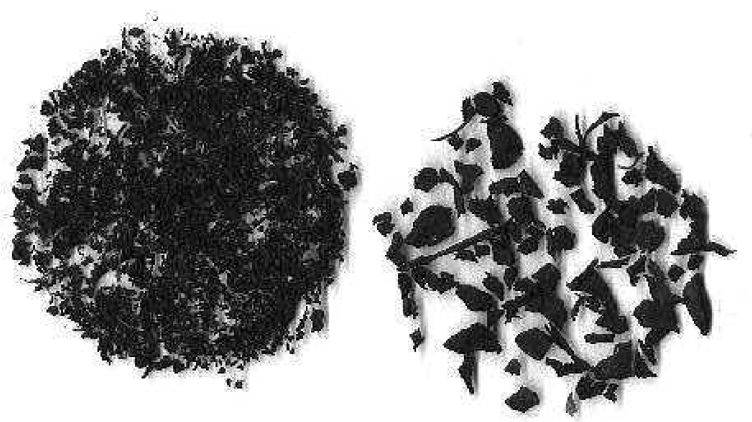

Figure 2. 1 gram of Crown III crumb rubber (left) as compared to 1 gram of Niche Recycling rubber (right).

Conclusions

The crumb rubber applied twice at depths of 0.125, 0.25, and 0.375 inches did not have any significant effect on the density of a perennial ryegrass turf under simulated traffic. The crumb rubber treatments did significantly increase the surface hardness of the turf on two of the three rating dates.

Due to the large size of the crumb rubber used in this study, the benefits of providing improved turf performance may not be noticeable until the season following the application.

A Procedure to Evaluate Golf Shoe Tread Types

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Funding Sources: Etonic Corporation

Introduction

The golf course industry has quickly accepted and encouraged the prohibition of metal spikes from golf courses. This exclusion of metal spikes is driven by a reduction of wear and damage on the golf course and in the clubhouse.

To fill the demand for alternative spikes, shoe companies have aggressively developed and marketed numerous spike and outsole designs. Unfortunately, there has not been a lot of research devoted to evaluating the effects that the new designs have on turfgrass quality, and more importantly, putting quality.

The objective of this study was to develop a procedure which could be used to evaluate the effect of golf shoe tread type on putting quality.

Materials and Methods

Three significantly different sole designs were used for this study to provide the best chance to create putting quality variation. The shoes used were conventional metal spikes (Foot Joy 98891), Womens Difference with DS-1 spikes (Etonic 8510), and Womens Stable Lites with molded soft- spike outsole (Etonic 8995).

The experimental site was located in University Park, PA. Two different areas were used for the study. One area had a rootzone comprised of native silt loam soil with a 3 to 4-inch layer of topdressing sand on the top (i.e., “push-up” style) and the other rootzone was an all sand rootzone. The turf composition on both areas was a mixture of Penncross creeping bentgrass and annual bluegrass maintained daily at 5/32 of an inch.

Plots were 2 by 15 ft and arranged in a randomized complete block design with five replications. A mechanical putter was built to roll the ball across the plot after traffic was applied. The putter minimized variability in ball roll and was almost 100% accurate. The putter was set at one end of a plot and 10 balls were rolled over the middle of the plot to determine the average stopping position of the balls. A putting green cup was placed on the average stopping position. A few more balls were rolled to ensure that the cup position was accurate. A hole was then cut with a cup cutter at the location, and the cup was installed. Care was taken not to walk on or disturb the ball roll path during the installation process.

Ten balls were rolled without any traffic being applied to serve as a control. Treatments were applied at five traverse intervals by simulating putting with a person wearing the treatment shoes. The person would begin by standing in front of the mechanical putter and addressing the ball. The ball was then putted from the adjacent plot towards the cup in the treatment plot. The person then turned and walked towards the cup, retrieved the ball, and returned towards the putter to repeat the process (equaling two traverses). Care was given to vary the traffic across the plot and to simulate normal walking and turning as much as possible.

Once the five traverses were applied, ten more ball rolls were made and number of putts made were recorded. Ninety traverses of traffic were applied in total. Data was analyzed using repeated measures analysis of variance using the mixed procedure of SAS.

The experimental sites were also characterized for organic matter content and surface hardness. Organic matter content was determined for the top ½ and 1 inch of the profile. Soil samples were removed with a ½ by 3 inch soil profiler. Ten samples at each depth were removed from each site. Samples were oven-dried at 102°C for 24 hours to remove moisture. The dried samples were weighed and put in a muffle furnace at 700°C for 12 hours to burn off all of the organic matter. The remaining inorganic matter was weighed, and organic matter content was calculated.

Surface hardness measurements were done with a Clegg Impact tester. The Clegg consists of a missile that is dropped through a guide tube. The missile contains an accelerometer that measures the peak deceleration (Gmax) as the missile impacts the surface. Gmax values increase as surface hardness increases.

Results and Discussion

There were significant differences for percentage of putts made between tread types on both rootzones. On the "push-up" style rootzone (Figure 1) there were significant differences between all three tread types (Table 1). The Foot Joy 98891 decreased the percentage of putts made the most, followed by Etonic 8510, and the shoe affecting putting the least was Etonic 8995. On the all sand

Figure 1. Percentage of putts made on a "push-up" style rootzone.

rootzone (Figure 2), the two Etonic shoes affected putting the same and significantly less than the metal spike shoe (Table 1).

The organic matter contents of both rootzones were very similar at both sampling depths (Figures 1 and 2). The Clegg Gmax values were different for the two rootzones, 90 g's and 63 g's for the push-up and all sand rootzones, respectively. The surface hardness differences may be a good indication as to why the results varied between rootzones.

Table 1. Averages of putts made for three different tread types on two different rootzones.

Treatment	"Push-Up" Style Rootzone	All Sand Rootzone
	-------------------------- % of Putts Made	---------------------------
Foot Joy 98891 (metal)	60 a*	47 a
Etonic 8510 (DS-1)	75 b	71 b
Etonic 8995 (outsole)	88 c	72 b

*Means within the same column followed by the same letter are not statistically different at p = 0.05.

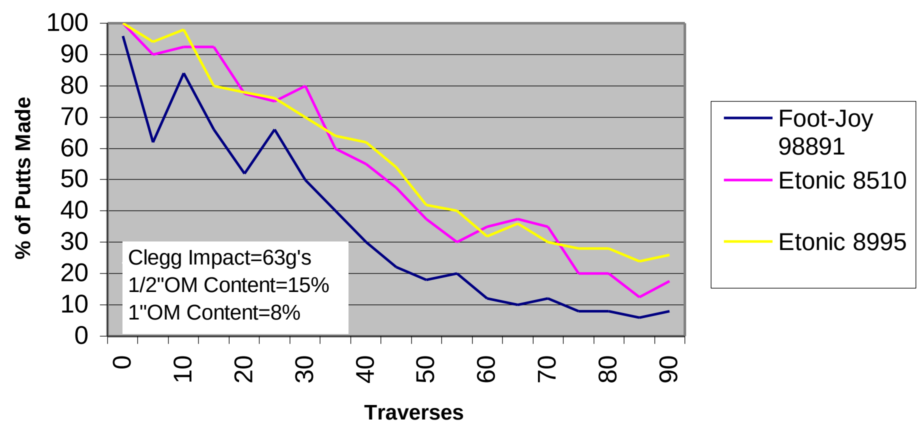

Figure 2. Percentage of putts made on an all sand rootzone.

Conclusions

The mechanical putter and procedure developed in this study appear to be appropriate to evaluate the effects of shoe tread type on putting quality. Significant differences between three different tread types were observed on two different rootzone mixes. More research should be conducted on other rootzones to evaluate the procedure under different conditions.

Cultivar Development and Extreme Temperature Tolerance of Greens-type *Poa annua* L.

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Introduction

Annual bluegrass (*Poa annua* L.) makes up a large portion of the putting surfaces in many regions of the US and Canada. Given its wide-spread occurrence in the golf industry, there is currently a need for high quality, commercially available sources of greens-type P. annua for use in constructing, renovating, and maintaining P. annua golf greens. Greens-type P. annua actually has many characteristics that make it enviable as a putting surface. Typically, greens-type *Poa* has high shoot densities, an upright growth habit that lacks grain, and aggressively inhabits golf greens maintained at extremely close (≤1/8 inch) mowing heights. A severe agronomic disadvantage of *Poa annua* L. is its susceptibility to extreme temperature stress. This project will seek to develop techniques to screen large numbers of germplasm accessions for tolerances to extreme temperatures and coverage by sheets of ice, and thereby attempt to aid the breeding program to improve the adaptation of greens-type *Poa annua* cultivars within regions of intended use. The purpose of this research is not to replace creeping bentgrass as a putting surface but rather to offer an alternative to those golf courses where *P. annua* is simply a better choice.

I. Breeding and Cultivar Development: Progress, Results, and Observations

Germplasm Collection and Evaluation: The germplasm collections from southern California (Industry Hills GC) and northern California (California Club GC, San Francisco Club GC, and Olympic Club) were entirely destroyed by an unidentified disease in our greenhouse this summer. My plans are to recollect from these regions as I believe this event was a greenhouse problem and might not have necessarily manifested itself under field grown conditions. Last year's germplasm collection from Oregon and Washington (a total of 279 selections) was established as solid sod in the experimental *Poa* green at the Valentine Research Facility. Color, density, overall quality, and dollar spot disease ratings were collected from these strains this fall.

Additional evaluation plots were seeded in the fall of 1999. To date most of our evaluation plots have been established as solid sod grown in the greenhouse. This seeded trial is the project's first fully seeded trial and the first established on a USGA spec green. The fall 99 evaluation trial consists of 16 entries with three replications. Plot size is approximately 4'x6'.

An interesting observation was made concerning nematode resistance in the field while collecting at the California Club GC. The nematode *Anguina pacificae* creates a very serious problem for *Poa* greens in northern California. At two major infestations, I noticed where the nematodes were apparently avoiding particular strains. I collected samples from each of two of these strains however, these strains were lost along with the rest of the California collection. I'm looking forward to revisiting these and other sites during the spring of 2000 when this pacific coast shoot gall nematode disease is active to further investigate the potential of biological control.

I have assembled a team of researchers to aid me in the investigation of alternative control strategies of the pacific coast shoot gall nematode. Dr. Mary Ann Bruns is a soil microbial ecologist and Norm Conrad is an extension specialist who teaches short-courses in nematology. Our intention to is assay various commercial products for biological control and to determine if any mechanism of resistance or differential tolerance exists in any of the local strains of *Poa annua*. To aid us in this work, we are currently preparing a grant proposal for consideration by the Northern California Golf Association and/or the Northern California Golf Course Superintendents Association.

Regional Testing: It is my intention to place increased emphasis on regional testing. Numerous individuals have made offers to establish and maintain golf green plots of this project's selected strains of *Poa annua*. This past summer, seed of three selections were sent to Jim Ross at Olds College for a Fall 99 establishment. As additional seed becomes available from these and other promising selections, I will begin to work with more and more cooperators for testing and evaluations. In the future, representative cooperators will be identified within specific regions across the USA and Canada who are willing to evaluate our elite strains of greens-type *Poa annua*:

Seed Production and Increase: Much of our work this fall was focused on generating seed increase for future regional testing and evaluation purposes. The spring 1999 seed harvest of selected strains was relatively good despite having a major snow mold infection of our seed production plots. In September 99 seed of three selected accessions were sown into seed production plots approximating 1,200 sq. ft each. An additional four accessions were sown into plots approximately 400 sq. ft each, an additional three accessions were sown into plots 60 sq. ft each, and an additional six accessions went into plots 30 sq. ft each. Although seed yield is strongly dependent on the accession, we expect the larger plots to yield between six and eight lbs. of seed.

As spring 2000 will be our largest scale seed harvest to date, we are still considering additional options for the best method of harvesting greens-type *Poa* seed. In any event, we should have plenty of seed for regional testing purposes for several of the selected accessions. One regional test generally requires about 60 grams of seed for three plots of size 4'x6'.

Numerous small seed production plots were also established in the fall of 1999 for a large number of additional accessions originating from Long Island, NY. Several of these strains look quite promising including one with excellent field resistance to dollar spot. This is the first group of accessions entering into our modified cultivar development scheme, which includes an early phase of seed increase.

Genetic Identification and Manipulation of Polyhaploids: *Poa annua's* evolutionary history (allopolyploidy) suggests that the observed sexual sterility of particular strains is likely due to the genetic state of these accessions being sterile dihaploids (plants derived from an unfertilized, reduced egg). The results of our previous research suggest that we are capable of manipulating the ploidy level of such sterile dihaploids, and in doing so, are able to restore their ability to set viable seed. We are continuing our efforts researching the genetics of our experimental dihaploids as well as to apply our new found knowledge to a wider array of sterile *Poa annua*s exhibiting high quality. I expect our work in the manipulation of polyhaploids to become an intregal part of the breeding program, enabling us to make greater progress in understanding the evolutionary events that occur on golf greens involving *Poa annua* and eventually allowing us to better identify and manipulate agronomically important traits in the species.

II. Extreme Temperature Tolerance: Progress, Results, and Observations

Assessing the relative low-temperature tolerance among ecotypes (Laval): This part of the project is performed in collaboration with Julie Dionne, Horticultural Research Center, Laval University and Dr. Yves Castonguay, Agriculture Canada Research Center in Ste-Foy. Previous results from the Laval group demonstrated that differences in low-temperature tolerance exist among *Poa* accessions. In the upcoming future, they will begin to examine the molecular basis of cold tolerance differences. I will continue to work with the Laval group and supply them with interesting and contrasting plant materials.

Assessing the relative survival of *Poa* and bentgrass given a cycling of freeze-thaw conditions: Last year's results suggested that neither *Poa* nor bentgrass was capable of surviving multiple freeze-thaw cycles and that survival progressively decreased as the number of freeze-thaw cycles increased. Our attempt this year to confirm this result was inconclusive as the experiment failed due to the plants becoming desiccated in the growth chamber. At this point, I am uncertain if this aspect of the project will continue due to limited time and resources.

Determining the artificial conditions for assessing heat tolerance among ecotypes: In September 1999 Rhonda Witmer was hired to assist in the field and greenhouse aspects of the breeding program. In addition, Rhonda has been performing the heat tolerance testing using a linear gradient sand heat bench. She has completed upgrades of the linear gradient sand heat bench and begun testing various greens-type *Poa*s and bentgrass. I look forward to very interesting data and results in the future.

Determining the artificial conditions necessary for assessing ice coverage tolerance among ecotypes: Our attempts to directly evaluate differential ice coverage tolerance among *Poa*s has not been successful. Mr. George Hamilton has taken on this part of the project as his Ph.D. dissertation. George is focusing on those environmental conditions that induce and reverse the hardening process. He has discovered a critical temperature difference between bentgrass and *Poa* during the hardening process and will continue to evaluate exposure times and response to day length to conclude his hardening experiments. Once completed, George will begin to examine the effects of ice coverage using a variety of hardening and de-hardening treatments.

Examining the root dynamics of ecotypes throughout the seasons and during periods of extreme temperature stress: Graduate student Eric Lyons, a National Science Foundation Fellow in Penn State's Root Biology program, has begun to research the root dynamics of greens-type *Poa annua* for his Ph.D. The purpose of his study will be to understand the rooting characteristics of different ecotypes throughout the entire year, while concentrating on times of extreme temperature stress (heat and cold). His study will examine characteristics of *Poa annua* root systems during cold acclimation, throughout the winter, and continue during spring root initiation to determine the ability of the root system to survive cold temperatures. Root mass, depth, viable length, and root fate will be assessed during the fall, winter, spring, and summer seasons in order to fully assess the root dynamics of contrasting *Poa* ecotypes. We will also attempt to correlate root dynamic parameters with plant survival and performance in times of extreme temperature stress to enable us to more efficiently evaluate our greens-type *Poa annua* germplasm resources. To this end, we built a 5,000 sq.ft. experimental USGA spec green to specifically study roots and in August sent Eric to work with Dr. B. Huang at Kansas State University. whose lab group performs similar research on bentgrass.

Creeping Bentgrass Morphogenesis and Competition

A. J. Turgeon
Department of Agronomy

1. Creeping bentgrass morphogenesis.

In cooperation with an undergraduate student, Jay Keller, we have documented--through an extensive series of photomicrographs--the growth and development of three creeping bentgrass cultivars: Penncross (low-density, prostrate-growing), Pennlinks (medium-density, upright-growing), and Penn G2 (high-density, upright-growing). This was done to gain a clearer understanding of the morphogenetic basis for the performance of these cultivars in the field. Currently, we are beginning a new series of morphogenetic investigations using three selections of annual bluegrass, including two perennial types and a wild, annual type.

2. Creeping bentgrass-annual bluegrass competition.

A field study was initiated in 1997 to study the competitive relationship between 10 annual bluegrass selections and three creeping bentgrass cultivars under two mowing heights. At the higher (7/16 inch) mowing height simulating fairway culture, most annual bluegrass selections essentially disappeared, reflecting the superior competitive ability of the creeping bentgrass at that height. At the lower (1/8 inch) height simulating greens culture, however, some annual bluegrass selections expanded their coverage while others contracted, compared with the 4-inch-diameter plugs used for initial establishment. Finally, the three creeping bentgrasses varied slightly in their competitive ability, based on the average size of annual bluegrass plugs; the most competitive was Penn A-4 while Pennlinks was least competitive.

Loss of Greens-Grade Potassium Containing Fertilizers Due to Mowing

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D. M. Petrunak, Research Technician
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Introduction

Potassium is found in relatively large levels within the turfgrass plant. This macro-nutrient has been associated with disease, drought, heat and cold tolerance of the plant, as well improved wear tolerance of turf (Beard, 1973; Turner and Hummel, 1992). Potassium can be provided to the plant in large enough quantities by soils containing appreciable amounts of clay. However, sandy soils are often used as the medium for growing fine turf because these soils are resistant to compaction and have good internal drainage characteristics. Specific guidelines have been developed for the construction of artificial sand: peat turfgrass rootzone mixes (USGA, 1993). At the same time, sandy soils and sand:peat rootzone mixes tend to be low in moisture and nutrient retention and, as a result, have low amounts of available potassium. Under these conditions the use of potassium fertilizers by turf managers can be quite extensive and is considered to be 1.5 to 4 kg K_2O/acre/yr (3 to 8 lbs./1000sq.ft. /yr.) split into 4 to 6 applications for bentgrass and bermudagrass putting greens (Beard, 1982).

The fate of potassium in agricultural soils includes adsorption to cation exhange sites, fixation by certain types of clay minerals, absorption by plants, leaching from sandy soils, runoff, and erosion (Brady, 1990). In turf the loss of potassium by runoff and erosion are probably minimal because of dense and perennial nature of the turf stand. Leaching could be a mode of loss when the turf is grown under sandy soil conditions. A unique means of potassium loss from a turfgrass site could be the removal of fertilizer potassium with turf clippings during routine mowing, especially from low cut turf found on golf course putting greens, bowling greens, tennis courts, cricket pitches and other sites where mowing heights may be ≤ 6 mm. Mancino and Hornstein (2000) reported that N loss from greens-grade granular fertilizers (SGN of 100 to 140) applied to a putting green (4 mm height of cut) could range from 7.5 to >30 % of the applied N, depending on the particular fertilizer. Work by Woolhouse (1973; 1974) found total mower fertilizer N loss to range from 17.1 to 20.9% from a perennial ryegrass sward maintained at a 4.76 mm height of cut.

The purpose of this study was to determine how much fertilizer potassium would be lost during routine mowing of a 'Pennlinks' creeping bentgrass putting green receiving potassium fertilizer applied at two typical rates of application.

Materials and Methods

Two mower loss studies were conducted at the Valentine Turfgrass Research Facility at The Pennsylvania State University, University Park. The study was conducted on a well-established 'Pennlinks' creeping bentgrass (*Agrostis palustris* Huds.) putting green having a sand-based rootzone mixture. This site was uniform in appearance with good turf density and 100% groundcover. Turf was maintained at a mowing height of 3.97 mm and mowed five days per week (Monday through Friday). Fertilization, irrigation and pest management practices on the green were performed as needed to maintain an acceptable putting surface prior to treatment initiation. Granular K fertilizer treatments (Table 1) were applied on 30 June 1999 and clippings were collected from 2 days after treatment (DAT) through 9 DAT (9 July). Treatments were applied again on 14 July 1999 and clippings collected from 2 DAT through 9 DAT (23 July 1999). All treatments were applied at 2.48 and 4.96 g K m^{-2}. Fertilizers were hand applied with a small glass shaker jar with perforated lid following mowing.

Turf was irrigated with 6.4 mm of water immediately following treatment application. Mowing and clipping collection was skipped the day after treatment (DAT), but was collected 2 DAT through 9 DAT. Following the first fertilizer treatment application, and due to drought conditions, irrigations (6.4 mm) were applied on 1 July, 6 July, and 8 July. No additional irrigation was applied after the second fertilizer application, but rain fell on 19 July (<2.5 mm), 21 July (12.7 mm), and 22 July (7.62 mm). In effect, both studies received about 25.4 mm of water over about a nine-day period. A rain cover was not used during the study because previous work by the authors had shown us that the fertilizers would stick to the dew that collected on the underside of the cover.

Fertilizers used in this study are shown in Table 1. Clipping collection began on 2 DAT and continued every day until no more granular fertilizer could be seen in the clipping collection basket. A walk-behind reel mower set to cut at 3.97 mm was used. Clippings from each plot were bagged and oven-dried at 60 C for 48 hours. The weight of the granular fertilizer in the clippings was determined by oven-drying the clipping sample (24 hr at 60 C) and then blowing the clippings out of the fertilizer with a small pneumatic seed cleaner (New Brunswick General Sheet Metal Works Seed Blower, model 1070-1, New Brunswick, NJ). The fertilizer granules were then weighed. We estimated % K loss by multiplying the weight of the fertilizer by its label K content.

Both studies were arranged in a completely randomized block design with four replications per treatment. Individual plots were 0.9 m x 2.4 m. Fertilizer treatment effects on daily and total fertilizer and K loss were determined using SAS ANOVA and LSD (p=0.05) (SAS Institute, 1994).

Results and Discussion

Study 1: The greatest amount of fertilizer loss occurred with the first mowing (2 DAT) (Table 2). Losses ranged from less than 0.5% to almost 18% of applied fertilizer depending upon the treatment. Fertilizer recovered in clippings was greatest with the UHS Signature treatment at the high application rate. Loss from the Signature treated plots receiving the lower application rate was equivalent, on a weight basis, to the Lebanon Isotek treatment at the higher rate of application. However, when loss was expressed as % applied fertilizer, much more material was lost from the Signature treated plots than the Isotek treated plots.

A decrease in application rate had the overall effect of decreasing the weight of material recovered by the mower for all treatments except the two Lesco products. The recovery of these two fertilizers in mowing clippings was very low compared to the other treatments and rate did not influence how much of this fertilizer, either on a weight or percentage basis, was recovered with the clippings. The % loss of Signature and Isotek went up as application rate went down while % loss of the Contec fertilizer remained the same. Mowing removal of the two Lesco products did not occur after this clipping collection.

During the second mowing (3 DAT), as with the first mowing (2 DAT), the greatest K and fertilizer losses occurred with UHS Signature and represented between 3% and 4% of the applied material. Unlike the first mowing, the higher rate of Signature resulted in a higher percentage of loss at the second mowing. Isotek and Contec fertilizer losses were between 1.3% and 2.5% of applied fertilizer with more loss, on a weight basis, occurring with the Isotek fertilizer.

At the high rate of application, mowing loss continued through the sixth mowing (7 DAT) for UHS Signature treated plots, the eighth mowing (9 DAT) for Isotek, and the fourth mowing (5 DAT) for Contec (Table 2). When applied at the lower application rate these losses did not occur after the third mowing (4 DAT) for Signature and Contec, and the fifth mowing (6 DAT) for Isotek.

As with daily loss, total K and fertilizer loss was greatest for UHS Signature at the higher rate of application (Table 2). However, on a percentage basis, more K and fertilizer was lost from Signature at the lower application rate and represented 5.5% of applied K and 22% of the applied fertilizer. Total mowing loss of the Isotek and Contec ranged from about 1 to 2 % of applied K, and 5 to 10 % of the applied fertilizer. . The two Lesco materials had losses of less than 1% of applied K or fertilizer. Application rate had an effect on the total amount (on a weight basis) of Isotek and Contec fertilizer removed due to mowing, but essentially had no effect on the % K and fertilizer lost from these products. Application rate had no effect on the total amounts of Lesco treatments being lost.

Study 2: Results from Study 2 agreed with those of Study 1. The second study confirmed that a majority of the fertilizer lost due to mowing occurred at the first mowing and that loss at 2 DAT was greatest with the higher application rate of all the treatments except the two Lesco products. As in Study 1, the loss of the Lesco products was very low and equal regardless of rate. Once again Signature resulted in the largest amount of loss for each application rate. Loss decreased with each progressive mowing and, as in Study 1, no Lesco product was detected beyond the first mowing.

When comparing Study 1 and Study 2 for the number of mowings in which each fertilizer was detected, Signature at the high rate, and Isotec and Contec at the low rate were detected in one extra mowing for Study 2. Signature at the low rate was detected in three additional mowings, and Contec at the high rate was detected in two additional mowings for Study 2. In contrast, Isotek at the high rate was found in two less mowings in Study 2.

Total loss data for Study 2 is in very close agreement with Study 1 with the greatest difference being only 383 mg/m^2 for Isotek at the high application rate. Both studies confirmed that these losses represented from well below 1% to about 22% of the applied fertilizer.

Mowing loss of the fertilizers used in this study appears to be only slightly related to the size of the materials tested (Table 1). The two Lesco products, which had the smallest size, also had the lowest loss (Tables 2 and 3). However, loss from the Contec and Isotek fertilizers were considerably less than the Signature fertilizer, even though Signature was slightly finer than Contec and considerably finer than Isotek. Signature also had a higher bulk density than Contec, 1.12 g/cc vs. 1.02 g/cc. Perhaps this should have aided in moving the Signature deeper into the turf canopy, but apparently did not have that effect.

The findings from these studies indicate that mowing loss of fertilizer can be a significant form of loss for certain fertilizers applied to putting greens if the clippings are removed from the green. Obviously, a finer grade of granular fertilizer will help the material work its way down into the turf canopy. Increasing the water-solubility of the material would also be beneficial by allowing the turf manager to more easily irrigate the material into the canopy. Other important cultural practices could include verticutting prior to fertilization to make the canopy less dense. Mowing without clipping removal would also allow more time for the material to move into the canopy. However, not all greens-grade materials can retain their nutrient release characteristics if damaged by mowing. The loss of granular fertilizers with clipping collection is an important problem that needs to be addressed if higher density bentgrass cultivars and lower heights of cut are used on putting greens.

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Table 1. Greens grade K-containing granular fertilizers used in mowing loss study.

Fertilizer	% K_2O	% SGN [†]				Manufacturer
		100	140	200	280	
Lesco Matrix 1	28	75	25	0	0	Lesco, Inc., Rocky River, OH
Lesco Matrix 2	22	75	25	0	0	Lesco, Inc., Rocky River, OH
Scotts Contec	26	60	40	0	0	The Scotts Co., Marysville, OH
Lebanon Isotek	22	2	49	47	2	Lebanon Seaboard Corp., Lebanon, PA
UHS Signature	30	67	33	0	0	United Horticultural Supply, Denver, CO

[†] % SGN = Percent fertilizer held on size grade number screens with 1.0, 1.4, 2.0, and 2.8 mm openings.

Table 2. Fertilizer and potassium losses due to mower pick up 2-9 days after fertilizer application (1st run).

Product	Rate	2 DAT		3 DAT		4 DAT		5 DAT		6 DAT	
	(g/m^2)	mg K/m^2 (%)	mg $fert/m^2$ (%)	mg K/m^2 (%)	mg $fert/m^2$ (%)	mg K/m^2 (%)	mg $fert/m^2$ (%)	mg K/m^2 (%)	mg $fert/m^2$ (%)	mg K/m^2 (%)	mg $fert/m^2$ (%)
UHS Signature	4.86	489.1 a	1964.3 a	196.9 a	790.8 a	82.6 a	331.6 a	12.7 b	51.0 b	12.7 b	51.0 b
15-0-30		2.5	10.05	1.01	4.04	0.42	1.70	0.06	0.26	0.06	0.26
UHS Signature	2.43	438.3 a	1760.2 ab	101.6 b	408.2 b	50.8 b	204.1 b	0.0 e	0.0 c	0.0 d	0.0 c
15-0-30		4.48	17.98	0.78	3.13	0.52	2.08	0	0	0	0
Lebanon Isotek	4.86	265.5 b	1454.1 b	74.5 c	408.2 b	37.3 b	204.1 b	18.6 a	102.0 a	18.6 a	102.0 a
11-3-22		0.99	5.42	0.28	1.52	0.14	0.76	0.07	0.38	0.07	0.38
Lebanon Isotek	2.43	144.4 cd	790.8 c	60.6 c	331.6 bc	13.8 c	102.0 c	9.3 d	51.0 b	9.3 c	51.0 b
11-3-22		1.08	5.9	0.46	2.47	0.14	0.76	0.07	0.38	0.07	0.38
Scotts Contec	4.86	165.2 c	765.3 c	66.1 c	306.1 c	21.9 c	102.0 c	11.0 c	51.0 b	0.0 d	0.0 c
13-2-26		0.73	3.38	0.29	1.35	0.10	0.45	0.05	0.22	0	0
Scotts Contec	2.43	82.6 d	382.7 d	33.0 d	153.1 d	10.8 cd	51.0 cd	0.0 e	0.0 c	0.0 d	0.0 c
13-2-26		0.73	3.38	0.29	1.35	0.10	0.45	0	0	0	0
Lesco	4.86	9.3 e	51.0 e	0.0 e	0.0 e	0.0 d	0.0 d	0.0 e	0.0 c	0.0 d	0.0 c
12-0-22		0.03	0.19	0	0	0	0	0	0	0	0
Lesco	2.43	9.3 e	51.0 e	0.0 e	0.0 e	0.0 d	0.0 d	0.0 e	0.0 c	0.0 d	0.0 c
12-0-22		0.07	0.38	0	0	0	0	0	0	0	0
Lesco	4.86	11.9 e	51.0 e	0.0 e	0.0 e	0.0 d	0.0 d	0.0 e	0.0 c	0.0 d	0.0 c
5-0-28		0.06	0.24	0	0	0	0	0	0	0	0
Lesco	2.43	11.9 e	51.0 e	0.0 e	0.0 e	0.0 d	1.0	0.0 e	1.0	0.0 d	1.0
5-0-28		0.11	0.49	0	0	0	0	0	0	0	0

Table 2. Continued.

Product	Rate	7 DAT		8 DAT		9 DAT		Total	
		mg K/m^2	mg fert/m^2	mg K/m^2	mg fert/m^2	mg K/m^2	mg fert/m^2	mg K/m^2	mg fert/m^2
	(g/m^2)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
UHS Signature	4.86	12.7 b	51.0 b	0.0 b	0.0 b	0.0 b	0.0 b	806.7 a	3239.8 a
15-0-30		0.06	0.26	0	0	0	0	4.11	16.57
UHS Signature	2.43	0.0 c	0.0 c	0.0 b	0.0 b	0.0 b	0.0 b	565.3 b	2270.4 b
15-0-30		0	0	0	0	0	0	5.52	22.14
Lebanon Isotek	4.86	16.3 a	89.3 a	7.0 a	38.3 a	4.7 a	25.5 a	442.5 c	2423.5 b
11-3-22		0.06	0.33	0.02	0.14	0.1	0.1	1.65	9.03
Lebanon Isotek	2.43	0.0 c	0.0 c	0.0 b	0.0 b	0.0 b	0.0 b	237.6 d	1301.0 c
11-3-22		0	0	0	0	0	0	1.78	9.7
Scotts Contec	4.86	0.0 c	0.0 c	0.0 b	0.0 b	0.0 b	0.0 b	264.3 d	1224.5 c
13-2-26		0	0	0	0	0	0	1.17	5.4
Scotts Contec	2.43	0.0 c	0.0 c	0.0 b	0.0 b	0.0 b	0.0 b	121.1 e	561.2 d
13-2-26		0	0	0	0	0	0	1.07	4.95
Lesco	4.86	0.0 c	0.0 c	0.0 b	0.0 b	0.0 b	0.0 b	9.3 e	51.0 e
12-0-22		0	0	0	0	0	0	0.03	0.19
Lesco	2.43	0.0 c	0.0 c	0.0 b	0.0 b	0.0 b	0.0 b	9.3 e	51.0 e
12-0-22		0	0	0	0	0	0	0.07	0.38
Lesco	4.86	0.0 c	0.0 c	0.0 b	0.0 b	0.0 b	0.0 b	11.9 e	51.0 e
5-0-28		0	0	0	0	0	0	0.06	0.24
Lesco	2.43	0.0 c	0.0 c	0.0 b	0.0 b	0.0 b	0.0 b	11.9 e	51.0 e
5-0-28		0	0	0	0	0	0	0.11	0.49

Means within a column followed by the same letter are not significantly different, LSD, $p = 0.05$.

Table 3. Potassium and fertilizer losses due to mower pick up 2-9 days after fertilizer application (2nd run).

Product	Rate	2 DAT		3 DAT		4 DAT		5 DAT		6 DAT	
	(g/m^2)	$mg\ K/m^2$	$mg\ fert/m^2$ (%)	$mg\ K/m^2$	$mg\ fert/m^2$ (%)	$mg\ K/m^2$	$mg\ fert/m^2$ (%)	$mg\ K/m^2$	$mg\ fert/m^2$ (%)	$mg\ K/m^2$	$mg\ fert/m^2$ (%)
UHS Signature	4.86	527.2 a	2117.3 a	82.6 a	331.6 a	44.5 a	178.6 a	38.1 a	153.1 a	25.4	102.0 a
15-0-30			10.83		1.7		0.91		0.78		0.52
UHS Signature	2.43	419.2 b	1683.7 b	50.8 b	204.1 b	38.1 a	153.1 ab	25.4 b	102.0 b	12.7	51.0 b
15-0-30			17.2		2.09		1.57		1.04		0.52
Lebanon Isotek	4.86	335.4 c	1836.7 ab	37.3 c	204.1 b	18.6 b	102.0 bc	18.6 c	102.0 b	9.3	51.0 b
11-3-22			6.85		0.76		0.38		0.38		0.19
Lebanon Isotek	2.43	181.7 e	994.9 c	37.3 c	204.1 b	14.0 b	76.5 c	9.3 d	51.0 c	9.3	51.0 b
11-3-22			7.42		1.2		0.57		0.38		0.38
Scotts Contec	4.86	258.7 d	1199.0 c	22.0 d	102.0 c	22.0 b	102.0 bc	22.0 bc	102.0 b	11.0	51.0 b
13-2-26			5.28		0.45		0.45		0.45		0.22
Scotts Contec	2.43	137.6 e	637.8 d	22.0 d	102.0 c	11.0 bc	51.0 cd	11.0 d	51.0 c	0	0.0 c
13-2-26			5.62		0.9		0.45		0.45		0
Lesco	4.86	2.3 e	12.8e	0.0 e	0.0 d	0.0 c	0.0 d	0.0 e	0.0 d	0	0.0 c
12-0-22			0.05		0		0		0		0
Lesco	2.43	4.7 e	25.5 e	0.0 e	0.0 d	0.0 c	0.0 d	0.0 e	0.0 d	0	0.0 c
12-0-22			0.19		0		0		0		0
Lesco	4.86	3.0 e	12.8 e	0.0 e	0.0 d	0.0 c	0.0 d	0.0 e	0.0 d	0	0.0 c
5-0-28			0.06		0		0		0		0
Lesco	2.43	11.9 e	51.0 e	0.0 e	0.0 d	0.0 c	0.0 d	0.0 e	0.0 d	0	0.0 c
5-0-28			0.49		0		0		0		0

continued on next page

Table 3. Continued.

Product	Rate	7 DAT		8 DAT		9 DAT		Total	
	(g/m^2)	mg K/m^2 (%)	mg fert/m^2 (%)	mg K/m^2 (%)	mg fert/m^2 (%)	mg K/m^2 (%)	mg fert/m^2 (%)	mg K/m^2 (%)	mg fert/m^2 (%)
UHS Signature 15-0-30	4.86	12.7	51.0 a 0.26	12.7 a	51.0 a 0.26	0.0 a	0.0 a 0	743.2 a	2984.7 a 15.26
UHS Signature 15-0-30	2.43	12.7	51.0 a 0.52	0.0 b	0.0 b 0	0.0 a	0.0 a 0	559.0 b	2244.9 b 22.93
Lebanon Isotek 11-3-22	4.86	9.3	51.0 a 0.19	0.0 b	0.0 b 0	0.0 a	0.0 a 0	428.6 c	2346.9 b 8.75
Lebanon Isotek 11-3-22	2.43	9.3	51.0 a 0.38	0.0 b	0.0 b 0	0.0 a	0.0 a 0	260.9 e	1428.6 c 10.65
Scotts Contec 13-2-26	4.86	11.0	51.0 a 0.22	0.0 b	0.0 b 0	0.0 a	0.0 a 0	346.8 d	1607.1 c 7.07
Scotts Contec 13-2-26	2.43	0	0.0 b 0	0.0 b	0.0 b 0	0.0 a	0.0 a 0	181.7 f	841.8 d 7.42
Lesco 12-0-22	4.86	0	0.0 b 0	0.0 b	0.0 b 0	0.0 a	0.0 a 0	2.3 g	12.8 e 0.05
Lesco 12-0-22	2.43	0	0.0 b 0	0.0 b	0.0 b 0	0.0 a	0.0 a 0	4.7 g	25.5 e 0.19
Lesco 5-0-28	4.86	0	0.0 b 0	0.0 b	0.0 b 0	0.0 a	0.0 a 0	3.0 g	12.8 e 0.06
Lesco 5-0-28	2.43	0	0.0 b 0	0.0 b	0.0 b 0	0.0 a	0.0 a 0	11.9 g	51.0 e 0.49

Means within a column followed by the same letter are not significantly different, LSD, p = 0.05.

Evaluation of Fungicides for Control of Gray Leaf Spot on a Perennial Ryegrass Fairway, 1999

Wakar Uddin, Assistant Professor
Michael D. Soika, Research Support Technologist
Department of Plant Pathology

Introduction

Gray leaf spot (*Pyricularia grisea*) has become an important disease on perennial ryegrass (*Lolium perenne*) golf course fairways in the Mid-Atlantic region and the Mid-West. This study was conducted at the Willow Hollow Golf Course, Leesport (Berks County), PA, on a three-way blend of perennial ryegrass. The objective was to evaluate various fungicides and fungicide mixtures for effectiveness of suppression of gray leaf spot.

Materials and Methods

The study was conducted on the 18th fairway of the Willow Hollow Golf Course. The soil pH was 5.5. The test plots were mowed three times per week at 0.75 inch cutting height. The experimental area was treated with Dimension 1EC at 1.1 fl oz per 1000 sq ft on 20 Apr for control of crabgrass. On 28 Apr Primo 1EC was applied at the rate of 0.75 fl oz per 1000 sq ft. On 28 May the experimental area was fertilized (21-3-14) with 1.2 lbs nitrogen per 1000 sq ft. Merit 75WP was applied on 2 Jun at 6.4 oz per acre for insect control. On 23 Jul and 13 Aug respectively, ProStar 70WP (2.1 oz per 1000 sq ft) and Subdue Maxx 2MC (1.0 fl oz per 1000 sq ft) were applied for control of brown patch and Pythium foliar blight. Treatment plots, 3 ft x 12 ft, were arranged in a randomized complete block design with four replications. Fungicides were applied with a CO_2-powered boom sprayer using TeeJet 8004 nozzles at 40 psi, in water equivalent to 2 gal per 1000 sq ft. Treatment applications were begun on 6 July, and continued on a 14-day interval through September, unless otherwise noted in table. On 23 August the experimental area was inoculated with a spore suspension of *P. grisea*, and covered with a polyethylene sheet to maintain leaf wetness and reduce radiational-cooling over night. The test area was then allowed to grow to a two-inch height, and maintained at that height through September. Disease severity was evaluated on 14 and 29 September. Data were subjected to analysis of variance, and mean values were separated using the Waller-Duncan k-ratio test (P=0.05).

Results and Discussion

Environmental conditions were conducive for disease development during early September, and disease incidence was high. In this study, Chipco Triton, the Polyoxorim Zn high rate applied on a 28-day interval, as well as the 4 oz rate of Polyoxorim Zn did not provide any significant level of control. In the 14 September evaluation, Compass at the 0.2 and 0.25 oz rates, three triazole fungicides (Lynx, Bayleton, and Banner Maxx) tank-mixed with Daconil Ultrex, the Heritage + Daconil Ultrex combination, and Daconil Ultrex were providing excellent control of Gray Leaf Spot. By 29 September, the same treatments were providing good control, as were as the Heritage treatments. Daconil Ultrex, alone or in combination with other fungicides, provided excellent control throughout the study, including the Lynx + Daconil Ultrex combination in which the Daconil Ultrex rate was 1.82 oz.

Table. Evaluation of Fungicides for Control of Gray Leaf Spot on a Perennial Ryegrass Fairway

Treatment, formulation, and product rate per 1000 sq ft	Disease Incidence[1] 14 Sep	29 Sep
Chipco Triton 1.67SC 0.50 fl oz	7.5 ab[2]	7.3 a[2]
Confidential[3]	8.3 a	7.3 a
Polyoxorim Zn 2.25WP 8.0 oz[4, 5]	6.5 bc	6.8 ab
Chipco Triton 1.67SC 1.00 fl oz	6.8 abc	6.3 abc
Confidential[3]	7.5 ab	5.8 a-d
Untreated check	7.3 abc	5.3 b-e
Confidential[3]	2.0 fgh	4.8 c-f
Polyoxorim Zn 2.25WP 4.0 oz[4]	5.8 c	4.8 c-f
Polyoxorim Zn 2.25WP 4.0 oz + Latron CS-7 L 0.25 % V/V[4]	4.0 d	4.5 def
Confidential[3]	3.0 def	4.0 efg
Compass 50WG 0.15 oz	2.3 efg	3.8 efg
Polyoxorim Zn 2.25WP 8.0 oz[4]	4.0 d	3.5 fgh
Lynx 45WP 1.11 oz[5]	3.5 def	3.5 fgh
Compass 50WG 0.20 oz	1.0 ghi	2.5 ghi
Heritage 50WG 0.40 oz[5]	4.0 d	2.5 ghi
Heritage 50WG 0.40 oz	4.0 d	2.5 ghi
Compass 50WG 0.25 oz	1.0 ghi	2.0 hi
Heritage 50WG 0.20 oz	3.8 de	1.8 i
Banner Maxx 1.24MC 1.00 fl oz + Daconil Ultrex 82.5WG 3.67 oz	0.5 hi	1.0 i
Lynx 45WP 0.56 oz + Daconil Ultrex 82.5WG 3.67 oz	0.0 i	1.0 i
Bayleton 50WP 0.50 oz + Daconil Ultrex 82.5WG 3.67 oz	0.0 i	1.0 i
Bayleton 50WP 1.00 oz + Daconil Ultrex 82.5WG 3.67 oz	0.0 i	1.0 i
Heritage 50WG 0.20 oz + Daconil Ultrex 82.5WG 3.67 oz	0.0 i	1.0 i
Lynx 45WP 0.56 oz + Daconil Ultrex 82.5WG 1.82 oz	0.0 i	1.0 i
Daconil Ultrex 82.5WG 3.67 oz	0.0 i	0.0 i

[1]0-10 visual rating scale, where 0=no disease, 1=10% plot necrotic, and 10=100% plot necrotic, mean of four replications.
[2]Means within column followed by the same letter do not significantly differ according to the Waller-Duncan k-ratio test (P=0.05).
[3]Treatment information not available.
[4]Treatment not applied after 31 Aug.
[5]Treatment applied on a 28-day interval (6 Jul, 3 and 31 Aug).

Evaluation of Fungicides for Control of Pythium Foliar Blight, 1999

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Introduction

Fungicides were evaluated to determine effectiveness of control of Pythium foliar blight. The study was conducted at the Landscape Management Research Center, University Park, PA, on perennial ryegrass (*Lolium perenne*, 'Pennfine'), maintained under golf course fairway management conditions.

Materials and Methods

The test area was mowed three times per week at 0.75 inches throughout the growing season. The soil was Hagerstown silt loam with soil pH of 6.9. Turfgrass was fertilized on 18 May with 1.0 lb nitrogen (Scotts 31-3-10) per 1000 sq ft, 10 Jun with 1.0 lb nitrogen (Nutralene 40-0-0) per 1000 sq ft, and on 21 Jun with 0.5 lb nitrogen (urea 46-0-0) per 1000 sq ft. Lesco Benomyl 50WP was applied at the rate of 2.0 oz per 1000 sq ft on 22 Jun and 3 Jul for control of brown patch. Trimec Classic 3.32EC (1.5 fl oz per 1000 sq ft) was applied on 22 Jun for control of broadleaf weeds. Treatment plots, 3 ft x 7 ft, were arranged in a randomized complete block design with three replications. Preventive treatments were applied on 5 Jul with a CO_2-powered boom sprayer using TeeJet 8004 nozzles at 40 psi, in water equivalent to 2 gal per 1000 sq ft. On 7 Jul, two days after treatment (DAT), the experimental turf area was enclosed in a 30 ft x 48 ft polyethylene greenhouse to minimize radiational cooling. The test area was then inoculated with a mycelial suspension of a 6-isolate pool of *Pythium aphanidermatum*. Curative treatments were applied on 9 Jul, two days after inoculation. During the experiment, the greenhouse was vented during daylight hours to maintain a temperature range of 85° to 95°F, and closed at night An internal intermittent misting system provided continuous high relative humidity and leaf surface wetness. On 16 Jul the blighted turf was assessed. Data were subjected to analysis of variance, and the mean values were separated by Duncan's New Multiple Range Test (P=0.05).

Results and Discussion

Throughout the experiment, conditions were conducive for infection and disease development, therefore resulting in high disease severity. The curative application of Banol, Quell, and the two experimental treatments AEB066752 provided better than 68% control under the heavy disease pressure in this experiment. The curative treatment of AEB066752 provided greater than 83% control.

Table. Evaluation of Fungicides for Control of Pythium Foliar Blight, 1999

Treatment, formulation, and product rate per 1000 sq ft	Disease Severity[1] 16 Jul
Untreated Check	10.00 a[2]
Banol 6SL 1.0 fl oz	7.17 ab
Subdue Maxx 2MC 1.0 fl oz	5.17 bc
Banol 6SL 2.0 fl oz	5.08 bc
Quell L 1.0 fl oz + Koban 30WP 5.8 oz	4.83 bc
Heritage 50WG 0.4 oz	4.50 bc
Banol 6SL 2.0 fl oz[3]	3.17 c
Quell L 1.0 fl oz	2.67 c
AEB066752 F 4.0 fl oz	2.17 c
AEB066752 F 4.0 fl oz[3]	1.67 c

[1]0-10 visual rating scale, where 0=no disease, 1=10% plot blighted, and 10=100% blighted, mean of three replications.
[2]Means within column followed by the same letter do not significantly differ according to Duncan's New MRT (P=0.05).
[3]Treatment applied as a curative application 9 Jul.

Control of Pythium Foliar Blight on Perennial Ryegrass, 1999

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Department of Plant Pathology

Introduction

The use of fungicides is an important means of contolling Pythium foliar blight. The study was conducted at the Valentine Turfgrass Research Center, University Park, PA, on perennial ryegrass (*Lolium perenne*, 'Pennfine'), maintained under golf course fairway management conditions. It consisted of two separate experiments, conducted in conjunction with each other, to evaluate fungicide effectiveness and length of control under severe infection pressure.

Materials and Methods

The two experiments in this study were conducted on perennial ryegrass maintained under golf course fairway management conditions, and mowed three times per week at 0.5 inch cutting height. The soil was Hagerstown silt loam with a soil pH of 7.0. The experimental area was fertilized on 17 May with 1.0 lb nitrogen (Scotts 31-3-10) per 1000 sq ft, 10 June with 1.0 lb nitrogen (Nutralene 40-0-0) per 1000 sq ft, and on 21 June with 0.5 lb nitrogen (urea 46-0-0) per 1000 sq ft. Lesco Benomyl 50WP (2.0 oz/1000 sq ft) was applied on 22 June and 2 July for control of brown patch. Trimec Classic 3.32EC (1.5 fl oz per 1000 sq ft) was applied on 15 June for control of broadleaf weeds. Treatment plots, 3 ft x 7 ft, were arranged in a randomized complete block design with three replications. In both experiments, fungicides were applied on 3 Jul with a CO_2-powered boom sprayer using TeeJet 8004 nozzles at 40 psi, in water equivalent to 2 gal per 1000 sq ft. On 4 July turf in Experiment 1 was enclosed in a 30 ft x 48 ft polyethylene greenhouse to reduce radiational cooling. An internal intermittent misting system provided continuous high relative humidity throughout the experiment. The greenhouse was vented during daylight hours to maintain a temperature range of 85° to 95°F. Vents were closed during the night. On 8 July, 5 days after treatment (DAT), disease severity was assessed in Experiment 1. On 10 July (7 DAT), the turf area of Experiment 2 was enclosed in a 30 ft x 48 ft polyethylene greenhouse, inoculated with a 6-isolate pool of *Pythium aphanidermatum*, and was maintained as described above for Experiment 1. On 16 July (13 DAT) disease severity in Experiment 2 was assessed. Data were subjected to analysis of variance, and the mean values were separated using the Waller-Duncan k-ratio Test (P=0.05).

Results and Discussion

In the first experiment (5 DAT), the two Compass plus Subdue Maxx combination treatments, and the Subdue Maxx treatment were providing excellent control of Pythium foliar blight. In the second experiment (13 DAT), none of the fungicides provided satisfactory control; however, the high rate Banol treatment was significantly different from the untreated check. It should be noted that conditions in the greenhouses, such as continuous leaf surface wetness, high relative humidity, and warm temperature, were highly conducive for infection by *P. aphanidermatum*, and subsequent disease development. The disease severity was extremely high throughout both of the experiments.

Table. Control of Pythium Foliar Blight on Perennial Ryegrass, 1999

	Disease Severity[1]	
	Experiment 1[2]	Experiment 2[3]
Treatment, formulation, and rate of product/1000 sq ft	8 Jul	16 Jul
Untreated Check	9.77 a[4]	10.00 a[4]
Compass 0.7 MC 0.85 fl oz + Subdue Maxx 2 MC 0.5 fl oz	0.50 cd	9.93 a
Compass 50 WG 0.15 oz + Subdue Maxx 2 MC 0.5 fl oz	0.33 d	9.93 a
Subdue Maxx 2 MC 1.0 fl oz	0.33 d	9.50 ab
Heritage 50 WG 0.4 oz	4.43 b	9.33 ab
Banol 6 SL 1.3 fl oz	3.67 bc	8.00 ab
Aliette Signature 80 WG 4.0 oz	3.17 bcd	8.00 ab
Banol 6 SL 2.0 fl oz	2.83 bcd	7.50 b

[1]0-10 visual rating scale where 0=no disease, 1=10% plot necrotic, and 10=100% plot necrotic, mean of three replications.

[2]Treatments were applied 3 Jul. Disease severity was evaluated 8 Jul, five days after treatment application.

[3]Treatments were applied 3 Jul. Disease severity was evaluated 16 Jul, 13 days after treatment application.

[4]Within a column, means followed by the same letter do not significantly differ according to Waller-Duncan k-ratio test (P=0.05).

Evaluation of Fungicides for Control of Dollar Spot on a Putting Green, 1999

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Department of Plant Pathology

Introduction

The use of fungicides for managing dollar spot (*Sclerotinia homoeocarpa*) on golf courses is a commonly used practice to maintain high quality playing surfaces. This study was conducted at the Valentine Turfgrass Research Center, University Park, PA, on a creeping bentgrass (*Agrostis Palustris*, 'Penncross') green. The study included various fungicides, rates, and/or application intervals to investigate control strategies and fungicide efficacy.

Materials and Methods

The experiment was conducted on creeping bentgrass maintained under golf course greens management conditions, mowed at 0.16 inch cutting height. The soil was a modified sandy clay loam with a soil pH of 7.0. The test area was fertilized on 19 May with 1.0 lb nitrogen (Lebanon 28-7-14) per 1000 sq ft. Treatment plots, 3 ft x 11 ft, were arranged in a randomized complete block design with three replications. Treatments were applied with a CO_2-powered boom sprayer, using TeeJet 8004 nozzles, at 40 psi, in water equivalent to 2 gal per 1000 sq ft. Applications were made on 9 and 23 June, and 7 and 21 July, except as noted in the table. The experimental turf area was inoculated on 18 June, nine days after the first treatment application, by hand-broadcasting *S. homoeocarpa*-infested ryegrains, at the rate of 20-30 grains per sq ft. A mixture of five isolates of *S. homoeocarpa* was used in the inoculation. Disease incidence was evaluated on 7, 14, 21, and 28 July, and 5 August. Data were subjected to analysis of variance, and the mean values were separated by Waller-Duncan k-ratio test (P=0.05).

Results and Discussion

Dollar spot disease incidence was moderate and consistent during the experiment. Fore 80WP applied on a 14-day interval did not provide effective dollar spot control in this experiment. By the 5 August evaluation, most of the treatments in this study were providing excellent control of dollar spot. The 0.556 oz rate of Lynx, the 0.6 oz rate of Eagle, and the half-rate (1.8 oz) of Daconil Ultrex (applied every seven days) provided complete control of dollar spot throughout the study.

Table. Evaluation of Fungicides for Control of Dollar Spot on a Putting Green, 1999

	Dollar Spot Incidence[1]				
Treatment, formulation, and rate per 1000 sq ft	7 Jul	14 Jul	21 Jul	28 Jul	5 Aug
Untreated Check	4.7 a[2]	2.0 a[2]	2.3 b[2]	3.2 ab[2]	3.7 a[2]
Fore 80WP 8.0 oz	3.9 a	1.3 b	3.2 a	3.8 a	3.6 a
Banner Maxx 1.24ME 0.5 fl oz	0.3 cd	0.0 c	0.1 d	2.3 abc	0.7 b
Daconil Ultrex 82.5WG 3.8[3] oz	0.0 d	0.0 c	0.4 d	0.2 d	0.6 bc
Cleary 3336 4.5F 1.0 fl oz	0.1 d	0.0 c	0.0 d	0.2 d	0.3 b-e
GX-611 6F 4.2 fl oz	0.0 d	0.0 c	0.1 d	0.0 d	0.2 cde
Bayleton 25DF 0.5 oz	0.4 cd	0.1 c	0.0 d	1.2 bcd	0.1 de
Eagle 40WP 1.0[4] oz	0.6 cd	0.0 c	0.0 d	0.0 d	0.0 e
Chipco 26GT 2SC 3 fl oz	0.2 cd	0.0 c	0.3 d	0.0 d	0.0 e
Daconil Ultrex 82.5WG 3.8 oz	0.1 d	0.0 c	0.1 d	0.0 d	0.0 e
Eagle 40WP 0.5 oz	0.0 d	0.1 c	0.0 d	0.0 d	0.0 e
Lynx 45WP 0.278 oz	0.1 d	0.0 c	0.0 d	0.0 d	0.0 e
Lynx 45WP 0.556 oz	0.0 d	0.0 c	0.0 d	0.0 d	0.0 e
Eagle 40WP 0.6 oz	0.0 d	0.0 c	0.0 d	0.0 d	0.0 e
Daconil Ultrex 82.5WG 1.8[5] oz	0.0 d	0.0 c	0.0 d	0.0 d	0.0 e

[1]Values represent number of infection centers per square foot, mean of three sub-samples for each of three replications.
[2]Means within a column followed by the same letter do not significantly differ according to the Waller-Duncan k-ratio test (P=0.05).
[3]Treatment applied on a 21-day interval (9 and 30 Jun, and 21 Jul).
[4]Treatment applied on a 28-day interval (9 Jun and 7 Jul).
[5]Treatment applied on a 7-day interval (9, 16, 23, 30 Jun, and 7, 14, and 21 Jul).

Control of Brown Patch with Fungicides, 1999

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Introduction

Brown Patch (*Rhizoctonia solani*) can be a serious disease on golf courses during warm and humid periods of summer. This study was conducted at the Valentine Turfgrass Research Center, University Park, PA on colonial bentgrass maintained under golf course fairway management conditions. The objective of the study was to evaluate various fungicides, fungicide rates and/or application intervals, and tank-mixtures for effectiveness in controlling brown patch.

Materials and Methods

The experiment was conducted on colonial bentgrass (*Agrostis tenuis*, 'Bardot') mowed three times per week at 0.5 inch cutting height. The soil was Hagerstown silt loam with a soil pH of 6.4. The test area was fertilized on 19 May with with 1.0 lb nitrogen (Lebanon 28-7-14) per 1000 sq ft, and on 11 June with 1.0 lb nitrogen (Nutralene 40-0-0) per 1000 sq ft. Treatment plots, 3 ft x 8 ft, were arranged in a randomized complete block design with three replications. Treatments were applied with a CO_2-powered boom sprayer, using TeeJet 8004 nozzles, at 40 psi, in water equivalent to 2 gal per 1000 sq ft. Applications were made on 28 June, 12, and 26 July, unless otherwise noted in the table. Hot and dry weather conditions prevailed throughout the test period, and disease severity was moderate. Brown patch incidence was variable throughout the experimental area. Disease severity was greatest in early July, with 46% of the untreated check plots blighted. By the end of July less than 15% of the untreated checks plots were blighted. Treatment plots were evaluated on 9, 19, and 26 July. Data were subjected to analysis of variance, and the mean values were separated by the Waller-Duncan K-ratio Test (P=0.05).

Results and Discussion

In the 9 July evaluation, when disease severity was greatest, 15 of the 18 treatments were providing control significantly different from the untreated check. On 19 July, only Daconil Weatherstik and the Heritage treatments were significantly better than the untreated check plots, despite the lower disease pressure. In the 26 July evaluation all treatments, except two of the three Eagle treatments, were providing control significantly different from the check, although, only 13% of the check plots were infected at that time. Two Heritage treatments provided complete control of brown patch throughout the experiment.

Table. Control of Brown Patch with Fungicides, 1999

Treatment, formulation, and product rate per 1000 sq ft	Disease Severity[1] 9 Jul	19 Jul	26 Jul
Eagle 40WP 1.0 oz[2]	0.87 bc[3]	0.83 abc[3]	1.67 a[3]
Untreated Check	4.60 a	1.83 ab	1.33 ab
Eagle 40WP 0.6 oz	2.17 bc	0.67 abc	1.00 b
Daconil Weatherstik 6F 4.0 fl oz	1.40 bc	0.00 c	0.25 c
Eagle 40WP 0.5 oz	1.33 bc	0.20 bc	0.23 c
Banner Maxx 1.24MC 2.0 fl oz[4]	2.00 bc	1.50 abc	0.20 c
Bayleton 50WP 0.5 oz[4]	4.50 a	2.17 a	0.20 c
Daconil Ultrex 82.5WG 3.8 oz	1.83 bc	0.33 bc	0.17 c
GX-611 6F 4.2 fl oz	2.00 bc	0.20 bc	0.17 c
Compass 50 WG 0.15 oz + Banner Maxx 1.24MC 1.0 fl oz[4]	1.07 bc	0.67 abc	0.17 c
Chipco 26GT 2SC 3.0 fl oz[4]	1.33 bc	1.17 abc	0.03 c
Cleary's 3336 F 4.5F 2.0 fl oz	1.60 bc	0.20 bc	0.03 c
ProStar 70WP 1.5 oz[4]	2.43 ab	1.17 abc	0.00 c
Compass 0.15 oz + Banner Maxx 1.0 fl oz + Primo Maxx 0.2 fl oz[4]	1.00 bc	0.53 abc	0.00 c
Heritage 50WG 0.4 oz[2]	0.07 c	0.17 c	0.00 c
Heritage 50WG 0.2 oz[4]	0.10 c	0.00 c	0.00 c
Heritage 50WG 0.2 oz	0.00 c	0.00 c	0.00 c
Heritage 50WG 0.4 oz[5]	0.00 c	0.00 c	0.00 c

[1]0-10 visual rating scale, where 0=no disease, 1=10% plot blighted, and 10=100% plot blighted, mean of three replications.
[2]Treatment applied on 28-day interval (28 Jun only).
[3]Within column, means followed by the same letter do not significantly differ according to Waller-Duncan k-ratio test (P=0.05).
[4]Treatment applied on a 21-day interval (28 Jun and 19 Jul).
[5]Treatment applied on a 35-day interval (28 Jun).

Applications of MacroSorb Foliar to Improve the Quality of a Putting Green

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Introduction

This study was conducted on the eighteenth putting green at the Penn State White Golf Course in State College PA. The objective of the study was to evaluate the effect of MacroSorb Foliar applications on the quality of a mixed *Poa annua*/creeping bentgrass putting green located in an area of relatively dense tree canopy shade. This green had a history of reduced quality as the stress of summer growing conditions occurred.

Methods and Materials

This study was a randomized complete block design with three replications. All of the treatments were applied on May 4, 1999 using a three foot CO_2 powered boom sprayer calibrated to deliver 40 gpa using two, flat fan, 6504 nozzles at 40 psi. Treatments were applied every ten days (10 DAT) or every fourteen days (14 DAT). There were a total of six applications for the 10 DAT cycle and four in the 14 DAT cycle.

Results and Discussion

Turf quality was rated five times during the duration of the experiment (Table). At no time was turf quality found to be different whether treated with MacroSorb Foliar or not. The 1999 season was unusual in the sense of being very dry with many days with abundant sunlight. Such conditions (particularly sunlight) are uncharacteristic for central Pennsylvania, which usually has a significant number of cloudy days, which intensifies turf quality problems in shaded locations.

Table Quality ratings taken in 1999 of a shaded *Poa annua*/creeping bentgrass putting green. A rating scale of 0 – 10 was used where 0 = poorest, 7 = acceptable, and 10 = best.

Treatment	Form	Rate	Timing	(---------------Quality-------------)				
		(oz/M)		5-4	6-1	7-7	8-3	9-1
MACROSORB FOLIAR	L	2	14 DAT	8.0	9.0	9.0	9.0	9.0
CHECK				8.0	9.0	9.0	9.0	9.0
MACROSORB FOLIAR	L	2	10 DAT	8.0	9.0	9.0	9.0	9.0

Evaluation of Slow Release N Fertilizers on Creeping Bentgrass Fairways

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Introduction

The objective of this study was to evaluate the performance of several experimental polymer-coated slow release fertilizers in comparison to industry standards. Slow release fertilizers have the advantage of a longer-lived color response with little danger of burn damage that can occur with quick release fertilizers. However, some slow release materials may require six weeks or more before the desired turf response occurs. The desire is to produce a PCU having a quicker N release property, but still provide good slow-release characteristics.

Materials and Methods

Treatments were applied on 27 May 99 at a rate of 1lb N/1000 ft^2. Nitrogen treatments are shown in Table 1. The study site received approximately 0.5" of water after application of treatments. The study was conducted on an established stand of 'Penneagle' creeping bentgrass maintained at 0.5" height of cut. The area was mowed three times per week with clippings removed from the site to prevent cross contamination of treatments. The study was a randomized complete block design with four replications, with individual plots measuring 3' x 8'.

The turf was evaluated weekly for color beginning at 1 week after treatment (WAT) and continuing until 14 WAT. Color was evaluated on a 1-9 scale with 1 being brown, 9 being excellent, and 6 indicating acceptable color. Color data were subjected to analysis of variance and Fisher's Least Significant Difference for mean separation.

Results and Discussion

At 1 WAT, urea and PolyS produced significantly better color than all other fertilizers. All treatments except Polyon, Exp 43-0-0A, and the unfertilized control produced turf of acceptable color.

At 2 WAT, urea, PolyS, Exp 41-0-0A, and Trikote produced turf of very good color. Urea treated plots continued to have the best color, although it was not significantly better than PolyS, Exp 41-0-0A, and Trikote. All treatments had significantly better color than the control. All treatments except IBDU, Polyon, and the control produced turf of acceptable color.

Three weeks after treatment, urea again produced the highest color rating, but was not significantly different from PolyS, Trikote, and Exp 41-0-0C. Only IBDU and the unfertilized control had color ratings below an acceptable level. In general, color ratings improved only slightly between 2 and 3 WAT. Color ratings for Polyon increased above an acceptable level at 3 WAT and continued to improve steadily until 9 WAT. Polyon usually requires about two to three weeks to improve turf color. Its effect usually lasts an additional six weeks.

Only the unfertilized turf had unacceptable color at 4 WAT. However, the color rating for Nitroform (6.00) was not significantly different from the control (5.50). Nitroform is highly dependent upon soil moisture, temperature, and microbial activity for N release. Color ratings for IBDU, a water dependent fertilizer, began to improve to acceptable levels at 4 WAT and continued to increase for several weeks.

At 5 WAT, Exp 41-0-0C and Exp 41-0-0B produced excellent color, having color ratings of 8.00. IBDU, Nitroform, and the control were the only treatments with a color rating of less than 7. Nitroform, with a color rating of 6.38, was significantly different from all other treatments, as was the control with a rating of 5.75.

All treatments, including the control, increased in color at 6 WAT. Eleven of the 15 treatments had a color rating of 8 or above. All treatments had very good color. The color of the Nitroform treated plots increased significantly and continued to improve until reaching peak color at 9 WAT.

At 7 WAT, the unfertilized control had significantly lower color than all other treatments. Exp 41-0-0A, Nutralene, urea, and PolyS produced equal color ratings which were significantly better than Nitroform. However, the color rating for the Nitroform treated plots was still very good. Even the unfertilized controls had good color ratings. The peak color rating for urea and Exp 41-0-0A occurred at 7 WAT. The peak color for PolyS treated plots began at 7 WAT and continued through 9 WAT.

Polyon, Exp 43-0-0A, and PolyS produced the best color at 8 WAT. At this point, all treatments had very good to excellent color. The unfertilized control was the only treatment with a color rating of less than 8. The peak color rating occurred at 8 WAT for Exp 41-0-0C, and began at 8 WAT and continued through 9 WAT for Exp 43-0-0A and Polyon.

Peak color occurred at 9 WAT for Trikote, Exp 41-0-0B, Nutralene, Methex 40, PolyPlus, Milorganite, IBDU, Nitroform, and the unfertilized control. Ten treatments, including IBDU, Exp 41-0-0B, Exp 43-0-0A, Methex 40, Polyon, Nutralene, urea, PolyS, Trikote, and Milorganite, had a color rating of 8.5. All treatments, including the control, produced excellent color.

At 10 WAT, color ratings decreased for all treatments, although overall, color was still good. Ten treatments had a color rating of 8.0.

Color continued to decrease at 11 WAT. All treatments except the control had very similar color ratings. Milorganite produced significantly higher color than Nitroform and the unfertilized control. Most treatments were not significantly different from one another. From 12-14 WAT, color ratings began to level off as fertilizers were depleted. At 14 WAT, there were no significant differences in color ratings between treatments, and all plots had acceptable color.

Overall, the best average color rating was produced by PolyS, followed by urea, Trikote, and Exp 41-0-0B. The unfertilized control had an average color rating of 6.53, which was significantly lower than all other treatments. Nitroform produced the second lowest average color rating, which is not unexpected considering its slow release properties.

Of the four experimental fertilizers, Exp 41-0-0A produced the quickest color response, having a rating of 7.63 two weeks after fertilizer application. Exp 41-0-0A also produced peak color soonest, but not until 7 WAT, while the others produced peak color at 8 or 9 WAT. The average (overall) color ratings produced by the four experimental fertilizers were not significantly different from one another. However, Exp 41-0-0A, Exp 41-0-0B, and Exp 41-0-0C had significantly higher color ratings than Polyon.

Early in the study, the color of some of the plots was not uniform. Uneven color appeared approximately two weeks after application and continued until approximately 5 WAT. This situation was most pronounced with Exp 43-0-0A, Polyon, and PolyPlus and may have been due to the low rate of application combined with the high nitrogen content of the fertilizer.

Table 1. Influence of 14 fertilizer treatments on the color of creeping bentgrass 1-14 weeks after application.

							Color[1]								
Treatment[2]	Average	3 Jun	10 Jun	18 Jun	25 Jun	1 Jul	8 Jul	14 Jul	22 Jul	30 Jul	5 Aug	13 Aug	19 Aug	26 Aug	2 Sep
Urea	7.79 ab	8.00 a	8.00 a	8.00 a	7.88 ab	7.88 ab	8.25 ab	8.50 a	8.38 a	8.50 a	8.00 a	7.00 ab	7.00 abc	6.88 ab	6.88 a
PolyS	7.81 a	7.75 a	7.88 a	7.88 ab	7.75 ab	7.75 abc	8.38 a	8.50 a	8.50 a	8.50 a	8.00 a	7.13 ab	7.38 a	7.00 a	7.00 a
Trikote	7.61 abc	6.38 cd	7.63 ab	7.75 abc	7.75 ab	7.63 abcd	8.13 ab	8.38 ab	8.38 a	8.50 a	8.00 a	6.88 abc	7.00 abc	7.13 a	7.00 a
Exp 41-0-0 B	7.59 bc	6.25 cd	7.13 cd	7.25 cd	7.88 ab	8.00 a	8.38 a	8.38 ab	8.38 a	8.50 a	8.00 a	7.00 ab	7.13 abc	7.00 a	7.00 a
Exp 41-0-0 C	7.56 c	6.13 cde	6.88 cd	7.63 abcd	8.00 a	8.00 a	8.13 ab	8.25 ab	8.38 a	8.25 abc	7.88 ab	7.00 ab	7.25 ab	7.00 a	7.00 a
Exp 41-0-0 A	7.51 cd	6.38 cd	7.63 ab	7.38 bcd	7.63 abc	7.75 abc	8.25 ab	8.50 a	8.25 ab	8.13 bc	7.75 b	7.00 ab	7.00 abc	7.00 a	6.88 a
Nutralene	7.48 cd	7.25 b	6.88 cd	6.63 ef	7.13 cde	7.25 def	8.38 a	8.50 a	8.38 a	8.50 a	7.75 b	7.13 ab	7.13 abc	7.00 a	6.88 a
Methex 40	7.46 cde	7.25 b	6.75 de	7.13 de	6.75 ef	7.25 def	8.00 abc	8.25 ab	8.38 a	8.50 a	8.00 a	7.13 ab	7.13 abc	7.00 a	6.88 a
PolyPlus	7.41 cde	6.50 c	7.25 bc	7.13 de	7.13 cde	7.25 def	8.13 ab	8.38 ab	8.00 b	8.38 ab	8.00 a	6.88 abc	6.88 bc	6.88 ab	6.88 a
Exp 43-0-0 A	7.42 cde	5.63 fg	6.38 ef	7.13 de	7.63 abc	7.78 abc	7.88 abc	8.25 ab	8.50 a	8.50 a	8.00 a	7.00 ab	7.25 ab	7.00 a	7.00 a
Milorganite	7.32 def	6.13 cde	6.38 ef	6.63 ef	7.00 def	7.13 ef	7.75 bcd	8.25 ab	8.38 a	8.50 a	8.00 a	7.25 a	7.13 abc	7.13 a	6.88 a
Polyon	7.25 efg	5.75 efg	5.63 g	6.38 f	7.13 bcd	7.38 cde	8.00 abc	8.38 ab	8.50 a	8.50 a	8.00 a	7.00 ab	7.00 abc	6.88 ab	6.75 a
IBDU	7.13 fg	6.00 def	5.63 g	5.63 gh	6.50 fg	6.88 f	8.13 ab	8.38 ab	8.38 a	8.50 a	7.88 ab	7.13 ab	7.00 abc	7.00 a	6.88 a
Nitroform	7.06 g	6.50 c	6.00 fg	6.13 fg	6.00 gf	6.38 g	7.50 cd	8.13 b	8.25 ab	8.38 ab	8.00 a	6.75 bc	7.13 abc	6.88 ab	6.88 a
Control	6.54 h	5.50 g	5.13 h	5.25 h	5.50 h	5.75 h	7.25 d	7.50 c	7.63 c	8.00 c	7.38 c	6.50 c	6.75 c	6.63 b	6.75 a

[1] Turf color is rated on a 1-9 scale with 1 = brown, 6 = acceptable, and 9 = dark green. Average values are the average of 14 weekly ratings.
[2] Treatments were applied on 27 May 99 at a rate of 1 lb N/1000 ft^2.
Means followed by the same letter are not significantly different, Fisher's Least Significant Difference, p = 0.05.

The Effect of Varying Rates of Iron Products on Creeping Bentgrass

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Introduction

The use of iron in promoting color in turfgrass has benefits because iron applications can increase color without an undesirable increase in clipping production, which can occur with excessive applications of nitrogen. However, application of certain forms or rates of iron can produce phytotoxicity on the turf for brief periods of time. The objective of this study was to evaluate several forms of iron at varying rates for turf color and phytotoxicity of bentgrass grown under fairway conditions. A second objective was to evaluate an experimental, organic granular iron source that is a by-product of the drinking water treatment process.

Materials and Methods

Iron treatments (Table) were applied on 6 August 99 at rates of 0.4, 0.8, and 1.2 lb Fe/1000 ft^2. Since the iron humate product contained 4% N, 10% K, and 2% Mn, equivalent amounts of urea, $MnSO_4$ monohydrate, and K_2SO_4 were added to the other treatments to balance the amount of those nutrients applied in the iron humate treatments. In addition, there were three treatments containing only N, Mn, and K at rates equivalent to the N, Mn, and K levels in the different Fe treatments. All treatments were applied using a CO_2 powered sprayer at 4 gal/1000 ft^2, except the iron humate treatments, which were applied as a granular material. The study site was watered briefly prior to treatment application so that treatments were applied to wet turf. In addition, the site was watered for approximately 30 minutes following treatment application to reduce the potential for phytotoxicity.

The study was conducted on an established stand of ‘Penneagle’ creeping bentgrass maintained at a 0.5” height of cut. The area was mowed three times per week with clippings removed from the site to prevent cross contamination of treatments. The soil type was a Hagerstown silt loam. The study was a randomized complete block design with three replications, with individual plots measuring 3’ x 8’.

The turf was evaluated for color 3 days after treatment (DAT) application and then weekly for the next five weeks. Color was evaluated on a 1-9 scale with 1 = brown, 6 = acceptable, and 9 = dark green. Color data were subjected to analysis of variance and LSD for mean separation.

Results and Discussion

For the color rating 3 DAT, all the Fe EDTA treatments, as well as all the iron sulfate treatments, had color ratings well below acceptable due to phytotoxicity from the iron treatments. Iron sulfate turned the turf a dark grey to black color while the Fe EDTA treated turf was brown and had more of a burnt appearance. All other treatments, including the unfertilized control, had acceptable color ratings and were not significantly different.

At the 17 August rating (9 DAT), the high rate of iron humate produced very good color, as did the medium and high rates of iron sulfate, which had recovered from the prior phytotoxicity. Of the treatments which had unacceptable color the previous week, only the medium and low rates of Fe EDTA still had unacceptable color and were slightly brown. All other treatments had better than acceptable color, except the unfertilized control.

Color ratings either leveled off or continued to improve the following week (16 DAT). The medium and high rates of iron sulfate produced the highest color ratings, but the were not significantly different from the high and medium rates of iron humate, the low rate of iron sulfate, and the high rate of N, Mn and K alone. All treatments produced turf of acceptable color.

At 24 DAT, the best turf color was produced by the high rate of iron humate, followed by the medium rate of iron humate, the high rate of N, Mn, and K alone, and all three rates of iron sulfate. However, all treatments had acceptable color, with most having good color.

There were no significant differences in turf color due to treatment at 32 or 37 DAT. There was a slight decrease in color for all treatments between the last two ratings.

The best overall color was produced by the high rate of iron humate. The medium and low rates of iron humate and all rates of N, Mn, and K alone all produced overall color ratings of 7.0 or above. All rates of iron sulfate and the high rate of iron EDTA produced better than acceptable color ratings. The medium and low rates of iron EDTA produced the lowest overall color ratings. However, this is due in part to very low color ratings 3 DAT.

The high rate of iron humate produced very good turf within 11 days of application. None of the iron humate treatments produced any burning, which would be an asset for a turf manager. Although the other iron treatments did recover completely from the phytotoxicity, there was a period of time when these plots exhibited very unacceptable color.

Table. Color ratings of creeping bentgrass treated with three rates of three iron-containing products.

Treatment	Rate	Color[1]						
	(lb/1000 ft^2)	9 Aug	17 Aug	24 Aug	31 Aug	8 Sep	13 Sep	Mean
Fe humate	1.2	7.0 a	7.8 a	7.5 ab	8.0 a	7.5 a	7.0 a	7.5 a
Fe humate	0.8	6.8 a	6.8 de	7.3 abc	7.5 abc	7.5 a	7.0 a	7.2 b
Fe humate	0.4	6.7 a	7.0 cde	7.0 bcd	7.2 bcd	7.3 a	6.8 a	7.0 b
Fe EDTA[2]	1.2	2.7 b	6.5 e	7.0 bcd	7.2 bcd	7.3 a	7.0 a	6.3 de
Fe EDTA	0.8	2.2 bc	5.8 f	6.8 cd	7.2 bcd	7.3 a	7.0 a	6.1 ef
Fe EDTA	0.4	2.2 bc	5.5 f	6.7 d	6.8 cd	7.2 a	7.0 a	5.9 f
$FeSO_4$	1.2	1.3 d	7.5 abc	7.7 a	7.7 ab	7.5 a	7.0 a	6.4 cd
$FeSO_4$	0.8	1.5 cd	7.7 ab	7.7 a	7.5 abc	7.3 a	7.0 a	6.4 cd
$FeSO_4$	0.4	1.8 cd	7.2 bcd	7.5 ab	7.3 abc	7.5 a	7.0 a	6.4 cd
N+Mn+K	0.4	7.0 a	6.7 de	7.0 bcd	7.0 bcd	7.5 a	7.0 a	7.0 b
N+Mn+K	1.2	7.0 a	6.8 de	7.3 abc	7.5 abc	7.5 a	7.0 a	7.2 b
N+Mn+K	0.8	6.8 a	6.8 de	7.0 bcd	7.2 bcd	7.5 a	6.8 a	7.0 b
Control	-	6.5 a	5.8 f	6.7 d	6.5 d	7.2 a	6.8 a	6.6 c

[1] Turf color is rated on a 1 to 9 scale with 1 = brown, 6 = acceptable, and 9 = dark green.
[2] Fe EDTA was in chelated form.
Mean values are the average of 6 weekly color ratings.
Means within a column followed by the same letter are not significantly different, LSD, p = 0.05.

Manganese Requirements of Annual Bluegrass and Creeping Bentgrass

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Introduction

Annual bluegrass and creeping bentgrass are two major components of cool-season turfgrass species on golf course putting greens, although annual bluegrass is often considered a very troublesome weed. Many genotypes of annual bluegrass are found on greens. Some genotypes are prolific seedhead producers while others flower infrequently or not at all. Their tolerance to very low mowing height and persistence make annual bluegrasses a very good and competitive turfgrass species on greens.

Because annual bluegrass has long been treated as a weed, the main problem encountered in managing annual bluegrass on greens is the lack of information on its nutritional requirements. Studies found that high levels of nitrogen, phosphorous, possibly potassium, and low levels of sulfur encourage annual bluegrass growth. However, we do not know what the micronutritional requirements of annual bluegrass are and how they compare with those of creeping bentgrass. Understanding the micronutrient requirements of annual bluegrass will help turf managers and scientists to develop a balanced fertilizer program to facilitate annual bluegrass growth or prevent its invasion on creeping bentgrass putting greens.

Manganese is an essential plant micronutrient. It serves as an activator of numerous enzymes, is a constituent of chlorophyll, and is involved in photosynthesis. An adequate and continuing supply of Mn is essential to turf color and growth. Excessive or inadequate Mn, however, may cause turfgrass injury.

Manganese deficiency occurs on a wide range of soil types and can be the result of low Mn levels or low Mn availability, especially in a calcareous or high pH soil. Incidence and severity of Mn deficiencies are manifested by wear stress, environmental stress, frequent clipping removal, occurrence of pests, and high soil nitrogen and potassium content. Deficiency symptoms in turfgrass include striped yellowish leaves (chlorosis) and slow growth.

Manganese toxicities are most commonly encountered in strongly acid soils ($pH<5.5$) but can occur at a pH higher than 5.5 in poorly drained or compacted soils, where reducing conditions favor production of divalent Mn. In addition, use of effluent irrigation water, Mn-containing fungicide, or organic fertilizers such as sewage sludge and poultry manure can also add excessive amounts of Mn into turf soil, which may lead to Mn toxicity on greens, especially in high rainfall areas. Toxicity is usually expressed first in leaves with little observable effect on roots except in severe cases.

A rate of 25-150 mg Mn kg^{-1} on a dry weight basis has been reported to sufficient for turfgrass. However, this value is an average and does not represent levels at which deficiency or toxicity will occur. Plant species, cultivars, genotypes, and even developmental stages may differ considerably in their ability to acquire Mn and their tolerance to excess Mn. It would be difficult to make fertilizer recommendations until these levels are better defined.

The objectives of this research are to determine the color and growth response of three frequently ands three infrequently flowering genotypes of annual bluegrass and three parents of creeping bentgrass to varying levels of Mn, and to determine if interspecific or intraspecific difference exists in their Mn requirements.

Materials and Methods

A greenhouse sand culture experiment was used in this study. BB, BR, and BW were the three parents of 'Penncross' creeping bentgrass. 11G-2, 18G-1, and 18G-2 represented the three genotypes of frequently flowering annual bluegrass while 9G-1, 9G-6, and 11G-6 were the three genotypes of infrequently flowering annual bluegrass. The plant materials were a kind gift of Dr. David Huff. The annual bluegrass was collected from golf course putting greens at Oakmont Country Club in Pennsylvania.

All strains were vegetatively propagated under greenhouse conditions in pots filled with 80% sand:20% peat mixture to ensure the genetic purity of individual strains. Tillers were washed of sand and transplanted to cones (4 cm in diameter x 22.5 cm in length) filled with white sand (U. S. Silica, particle size 0.15 to 1.0 mm, Mapleton, PA).

By the time of establishment (about six weeks), plants were clipped to about 1-2 centimeter one day before the Mn treatments were applied. Treatments began when plants were irrigated by hand with half-strength Hoagland's nutrient solution (pH 5.5-6.0) every other day. $MnCl_2$-Mn in Hoagland's nutrient solution at 0, 0.1, 0.2, and 5 mg l^{-1} rates in Experiment 1 and 0, 10, 20, and 50 mg Mn l^{-1} in Experiment 2 was applied to plants for three weeks.

The treatment of Mn and genotypes were factorially arranged in split-plots within a completely randomized block design with four replications. The temperature of the greenhouse was maintained at 25^0 C during the day and 15^0 C at night. No artificial light was used throughout the experimental period.

Turf leaf color was evaluated on a one (brown) to nine (excellent dark green) scale with six being acceptable green color. Color was rated three weeks after Mn treatments began or when acute deficiency or phytotoxicity symptoms appeared. Plant growth was measured by shoot fresh weight, shoot dry weight, and root dry weight. Shoot fresh weight was recorded three weeks after the Mn treatments. Dry weights were determined after samples were dried in an oven at 80^0 C for 48 hours. Dried plant tissue was ground through a 40 mesh sieve. Plant tissue total Mn was abstracted by acid-ashing procedure. Plant tissue Mn content was obtained by Flame Atomic Absorption Spectrophotometer.

Results and Discussion

*Turf color***.** Withholding Mn in nutrient solution (control) gave annual bluegrass and creeping bentgrass plants an interveinal chlorosis appearance on younger leaves in both experiments (Figure 1). Application of Mn alleviated deficiency symptoms at each level tested with increasing concentrations in nutrient solution up to 5 mg l^{-1} in the Experiment 1. A rate of 0.1 and 0.2 mg Mn l^{-1} was enough to produce acceptable leaf color for both annual bluegrass and creeping bentgrass. Excellent leaf color was observed at 5 mg Mn l^{-1} treatment. Leaf color among genotypes within species at the same levels of Mn tested was not significant at this point.

In Experiment 2, higher rates of Mn in nutrient solution were applied to annual bluegrass and creeping bentgrass. Although no inter- and intraspecific differences existed for exhibiting Mn deficiencies, annual bluegrass and creeping bentgrass do differ in their ability to withstand Mn phytotoxicities. A 10 mg Mn l^{-1} application rate caused annual bluegrass leaf tip burn (dieback), but no toxicity symptoms were observed in creeping bentgrass until the Mn concentration in nutrient solution reached 20 mg Mn l^{-1}. However, the two flowering types of annual bluegrass responded to Mn similarly.

Turf shoot growth. After three weeks, application of Mn at 0.1, 0.2, and 5 mg l^{-1} rates significantly increased annual bluegrass and creeping bentgrass shoot growth compared to untreated controls in Experiment 1. However, the highest shoot growth did not always correspond to the highest Mn concentration applied. A depressed plant shoot growth was obvious at higher Mn application rates in the Experiment 2. Along with the leaf tip burn, shoot growth was significantly reduced by 50 mg Mn l^{-1} application rates in both species (Figure 2).

Shoot dry weight was not significantly different among creeping bentgrass, frequently and infrequently flowering annual bluegrass at low Mn application rate in Experiment 1. However, these differences between species became clear at higher Mn application rates (>10 mg Mn l^{-1}) in Experiment 2. The three parents of creeping bentgrass produced greater shoot dry weight than annual bluegrass at each level of Mn tested. Shoot dry weight of the two flowering types of annual bluegrass was about the same. Again, there was no difference in shoot dry weight among the six genotypes of annual bluegrass and three parents of creeping bentgrass.

Root production. It should be noted that application of Mn at low rates had no significant effect on root dry weight production (Figure 3). Root dry weight production was significantly higher than untreated controls at higher levels of Mn applied Greater root growth was observed in creeping bentgrass than in annual bluegrass but was same between frequently and infrequently flowering annual bluegrass in Experiment 2.

Unlike shoot growth, root production in creeping bentgrass was not limited by highest Mn application rate. There was no significant difference in root production within species although interspecific difference was significant.

Plant tissue Mn content. In Experiment 1, we found that ‘Penncross’ creeping bentgrass and two flowering types of annual bluegrass tended to have similar Mn concentration in their shoot tissue at each level of Mn tested (Figure 4). Manganese concentration in shoot tissue increased from an average low of 10.6 mg kg^{-1} to an average high of 136.5 mg kg^{-1} as the Mn application rate in nutrient solution increased from 0 to 5 mg Mn l^{-1}. Manganese levels in deficient shoot tissue were about 10.6 mg kg^{-1} on a dry weight basis and were associated with yellowish leaf color and low shoot and root growth. Maximum shoot and root production was obtained when shoot tissue Mn concentration reached 136.5 mg kg^{-1}.

In Experiment 2, differences in shoot tissue Mn concentration were observed between creeping bentgrass, frequently and infrequently flowering annual bluegrass. When the same level of Mn was applied, annual bluegrass tended to have a higher shoot tissue Mn content than creeping bentgrass (Figure 4). Annual bluegrass took up more Mn than creeping bentgrass at the same level of applied Mn. Annual bluegrass and creeping bentgrass appear to differ in their sensitivity to applied Mn.

Creeping bentgrass needed a higher Mn application rate (20 mg Mn l^{-1}) to achieve toxic symptoms similar to annual bluegrass (10 mg Mn l^{-1}). Manganese concentration in toxic shoot tissue was 749.1 mg kg^{-1} for annual bluegrass and 787.0 mg kg^{-1} for creeping bentgrass. Differences between species in sensitivity to Mn toxicity appear to be largely related to differences in their uptake of Mn rather than differences in internal Mn requirements.

Since annual bluegrass had a much higher Mn concentration than creeping bentgrass at the same level of applied Mn, especially at high Mn application rates making Mn fertilizer recommendation may be difficult. We cannot manage annual bluegrass by Mn fertilization in the same manner as creeping bentgrass although we can use plant tissue analysis to predict the plant Mn status. By apply the same amount of Mn, we may create Mn deficiency in creeping bentgrass while causing annual bluegrass toxicity.

Conclusion

The results of this study indicate that Mn deficiency and toxicity in annual bluegrass and creeping bentgrass have a significant effect on leaf color and plant shoot growth. Shoot growth is more affected than root production. Manganese fertilization should be kept in an moderate range and plant shoot tissue Mn should be in a range of 10 to 136 mg/kg on dry weight basis.

There is a significant difference between annual bluegrass and creeping bentgrass in their ability to tolerate high levels of Mn. Creeping bentgrass can tolerate higher external Mn concentrations than annual bluegrass, due in part to the higher growth rate of creeping bentgrass.

Plant tissue analysis provides a suitable tool for predicting the likelihood of Mn toxicity in annual bluegrass and creeping bentgrass. However, using plant tissue analysis to manage Mn in annual bluegrass and creeping bentgrass greens is difficult because of interspecific differences in growth and Mn requirements. Low Mn application rates might be an efficient management strategy in promoting both annual bluegrass and creeping bentgrass color and growth but is less effective at high rates. Toxicity can easily result if Mn is applied at high rates in annual bluegrass. Care should be taken in managing creeping bentgrass/annual bluegrass putting greens using Mn as a nutrient.

Figure 1: Turf leaf color

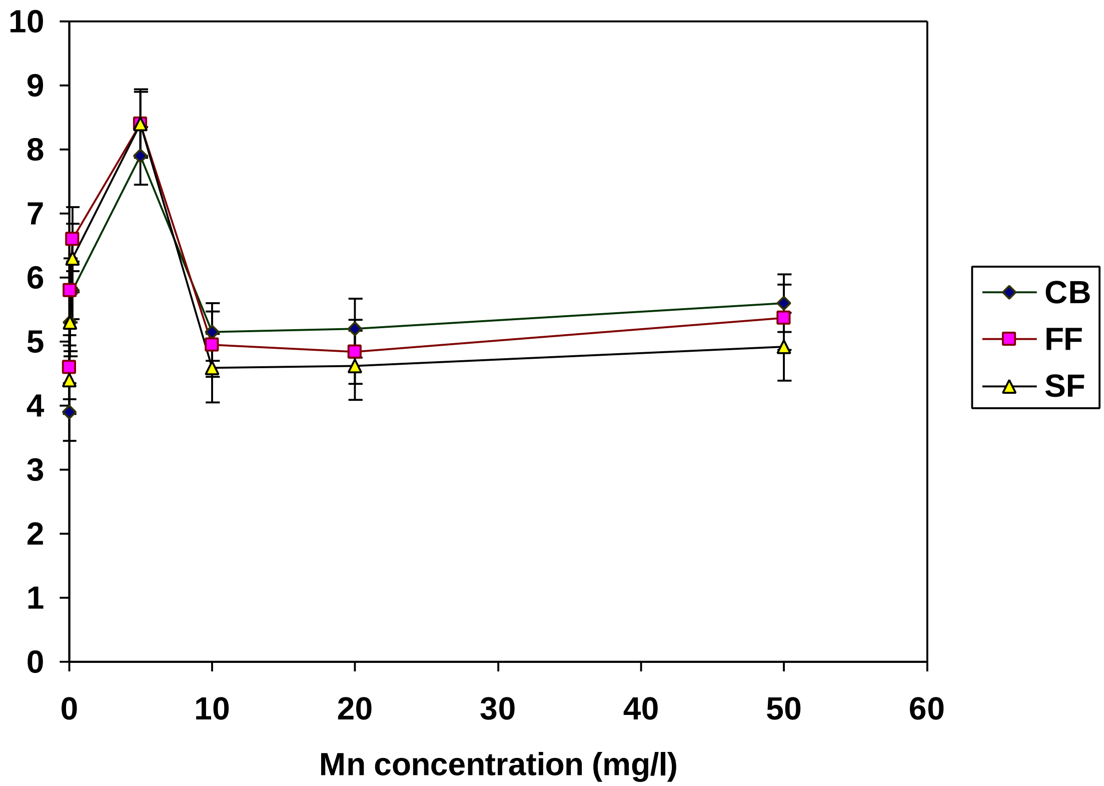


Figure 2: Shoot growth in response to Mn

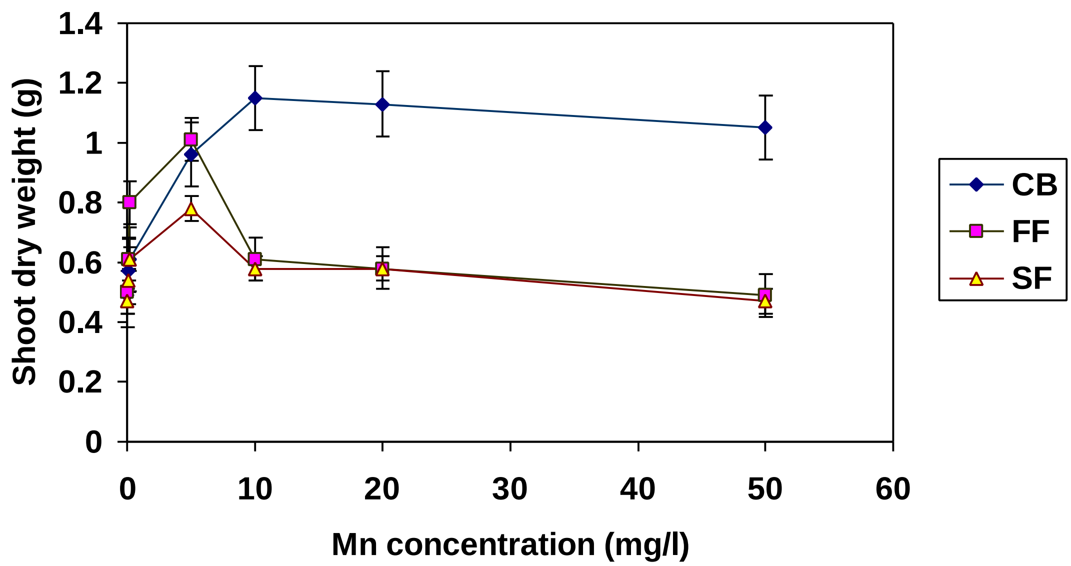


Figure 3: Root production

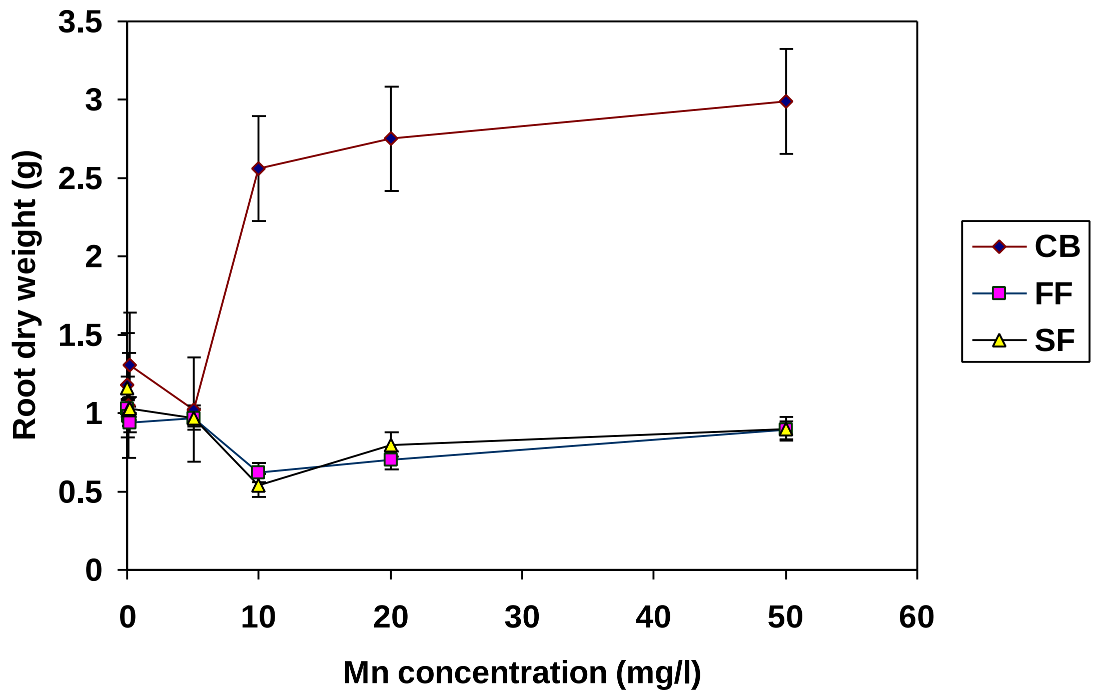
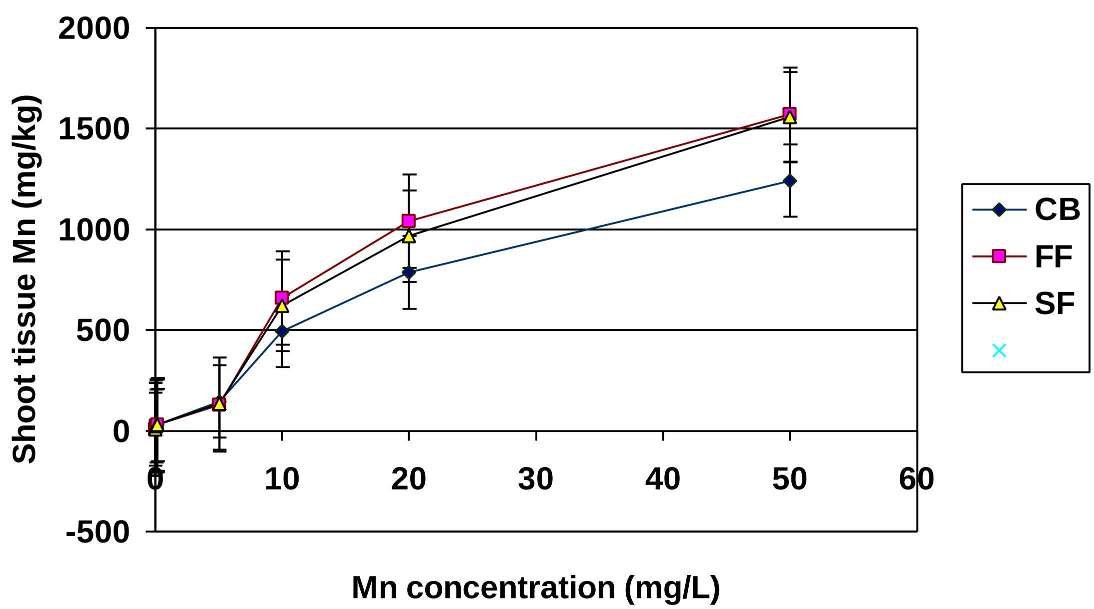


Figure 4: Mn effect on shoot tissue Mn content



The Effects of PCNB Formulation, Rate, and Application Timing on Putting Green Injury, Dollar Spot, and Annual Bluegrass Encroachment

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Funding Sources: Greater Pittsburgh GCSA, Northwestern Pennsylvania GCSA, and The Pennsylvania Turfgrass Council

Introduction

PCNB (pentachloronitrobenzene) is one of the oldest fungicides used on golf courses. Although it is used widely for the control of snow mold diseases, PCNB has been blamed for a variety of turf problems ranging from phytotoxicity to enhancing non-target diseases. Despite reports of turfgrass damage following applications of PCNB, very little research has been conducted on the combined effects of formulation, rate, and application timing on injury to creeping bentgrass/annual bluegrass putting greens. The objective of this study was to determine the influence of PCNB formulation, rate, and timing of applications on turfgrass injury, non-target diseases, and annual bluegrass encroachment on a creeping bentgrass/annual bluegrass putting green.

Materials and Methods

This experiment was conducted at the Joseph Valentine Turfgrass Research Center in University Park on a sand-based putting green composed of a 20-year-old stand of ‘Penncross’ creeping bentgrass (85 to 90%) and annual bluegrass (10 to 15%). The experiment began in the fall of 1996 and was conducted over three growing seasons. The test area received 3.0 lbs nitrogen/1000 ft^2/yr, split into four equal applications (one in late spring, two during the summer, and one in early fall). The test area was not fertilized from 3 weeks prior to the fall PCNB application until after the final injury rating was taken in spring. During 1997, plots were aerated mid-June - after the final injury rating was collected. In 1998 and 1999, the plots were aerated in late summer. Aeration was performed with a Toro Greens Aerator (model 09100) using 0.75-inch-diameter by 4.75-inch-long tines on 2.25 inch centers. Cores were removed with a core harvester and the holes were filled with a 80% sand:20% peat (v:v) topdressing mix. The turf was mowed at 5/32 inch and greens were irrigated whenever necessary to prevent stress.

Two formulations of PCNB, Turfcide 400 4F and Turfcide 10G, were applied at three different rates corresponding to the half, full, and 2X maximum label rates for pink and gray snow mold (Table 1). The 2X rate was included to represent what may happen in case of an application overlap. A Chipco 26019 Flo/Daconil Ultrex combination and an untreated control were included in the test for comparison with the PCNB treatments (Table 1).

Three application timings were used in the test: a late fall (applied December 1, 1996, November 20, 1997, and November 18, 1998); late winter (March 12, 1997, February 14, 1998, and February 18, 1999) before the turf came out of winter dormancy; and a spring application (April 26, 1997, April 7, 1998, and April 8, 1999) applied just after uniform spring green-up. Some treatments were applied only in late fall, some were applied in both late fall and late winter, some were applied in late fall and spring, and the remainder were applied in late fall, late winter, and spring. Rates and application timings for each treatment are listed in Tables 2 and 3.

Table 1. The amount of product and active ingredient applied for each fungicide product and formulation.

Turfcide 400 4F*	
Half rate: 6 fl oz product/1000 ft^2	0.19 lb ai/1000 ft^2
Full rate: 12 fl oz product/1000 ft^2	0.38 lb ai/1000 ft^2
2X rate: 24 fl oz product/1000 ft^2	0.76 lb ai/1000 ft^2
Turfcide 10G*	
Half rate: 5 lb product/1000 ft^2	0.5 lb ai/1000 ft^2
Full rate: 10 lb product/1000 ft^2	1.0 lb ai/1000 ft^2
2X rate: 20 lb product/1000 ft^2	2.0 lb ai/1000 ft^2
Chipco 26019 Flo and Daconil Ultrex	
Full rate: 8 fl oz and 8 oz product/1000 ft^2	0.13 lb ai and 0.41 lb ai/1000 ft^2

*The amount of active ingredient applied differs between Turfcide formulations. This is due to the fact that higher amounts of active ingredient are sometimes required for granular PCNB to be as effective in controlling snow mold diseases as sprayable forms.

Granular treatments were applied by hand using shaker jars and liquid formulations were applied in 2 gallons water/1000 ft^2 with a small plot sprayer equipped with 8004 flat fan nozzles at 32 psi.

The experimental design was a randomized complete block design with three replications per treatment. Ratings of turfgrass injury were based on a scale of 0 to 9, with 0 = no visible injury and 9 = severe injury (complete loss of green color). Ratings were taken when differences among treatments became apparent. Turfgrass injury ratings were taken on May 1 and June 1, 1997; April 11 and April 24, 1998; and April 16, April 22, and May 18, 1999.

Dollar spot disease was assessed by counting the number of spots (infection centers) per plot or by visual assessment on a 0 to 10 scale with 0 = no disease and 10 = severe disease. Dollar spot disease was assessed on June 23, July 22, and August 8, 1998. The percentage of annual bluegrass in each plot was assessed visually on June 30, 1999.

Appropriate statistical analyses were performed on turf injury, dollar spot, and annual bluegrass data to determine if differences were primarily due to treatment effects. Statistics included analysis of variance and a mean separation test (Fisher's protected least significant difference test at the 0.05 level of significance).

Results
Although an evaluation of spring green-up was not an objective of this study, green-up differences among treatments were noticed on April 22, 1997 (before the spring application took place). All PCNB treatments delayed spring green-up slightly when compared to the Chipco 26019 Flo/Daconil Ultrex combination and the untreated control. Two PCNB treatments; the Turfcide 400 4F full rate (0.38 lb ai/1000 ft^2) fall and late winter and Turfcide 400 4F full rate fall and 2X rate (0.76 lb ai/1000 ft^2) in late winter; showed the least amount of spring green-up on April 22 (data not presented). Spring green-up treatment differences were not noticed in 1998 and 1999.

Turfgrass injury:

Turfgrass injury, expressed as scorching of creeping bentgrass foliage (turf foliage appeared brown, red, yellow, and/or tan), became evident a few days after the spring applications in 1997, 1998, and 1999. Little to no injury was apparent on the annual bluegrass. Turfgrass injury ranged from a very slight discoloration (rating of 1 or less) to a severe foliar scorching (rating of 7 or 8 on the most severely-affected plots).

The greatest degree of injury in all three years of the test was caused by the spring-applied Turfcide 400 4F treatments. The most severe injury resulted from Turfcide 400 4F full rate in fall and 2X rate in spring followed by the Turfcide 400 4F full rate in fall and full rate in spring. A moderate amount of injury was apparent on at least one rating date in all three years of the test with the Turfcide 400 4F full rate in fall and half rate (0.19 lb ai/1000 ft^2) in spring and the Turfcide 400 4F full rate in fall, half rate in winter, and half rate in spring. Injury was usually visible within a week of each spring application and lasted for 3 to 5 weeks. No injury was observed with any of the Turfcide 400 4F treatments applied in fall only or in fall and winter (except on one occasion in 1999 where slight injury occurred from the Turfcide 400 4F full rate in fall and 2X rate in late winter treatment).

Despite higher amounts of active ingredient applied with the 10G formulation, less injury resulted from Turfcide 10G treatments than Turfcide 400 4F treatments. Only slight injury was observed on May 1, 1997 and May 18, 1999 on turf treated with Turfcide 10G full rate (1.0 lb ai/1000 ft^2) in fall, half rate (0.5 lb ai/1000 ft^2) in winter, and half rate in spring. No injury was observed as a result of this treatment in 1998. Slight injury from two other Turfcide 10G treatments [full rate in fall, 2X rate (2.0 lb ai/1000 ft^2) in spring and the full rate in fall, 2X rate in winter] was recorded on May 18, 1999. None of the other Turfcide 10G treatments produced turfgrass injury.

Effects on dollar spot:

Differences in dollar spot severity were apparent among some treatments in June, July, and August, 1998 (Table 3). The Turfcide 10G treatments that resulted in reduced dollar spot severity (when compared with the untreated control) on one or more of the three 1998 rating dates all involved repeat applications in winter and/or spring. Only two Turfcide 400 4F treatments showed reduced dollar spot relative to the untreated control; the full rate in fall and 2X rate in spring and the full rate in fall and full rate in spring. More of the Turfcide 10G treatments were suppressive to dollar spot than the Turfcide 400 4F treatments, perhaps due to the higher amount of active ingredient applied with the Turfcide 10G treatments. No dollar spot suppression was observed when applications of either formulation were made only in late fall. The only treatment that showed more dollar spot than the untreated control was Turfcide 400 4F fall only treatment on June 23, 1998.

Although brown patch and dollar spot were evident in the test area during August and September, 1997 and 1999; disease ratings revealed no differences among treatments. Therefore, no disease data is presented for these years.

Effects on annual bluegrass:

Differences in annual bluegrass populations were apparent among some treatments during the spring of 1999. All Turfcide 10G-treated plots showed higher percentages of annual bluegrass than the untreated control and the Chipco 26019 Flo/Daconil Ultrex combination. Generally, the Turfcide 10G-treated plots showed more annual bluegrass than plots treated with Turfcide 400 4F. The only Turfcide 400 4F treatments that had more annual bluegrass than the untreated control and the Chipco 26019 Flo/Daconil Ultrex combination were those that included the full and 2X rates applied in spring. These two treatments showed the greatest degree of injury to bentgrass turf during the three year test period.

Conclusions

When applied in late fall only (no repeat applications) at maximum label rates for snow mold diseases, Turfcide 10G and Turfcide 400 4F caused no injury to creeping bentgrass or annual bluegrass maintained as a putting green. No injury occurred when repeat applications of the 4F and 10G formulations were made at full- or half-label rates in late winter while the turf was still dormant. However, when repeat applications of Turfcide 400 4F were made on turf that was actively growing in spring, injury did occur. The severity of injury from spring applications increased with increasing rates of the 4F.

Generally, Turfcide 10G treatments caused less injury than Turfcide 400 4F treatments, even though higher rates of active ingredient were applied. The only instance of injury resulting from 10G treatments was in May of 1997 and 1999 and this injury was slight (1.0 to 1.3 on a scale of 0 to 9). Although it appears from these results that the 10G formulation is safer than the 4F formulation when applied to actively-growing turf, the Turfcide 10G treatments produced higher amounts of annual bluegrass than most of the Turfcide 400 4F treatments as well as the controls. Although the reason(s) for this are not known, the Turfcide 10G treatments may be causing a reduction in the competitiveness of creeping bentgrass with no adverse visual effects on the turf. If this is true, the affect may be due to the higher amount of active ingredient used with the 10G formulation.

The reason dollar spot suppression occurred with some PCNB treatments in 1998, but not in 1997 or 1999, could be due to an earlier initial infection in 1998 (June) than in the other two years (August). Since there would probably be more residual PCNB in the soil in June than in late summer, this may explain why disease suppressive effects occurred in 1998, but not in the other years of the test.

The 10G formulation generally showed stronger dollar spot suppression than the 4F. This was probably due to the higher rates of PCNB from granular treatments resulting in more residual PCNB in the soil at the time of dollar spot infection.

Table 2. Turfgrass injury ratings following PCNB applications on a creeping bentgrass and annual bluegrass putting green.

	Rate/Timing			1997 Injury Ratings		1998 Injury Ratings		1999 Injury Ratings			Mean of all
Treatment	Fall	Winter	Spring	5/1/97	6/1/97	4/11/98	4/24/98	4/16/99	4/22/99	5/18/99	Injury Ratings
	- - - lb ai/1000 ft^2 - - -			- 0 - 9 scale* -							
Control	--	--	--	0 e**	0 d	0 d	0 e	0 d	0 e	0 c	0 d
Chipco/Daconil	0.13 + 0.41	--	--	0 e	0 d	0 d	0 e	0 d	0 e	0 c	0 d
Turfcide 10G	1.0	--	--	0 e	0 d	0.3 d	0 e	0 d	0 e	0 c	0 d
Turfcide 10G	1.0	0.5	--	0.3 de	0 d	0.3 d	0.3 e	0 d	0 e	0 c	0.1 d
Turfcide 10G	1.0	--	0.5	0 e	0 d	0.3 d	0 e	0 d	0 e	0 c	0.2 d
Turfcide 10G	1.0	1.0	--	0 e	0 d	0 d	0 e	0 d	0 e	0.3 c	0 d
Turfcide 10G	1.0	--	1.0	0.3 de	0.3 d	0.3 d	0.3 e	0 d	0 e	0.7 abc	0.3 d
Turfcide 10G	1.0	2.0	--	0.7 de	0 d	0 d	0 e	0 d	0 e	1.3 a	0.3 d
Turfcide 10G	1.0	--	2.0	0 e	0 d	0 d	0 e	0 d	0 e	1.3 a	0.3 d
Turfcide 10G	1.0	0.5	0.5	1.0 d	0 d	0 d	0 e	0 d	0 e	1.0 ab	0.3 d
Turfcide 400 4F	0.38	--	--	0 e	0 d	0.3 d	0 e	0 d	0 e	0 c	0 d
Turfcide 400 4F	0.38	0.19	--	0 e	0 d	0.3 d	0.7 de	0 d	0 e	0 c	0.1 d
Turfcide 400 4F	0.38	--	0.19	2.7 c	1.7 b	3.0 c	2.7 bc	1.0 c	0.7 de	0 c	1.7 c
Turfcide 400 4F	0.38	0.38	--	0 e	0 d	1.3 d	1.3 cde	0.3 d	0 e	0 c	0.4 d
Turfcide 400 4F	0.38	--	0.38	3.7 b	1.7 b	4.7 b	3.7 b	1.7 b	2.3 b	0.7 abc	2.6 b
Turfcide 400 4F	0.38	0.76	--	0 e	0 d	0.3 d	0.3 e	0.3 d	1.0 cd	0.3 bc	0.3 d
Turfcide 400 4F	0.38	--	0.76	6.0 a	3.7 a	7.7 a	5.7 a	3.3 a	3.7 a	1.3 a	4.5 a
Turfcide 400 4F	0.38	0.19	0.19	2.0 c	0.7 c	3.0 c	2.0 cd	1.0 c	1.7 bc	0 c	1.5 c

* Injury ratings based on 0 - 10 visual assessment scale ; 0 = no visible injury and 9 = severe injury (complete loss of green color).

** Column numbers followed by the same letter are not significantly different as determined by Fisher's Protected Least Significant Difference test at 0.05 level of significance.

Table 3. Dollar spot and *P. annua* ratings following PCNB applications on a creeping bentgrass and annual bluegrass putting green.

Treatment	Rate/Timing			# of Infection Centers		Visual Rating	% Annual bluegrass
	Fall	Winter	Spring	6/23/98	7/22/98	8/8/98	6/30/99
	- - - lb ai/1000 ft^2 - - -					- 0 - 10 scale* -	
Control --	--	--	--	26 b-d**	68 a-c	5.0 ab	12 g
Chipco/Daconil	0.13 + 0.41	--	--	28 a-c	83 ab	4.7 a-c	11 g
Turfcide 10G	1.0	--	--	22 b-e	49 a-d	3.3 b-g	32 bcd
Turfcide 10G	1.0	0.5	--	17 b-f	57 a-d	4.0 a-e	32 bcd
Turfcide 10G	1.0	--	0.5	7 e-g	36 b-d	2.7 d-h	38 ab
Turfcide 10G	1.0	1.0	--	3 fg	11 d	2.3 e-h	40 a
Turfcide 10G	1.0	--	1.0	5 fg	23 cd	2.0 f-h	38 ab
Turfcide 10G	1.0	2.0	--	4 fg	23 cd	2.7 d-h	34 a-d
Turfcide 10G	1.0	--	2.0	1 g	10 d	1.3 h	40 a
Turfcide 10G	1.0	0.5	0.5	7 e-g	93 a	4.3 a-d	37 abc
Turfcide 400 4F	0.38	--	--	43 a	93 a	5.7 a	16 fg
Turfcide 400 4F	0.38	0.19	--	25 b-d	84 ab	4.3 a-d	15 fg
Turfcide 400 4F	0.38	--	0.19	14 c-g	52 a-d	3.0 c-h	21 ef
Turfcide 400 4F	0.38	0.38	--	28 a-c	52 a-d	3.3 b-g	18 fg
Turfcide 400 4F	0.38	--	0.38	5 fg	11 d	1.7 gh	28 de
Turfcide 400 4F	0.38	0.76	--	30 ab	55 a-d	3.3 b-g	18 fg
Turfcide 400 4F	0.38	--	0.76	1 g	14 d	1.7 gh	30 cd
Turfcide 400 4F	0.38	0.19	0.19	13 d-g	38 b-d	3.7 b-f	21 ef

* The visual dollar spot rating scale is 0 to 10 ; 0 = no evidence of disease and 10 = severe infestation.

** Column numbers followed by the same letter are not significantly different as determined by Fisher's Protected Least Significant Difference test at 0.05 level of significance.

Summer Management of Hairy Chinch Bug with DeltaGard, Dursban, Scimitar, Talstar, and Tempo Formulations on Established Fescue

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Introduction

Hairy chinch bug (HCB) populations at select areas across the Commonwealth in 1998 were major pests of fine leafed fescue home lawns. The major objective of this experiment was to determine the effectiveness of synthetic pyrethroid formulations in comparison to chlorpyrifos.

Materials and Methods

The site used for this study was located in Somerset County on turfgrass with significant thatch. The turfgrass area consisted primarily of fine leafed fescue. Treatment plots were 5 X 6 ft arranged in a RCB (randomized complete block) design and replicated 3 times. Granular formulations were applied with a hand held shaker with top dressing sand used to provide even distribution of product. Liquid formulations were applied by using a a CO_2 compressed air sprayer with 4 8002VS TeeJet nozzles mounted on a 6 ft boom, operating at 28 psi, and applied in 227 ml of water/30 ft^2 or delivering 2 gal/1000 ft^2. At treatment time (18 Aug) the following soil and environmental conditions existed: air temperature, 78 ^oF; soil temperature at 1 inch depth, 73 ^oF; soil temperature at 2 inch depth, 69 ^oF; RH, 79%; amount of thatch, 1.0 inch; soil textural class, silt loam; soil particle size analysis: 28.8% sand, 57.7% silt, 13.5% clay; % water content (% by wt), 14.6%; organic matter, 5.8%; water pH, 7.0; soil pH, 6.5; application time, mid morning; and partly cloudy skies. Immediately after treatment the experimental area received 0.055 inch of irrigation. HCB was sampled by driving a 6 inch-diam stainless steel cylinder into the turf, filling it with water, and counting the number of HCB nymphs and adults floating to the surface during a 10 min period 24 Aug and 31 Aug. Two floatation samples were taken randomly from each replicate, and the total number of HCB from each sample was recorded and converted to a ft^2 count.

Results and Discussion

An average of 177.0 HCB nymphs and adults/ft^2 was recorded 18 Aug before treatment. Post treatment counts completed 24 Aug and 31 Aug indicated that all treatments provided significant control. The Table summarizes treatment results. Talstar GC Flowable, Talstar PL G, DeltaGard GC Granular, and Scotts Insecticide III formulations provided excellent control of HCB. No phytotoxicity was noted.

Table. Hairy chinch bug (HCB) results summary.

Treatment/ formulation	Rate lb (AI)/acre	Avg no. HCB/ft^2 24 Aug	31 Aug*
Talstar GC Flowable	0.1	5.0 c	1.6 cd
Talstar GC Flowable	0.2	0.0 c	0.1 cd
Scimitar CS	0.066	37.5 b	38.6 b
Tempo Ultra 1SC**	0.138	21.2 bc	12.9 bcd
DeltaGard GC 5SC	0.13	14.5 bc	19.0 bc
Dursban Pro	1.0	11.0 c	15.4 bcd
Talstar PL Granular	0.2	0.0 c	0.0 d
DeltaGard GC Granular	0.13	14.3 bc	4.7 cd
Scotts Insecticide III	1.0	1.7 c	0.8 cd
Untreated Control	--	109.8 a	92.5 a

Means followed by the same letter are not significantly different (P = 0.05, WD).

* Arcin transformed data.

** Experimental formulation of Tempo.

*** Apply registered formulations only according to label directions. In some cases experimental rates may have been used.

Annual Bluegrass Weevil Suppression with Formulations of Chlorpyrifos, DeltaGard, and Scimitar

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Introduction

Annual bluegrass weevil (ABW) (formerly *Hyperodes* spp.) remains a significant pest of annual bluegrass. Populations have increased at various locations across the state. The primary objective of this experiment was to compare the effectiveness of synthetic pyrethroid formulations with chlorpyrifos to reduce natural adult populations of this weevil pest.

Materials and Methods

This experiment was conducted on turfgrass located in Bedford County. The turfgrass consisted primarily of annual bluegrass (70%) and Kentucky bluegrass (30%). Applications were made when flowering dogwood was in full bloom. Treatment plots were 5 x 6 ft, arranged in a RCB design and replicated 4 times. Liquid formulations were applied in 1 gal of water with a hand held sprinkling can followed by an additional gal of water. At treatment time (28 April), the following soil and environmental conditions existed: air temperature, 56 ^{o}F; soil temperature at l inch depth, 60 ^{o}F; soil temperature at 2 inch depth, 59 ^{o}F; RH, 52%; amount of thatch, 0.1875-0.25 inches; soil textural class, silt loam; soil particle analysis: 23.0% sand, 57.3% silt, 19.6% clay; soil percent water weight (percent by weight), 31.2; organic matter, 6.3%; soil pH, 5.8; water pH, 7; application time, noon; and clear skies. Granular formulations only were irrigated with 0.11 inch water immediately after treatment. Post treatment counts were made on 4 June. ABW control was evaluated by removing two 4 inch cup cutter sod samples from each replicate and recording the total number of annual bluegrass weevil life stages (larva, pupa, adult) per sample. Totals were then converted to a ft^2 count.

Results and Discussion

ABW adults were actively observed on turfgrass before treatment. All treatments provided significant control and results are summarized in the Table. The newly introduced DeltaGard GC Granular and 5SC insecticide formulations provided good to excellent reduction in comparison to Scimitar and Dursban treatments. No phytotoxicity was noted.

Table. Results summary for suppression of annual bluegrass weevil (ABW) with formulations of DeltaGard, Scimitar, and Scott's Insecticide III.

Treatment/ formulation	Rate lb (AI)/acre	Avg. no. ABW/ft^2 (All life stages) 4 Jun	% Reduction
DeltaGard GC 5SC	0.13	7.2 b[1]	84.5
DeltaGard GC Granular	0.13	4.3 b	90.7
Scotts Insecticide III	2.0	0.0 b	100.0
Scimitar CS[2]	0.03	0.0 b	100.0
Scimitar CS[2]	0.06	2.9 b	93.8
Untreated Control	--	46.4 a	--

[1]Means followed by the same letter are not significantly different (P = 0.05, WD).
[2]Formulation is not registered for use on golf courses.
* Apply registered formulations only according to label directions. In some cases experimental rates may have been used.

Evaluation of Mach 2, Merit, and Conventional Formulations for Residual Suppression of White Grubs on Home Lawns

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Introduction

A wide array of formulations are available for suppression of white grubs in home lawns. Although spring management of white grubs seldom is suggested, the primary objective of this experiment was to determine spring reduction of white grub species as well as residual control.

Methods and Materials

Treatment plots were established at the Valentine Turfgrass Research Center located at The Pennsylvania State University. The turfgrass area consisted primarily of perennial ryegrass (100%). Treatment plots were 9 x 6 ft, arranged in a randomized complete block design and replicated 3 times. Liquid formulations were applied by using a hand held sprinkling can and 4 gal of water. Granular formulations were applied with a hand-held shaker and mixed with fine top dressing sand to facilitate product distribution. At treatment time (7 May) the following soil and environmental conditions existed: air temperature, 56^{o} F; soil temperature at l inch depth, 60^{o} F; soil temperature at 2 inch, 58^{o} F; relative humidity, 95%; amount of thatch, 0.0625-0.125 inch; soil textural class, silt loam; soil particle size analysis: 15.1% sand, 59.2% silt, 25.6% clay; organic matter, 3.1%; soil percent water content (percent by weight), 20.4; water pH, 7.0; soil pH, 5.8; treatments were applied in late-morning; 1.7 inch of rainfall was recorded from 7 May through 12 May; and sunny skies. Select treatments were irrigated with 0.125 inch of water immediately after treatment. Post-treatment counts were completed on 20 May and 16 Sept. Three ft^2 sod samples were randomly taken from each replicate, and the total number of white grubs/ft^2 was recorded. White grubs recovered consisted primarily of Japanese beetle grubs (98.3%).

Results and Discussion

An average of 7.8 grubs/ft^2 was recorded on 24 April. All treatments provided significant control of Japanese beetle grubs 13 days after treatment (DAT) while only seven treatments provided significant control on 16 Sept. Results are summarized in the Table. No phytotoxicity was noted.

Table. Japanese beetle white grub efficacy summary for 1998.

Treatment/formulation	Rate lb (AI)/acre	Avg. No. Japanese beetle grubs/ ft^2 20 May Living	20 May Dead[1]	16 Sep Living	16 Sep %Red[2]
Mach 2 1.0%G[3, 5]	0.91	4.4 b	3.0 abc	0.4 c	96.9
Mach 2 1.0%G[3, 5]	1.00	2.6 bc	2.7 bc	1.0 c	92.2
Mach 2 1.0%G[3, 5]	1.50	4.0 bc	3.8 ab	0.0 c	100.0
Mach 2 1.0%G[4, 5]	0.91	4.6 b	3.6 ab	0.0 c	100.0
Mach 2 1.0%G[4, 5]	1.00	3.7 bc	4.6 ab	0.1 c	99.2
Mach 2 1.0%G[4, 5]	1.50	4.9 b	5.1 ab	0.0 c	100.0
Spectracide 3X Insect Control[3]	0.27	4.4 b	5.3 ab	17.4 a	0.0
Ortho Diazinon Turf Insect Control[3]	4.4	2.4 bc	6.0 a	8.4 b	34.4
Scotts GrubEx[3]	0.25	4.8 b	3.4 ab	0.0 c	100.0
Spectracide Diazanon Multi-purpose Insect Spray[3]	4.3	2.1 bc	3.2 abc	10.0 b	21.9
Ortho Diazinon Ultra Insect Spray[3]	4.04	1.2 c	5.4 ab	8.3 b	35.2
Untreated Control	--	11.6 a	0.0 c	12.8 ab	--

[1]Avg no dead grubs recovered from treatments 13 DAT. In some instances grubs were in a moribund state (*i.e.*, they would not respond to any type of tactile stimulation and did not move off sampling boards).
[2]Percent Reduction
[3]Treatments watered in immediately following treatment.
[4]Post-treatment irrigation delayed for 24 hrs. Irrigation was not necessary since rainfall occurred soon after treatment.
[5]Mach 2 1.0%G is an experimental formulation.
Apply formulations only according to label rates. In some cases experimental rates may have been used.
Means followed by the same letter are not significantly different (P = 0.05, WD).

Response of Kentucky Bluegrass and Perennial Ryegrass to the Applications of Proxy Under Reduced Light Conditions

Dr. T. L. Watschke and J. A. Borger
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Introduction

Little is known about the effects that the growth regulator (Proxy) might have on the turf quality of perennial ryegrass and Kentucky bluegrass grown under different levels of shade. Six studies were conducted on a mature stand of perennial ryegrass (three studies) and Kentucky bluegrass (three studies) at the Landscape Management Research Center, Penn State University, University Park, PA. The objective of the studies was to determine whether Proxy treated turf would have improved quality under varying levels of shade.

Methods and Materials

Each study was a randomized complete block design with three replications. All of the treatments (Proxy at 3,5, and 10 oz/M) were applied on June 21, 1999 using a three foot CO_2 powered boom sprayer calibrated to deliver 40 gpa using two, flat fan, 6504 nozzles at 40 psi.

Each study area was covered with a shade cloth (kept twenty inches above the turf canopy with a wooden rack) to simulate shade. Shade was imposed at three levels (30, 55 and 73 percent light filtering). The racks with shade cloth were removed each week to record data and mow and then returned.

All test sites were maintained at two and one half inches with a rotary mower with clippings removed. The test site was irrigated as needed for the duration of the study. Color ratings were taken approximately every seven days for six weeks. Fresh weights (g) were harvested using a twenty inch rotary mower making one pass per plot on August 3.

Results and Discussion

On July 20, (approximately one month after treatment) the color ratings for Kentucky bluegrass tended to produce a trend whereby a slight increase in color was observed as the rate of Proxy increased from 3 to 10 oz/M across all three levels of shade (Table1). On July 27, Kentucky bluegrass treated with Proxy at the lowest level of shade (30%) had a slightly better color than untreated turf. This trend was not found on the final rating date (Aug 3).
Kentucky bluegrass shaded at the 55% level tended to have improved color on July 27 compared to untreated turf. By the final rating date (Aug 3) all Proxy treated Kentucky bluegrass was rated below the acceptable level of 7. Only untreated turf was rated as acceptable.
On July 20, Kentucky bluegrass treated with Proxy at the 10 oz/M rate and exposed to 73% shade was rated above the acceptable level (7). At 73% shade, all treated and untreated Kentucky bluegrass was rated to have unacceptable color on the final two rating dates (Jul 27 and Aug 3).

At the 30% shade level Proxy treated perennial ryegrass color was rated lower than untreated turf but not below the level of acceptability of 7. By July 27 only the perennial ryegrass treated with Proxy at 3 oz/M was rated lower that untreated turf. On the final rating date (Aug 3) all perennial ryegrass (treated and untreated) was rated 8.5 for color.

When perennial ryegrass was subjected to a 55% shade and rated for color only the 5 and 10 oz/M rate of Proxy on July 13 were below that of untreated turf.

On July 13 all Proxy treated perennial ryegrass under 73% shade had color ratings below untreated turf but not below a level of acceptability. On July 27 perennial ryegrass treated at the 3 and 10 oz/M rates of Proxy had poorer color than the untreated perennial ryegrass. By the final rating date (Aug 3) all perennial ryegrass treated with Proxy was rated to have poorer color than untreated turf. Regardless of treatment, the color ratings of the perennial ryegrass was never rated below the acceptable level.

After harvesting fresh weights of perennial ryegrass grown at 55% shade on Aug 3 the untreated turf produced 137.7 grams of clippings which was significantly more than the perennial ryegrass treated at any rate of Proxy (Tables 2 and 3).

More shade/Proxy research should be conducted in the future. Although, some interesting results were found in these studies, the shade canopies should be put in place just after turf green up in the spring and treatments withheld until the turfgrass is acclimated to the shade environment. The study should then be conducted for the entire growing season.

Table 1. Color ratings of Kentucky bluegrass and perennial ryegrass with varying degrees of shade and rates of Proxy.

Treatment	Form	Rate (oz/M)	Color 6-29	7-6	7-13	7-20	7-27	8-3
Kentucky bluegrass 30 % shade								
CHECK			8.8[1]	8.8	8.5	8.8	7.7	8.5
PROXY	2SL	3	8.8	8.8	8.6	8.9	8.0	8.5
PROXY	2SL	5	8.8	8.8	8.7	8.9	8.2	8.5
PROXY	2SL	10	8.8	8.8	8.8	9.0	8.3	8.5
Kentucky bluegrass 55 % shade								
CHECK			8.8	8.7	8.5	8.8	7.5	7.1
PROXY	2SL	3	8.8	8.7	8.7	8.8	7.9	6.8
PROXY	2SL	5	8.8	8.7	8.8	8.9	8.0	6.7
PROXY	2SL	10	8.8	8.7	8.8	9.0	7.7	6.5
Kentucky bluegrass 73 % shade								
CHECK			8.8	8.7	8.3	6.2	4.8	4.0
PROXY	2SL	3	8.8	8.7	8.3	6.3	5.3	4.4
PROXY	2SL	5	8.8	8.7	8.8	6.8	4.3	4.0
PROXY	2SL	10	8.8	8.7	8.8	7.2	4.0	3.5
Perennial ryegrass 30 % shade								
CHECK			8.8	8.8	8.3	8.5	8.0	8.5
PROXY	2SL	3	8.8	8.8	8.2	8.5	7.9	8.5
PROXY	2SL	5	8.8	8.8	8.2	8.5	8.0	8.5
PROXY	2SL	10	8.8	8.8	8.0	8.5	8.0	8.5
Perennial ryegrass 55 % shade								
CHECK			8.8	8.8	8.7	8.5	8.0	8.5
PROXY	2SL	3	8.8	8.8	8.7	8.5	8.0	8.5
PROXY	2SL	5	8.8	8.8	8.5	8.5	8.0	8.5
PROXY	2SL	10	8.8	8.8	8.6	8.5	8.0	8.5
Perennial ryegrass 73 % shade								
CHECK			8.8	8.8	8.7	8.5	7.8	8.0
PROXY	2SL	3	8.8	8.8	8.6	8.5	7.6	7.5
PROXY	2SL	5	8.8	8.8	8.6	8.5	7.8	7.8
PROXY	2SL	10	8.8	8.8	8.5	8.5	7.5	7.8

1 - where 0 = brown, 7 = acceptable and 10 = dark green

Table 2. Fresh weight (grams) harvested on Aug 3 from Kentucky bluegrass grown under varying degrees of shade and treated with three rates of Proxy.

Treatment	**Form**	**Rate**	**(----------Degree of Shade------------)**		
		Oz/M	**30**	**55**	**73**
CHECK			119.0a[1]	195.7a	175.0a
PROXY	2SL	3	142.7a	201.3a	191.0a
PROXY	2SL	5	132.3a	225.7a	178.0a
PROXY	2SL	10	157.3a	232.7a	186.7a

1 - Means followed by same letter in the same column do not significantly differ (P=0.05, Duncan's New MRT).

Table 3. Fresh weight (grams) harvested on Aug 3 from perennial ryegrass grown under varying degrees of shade and treated with three rates of Proxy

Treatment	**Form**	**Rate**	**(----------Degree of Shade------------)**		
		Oz/M	**30**	**55**	**73**
CHECK			82.3a[1]	137.7a	155.7a
PROXY	2SL	3	89.7a	119.7b	147.7a
PROXY	2SL	5	82.7a	119.7b	150.0a
PROXY	2SL	10	84.0a	121.7b	159.0a

1 - Means followed by same letter in the same column do not significantly differ (P=0.05, Duncan's New MRT).

Spring Overseeding of Creeping Bentgrass After a Late Summer Pre-Emergence Application

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Introduction

This study was conducted on a mature stand of perennial ryegrass (*Lolium perenne* L.) at the Valentine Turfgrass Research Center, Penn State University, University Park, PA. The objective of the study was to determine the spring establishment rate of creeping bentgrass after pre-emergence herbicides were applied late the previous summer for control of *Poa annua*.

Methods and Materials

This study was a randomized complete block design with three replications. All of the late summer treatments were applied on September 7, 1998 using a three foot CO_2 powered boom sprayer calibrated to deliver 80 gpa using two, flat fan, 6504 nozzles at 30 psi. After the application of treatments the test site received 0.5” of water. The test area was maintained at 7/8” using a triplex reel mower returning the clippings to the site. Glyphosate was applied at 5 lbs ai/A on September 21, 1998 to the test site to kill the ryegrass and create conditions similar to winter kill the following spring.

On April 28, 1999, the test site was prepared for seeding by making one pass using 3/4” hollow core aerification and two passes with a verticutting unit. The test site was seeded with 0.5 lb/M ‘Penneagle’ creeping bentgrass (*Agrostis palustris* Huds.) using a 10 to 1 ratio of greens grade Milorganite to bentgrass seed. The seeding was accomplished using a three-foot drop seeder. In addition to the seeding, the test site received 0.75 lb N/M from a 19-26-5 starter fertilizer at the time of seeding. The seedbed was maintained until the final rating on June 3, 1999.

Results and Discussion

Both rates of Barricade and Dimension significantly reduced the establishment rate of the seeded creeping bentgrass (less than 10 percent ground cover). The untreated plots and those treated with bensulide had a similar ground cover (over 85 percent). It appears that the use of Barricade and Dimension for pre-emergence control of annual bluegrass can cause problems if a need arises to seed creeping bentgrass into the treated areas the following spring. Both materials appear to have considerably more soil residual than bensulide.

Table. Ground cover ratings (percent) of the seeded creeping bentgrass after a late summer application of pre-emergence herbicides. Ratings were taken on June 3, 1999.

Treatment	**Form**	**Rate (LB Ai/A)**	**%Cover**
BARRICADE	65 WG	0.38	8.3b[1]
BARRICADE	65 WG	0.5	10.0b
CHECK	--	--	88.3a
BENSULIDE	4 L	12.5	88.3a
DIMENSION	1 EC	0.5	8.3b

1 – Means followed by the same letter do not significantly differ (P = 0.05, Duncan's New MRT).

Seedhead Suppression of Annual Bluegrass

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Introduction

This study was conducted on a mature stand of *Poa annua* at the Landscape Management Research Center, University Park, PA. The objective of the study was to evaluate selected herbicides and growth regulators for the seedhead suppression of *Poa annua*.

Methods and Materials

All of the Prograss/Sprint/urea treatments were applied on April 14, 1999 using a three-foot CO_2 powered boom sprayer calibrated to deliver 40 GPA using two 6504 nozzles at 40 psi. The balance of the treatments were applied on April 21, 1999 using the same application methods and equipment. The turf was maintained using practices for irrigation, mowing and fertilization that would be typical for a fairway.

Seedheads were emerging at the time of the April 21, 1999 treatment. The April 14, 1999 application was timed to follow the first mowing of the growing season.

Results and Discussion

All treatments provided some level of seedhead suppression (Table). No treatment caused an unacceptable level of phytotoxicity. The two low rates of Prograss/Sprint/urea provided similar seedhead suppression (53.3 % on May 18). The high Prograss rate caused a seedhead suppression rating of 71.1% on May 18. Turf treated with Embark T/O with or without Ferromec had very little seedhead suppression (23% at the best). The timing of application for the Embark was too late for good efficacy as such treatment properly timed usually yields seedhead suppression in the 90% range. It appears that the application of the Prograss treatments seven days earlier than the Embark applications provided an efficacy advantage for the Prograss.

Table. Ratings of phytotoxicity (April 21, 1999) and percent suppression of *Poa annua* seedheads (May 5 and May 18, 1999) on a mature stand of *Poa annua*.

Treatment	Form	Rate	Phytotoxicity	% Suppression	
				5-5	5-18
Prograss	1.5EC	0.75 LB A/A	7.5[1]a[2]	21.7bc	53.3b
Sprint	G	3 OZ/M			
Urea	46 G	0.1 LB A/M			
Prograss	1.5EC	1.0 LB A/A	7.5a	43.3ab	53.3b
Sprint	G	3 OZ/M			
Urea	46G	0.1 LB A/M			
Prograss	1.5EC	1.5 LB A/A	7.5a	61.7a	71.7a
Sprint	G	3 OZ/M			
Urea	46G	0.1 LB A/M			
Check			7.5a	0.0c	0.0d
Embark T/O	0.2L	40 OZ/A	7.5a	15.0c	23.3c
Embark T/O	0.2L	40 OZ/A	7.5a	10.0c	23.3c
Ferromec	L	5 OZ/M			

[1]Rating scale of 0 = brown 7 = acceptable 10 = dark green.
[2]Means followed by same letter do not significantly differ (P=.05Duncan's New MRT)

Seedhead Suppression of Annual Bluegrass on a Putting Green

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Introduction

This study was conducted on a mixed stand of creeping bentgrass (*Agrostis stolonifera*) and *Poa annua* at the Penn State Blue Golf Course in State College, PA. The objective of the study was to evaluate selected growth regulators, with and without additional adjuvants, for the seedhead suppression of *Poa annua*.

Methods and Materials

All of the treatments were applied on April 21, and, in some cases, April 29 and May 5, 1999 using a three-foot CO_2 powered boom sprayer calibrated to deliver 40 GPA using two 6504 nozzles at 40 psi. The turf was maintained using practices for irrigation, mowing, and fertilization that would be typical for a green. The green did not receive any aerification/topdressing prior to or during the study.

Results and Discussion

On May 11, 1999 none of the treatments were rated to have caused a significant phytotoxicity to the turf compared to turf that was not treated (Table). Slight decreases in color were noted, but none was judged to be unacceptable. It should be noted that the experimental site was very low in nitrogen fertility and was in some degree of moisture stress due to problems with the golf course irrigation system.

On May 19, 1999 the percentage of seedhead suppression due to chemical treatments was rated (Table). The seedhead suppression for this experiment across the treatments was lower this year than in the past. The reduced efficacy can be explained by the stress condition of the turf following treatment. The severe environmental conditions likely hindered absorption and translocation of the materials resulting in the reduced efficacy. Even so, it appeared that by using either Seaweed Cocktail or MacroSorb Foliar with 40 oz/A of Embark T/O, the amount of seedhead suppression tended to be greater than for the other treatments. There does not appear to be compelling evidence in the data that MacroSorb Foliar is capable of altering the antagonism of efficacy associated with using Embark T/O with Ferromec. There does, however, appear to be some enhancement of efficacy when Ferromec is not used.

Table 1. Ratings of Phytotoxicity (May 11, 1999) and percent suppression of *Poa annua* seedheads (May 19, 1999) on a *Poa annua*/creeping bentgrass putting green.

Treatment	Form	Rate	Timing	Phytotoxicity	% Suppression
EMBARK T/O	0.2L	40 OZ/A		7.7[1]a[2]	70.0a
EMBARK T/O	0.2L	40 OZ/A		8.0a	71.7a
FERROMEC	L	5 OZ/M			
EMBARK T/O	0.2L	40 OZ/A		8.2a	68.3a
FERROMEC	L	5 OZ/M			
SURFSIDE 37	L	2 OZ/M			
SURFSIDE 37	L	2 OZ/M	2WAT		
EMBARK T/O	0.2L	40 OZ/A		7.8a	70.0a
FERROMEC	L	5 OZ/M			
SEAWEED COCKTAIL	L	0.5 GAL/A			
SURFSIDE 37	L	2 OZ/M			
SURFSIDE 37	L	2 OZ/M	2WAT		
SEAWEED COCKTAIL	L	0.5 GAL/A	2WAT		
EMBARK T/O	0.2L	40 OZ/A		7.9a	73.3a
SEAWEED COCKTAIL	L	0.5 GAL/A			
SEAWEED COCKTAIL	L	0.5 GAL/A	2WAT		
CHECK				8.1a	0.0b
EMBARK T/O	0.2L	40 OZ/A		7.7a	73.3a
MACRO-FOLIAR	L	2 OZ/M			
MACRO-FOLIAR	L	2 OZ/M	1WAT		
MACRO-FOLIAR	L	2 OZ/M	2WAT		
EMBARK T/O	0.2L	40 OZ/A		8.2a	66.7a
FERROMEC	L	5 OZ/M			
MACRO-FOLIAR	L	2 OZ/M			
MACRO-FOLIAR	L	2 OZ/M	1WAT		
MACRO-FOLIAR	L	2 OZ/M	2WAT		
EMBARK T/O	0.2L	40 OZ/A		8.3a	71.7a
FERROMEC	L	5 OZ/M			
SEAWEED COCKTAIL	L	0.5 GAL/A			
SEAWEED COCKTAIL	L	0.5 GAL/A	2WAT		
EMBARK T/O	0.2L	30 OZ/A		8.0a	63.3a
MACRO-FOLIAR	L	2 OZ/M			
MACRO-FOLIAR	L	2 OZ/M	1WAT		
MACRO-FOLIAR	L	2 OZ/M	2WAT		
EMBARK T/O	0.2L	30 OZ/A		8.2a	58.3a
FERROMEC	L	5 OZ/M			
MACRO-FOLIAR	L	2 OZ/M			
MACRO-FOLIAR	L	2 OZ/M	1WAT		
MACRO-FOLIAR	L	2 OZ/M	2WAT		
EMBARK T/O	0.2L	20 OZ/A		7.8a	65.0a
SEAWEED COCKTAIL	L	0.5 GAL/A			
SEAWEED COCKTAIL	L	0.5 GAL/A	2WAT		
EMBARK T/O	0.2L	20 OZ/A		8.5a	55.0a
EMBARK T/O	0.2L	30 OZ/A		7.8a	61.7a

1 – Rating scale of 0 = brown, 7 = acceptable, 10 = dark green.

2 - Means followed by same letter do not significantly differ (P=. 05 Duncan's New MRT)

Control of *Poa Annua* in a Stand of Kentucky Bluegrass

Dr. T. L. Watschke and J. A. Borger
Department of Agronomy

Introduction

This study was conducted on a mature mixed stand of Kentucky bluegrass ("Midnight") and *Poa annua* at the Landscape Management Research Center, Penn State University, University Park, PA. The objective of the study was to evaluate the control of *Poa annua* from a mixed stand of Kentucky bluegrass and *Poa annua* using PGRs.

Methods and Materials

This study was a randomized complete block design with three replications. All of the treatments were applied on May 27, 1999 using a three foot CO_2 powered boom sprayer calibrated to deliver 40 gpa using two, flat fan, 6504 nozzles at 40 psi. A sequential application of Primo was applied on June 18, 1999 and Proxy on July 8, 1999 using the afore mentioned application technique.

Results and Discussion

Phytotoxicity (color) ratings were made on eleven dates during the course of the study (Table 1). Only slight changes were observed in color, i.e. Proxy treated turf (highest) had lower color ratings than untreated turf on July 30, 1999. Primo treated turf had higher color ratings than untreated turf on June 18, July 14, July 22 and July 30, 1999.

With regard to changes in the percentage of *Poa annua* in the plots (Table 2), the untreated turf had an increase in *Poa annua* from 33.3% on May 26, 1999 to 46.7% on September 7, 1999. At the September rating date, no differences were found for treated verses untreated turf in terms of *Poa annua* percentage. The only significant difference in *Poa annua* percentage was found on July 30, 1999 when there was less *Poa annua* in Primo treated turf. The percentage of *Poa annua* for all treatments tended to decrease from May to July and increase from July to September.

Table 1. Color ratings on a scale of 0-10 where 0 = brown, 7= acceptable, and 10 = dark green of PGR's applied to a mixed stand of Kentucky bluegrass and *Poa annua*.

Treatment	**Form**	**Rate (oz/M)**	**(----Color----)** **6-3**	**6-10**	**6-18**	**6-25**	**7-8**	**7-14**
PROXY	2SL	3	8.5	8.0	8.1	8.0	7.8	8.8
PROXY	2SL	5	8.5	8.0	7.8	8.0	7.8	8.8
PROXY	2SL	10	8.5	8.0	7.8	8.0	7.8	8.8
CHECK			8.5	8.0	7.8	8.0	7.8	8.7
PRIMO	1EC	0.5	8.5	8.0	8.1	8.0	7.8	8.9

Table 1 (Continued)

Treatment	**Form**	**Rate (oz/M)**	**(----Color----)** **7-22**	**7-30**	**8-5**	**8-12**	**8-19**
PROXY	2SL	3	8.8	8.6	8.5	8.5	8.5
PROXY	2SL	5	8.8	8.4	8.5	8.5	8.5
PROXY	2SL	10	8.8	8.3	8.5	8.5	8.5
CHECK			8.7	8.5	8.5	8.5	8.5
PRIMO	1EC	0.5	8.9	8.6	8.5	8.5	8.5

Table 2. Ratings of percent *Poa annua* in a mixed stand of Kentucky bluegrass and *Poa annua*.

Treatment	**Form**	**Rate (oz/M)**	**(----% *Poa annua*----)** **5-26-99**	**6-25-99**	**7-30-99**	**9-7-99**
PROXY	2SL	3	50.0a[1]	48.3a	31.7ab	41.7a
PROXY	2SL	5	41.7a	43.3a	36.7a	50.0a
PROXY	2SL	10	28.3a	30.0a	28.3ab	41.7a
CHECK			33.3a	31.7a	35.0ab	46.7a
PRIMO	1EC	0.5	40.0a	38.3a	25.0b	36.7a

1 – Means followed by same letter do not significantly differ (P= 0.05 Duncan's New MRT)

Poa annua Control Using Summer Applications of Prograss

Dr. T. L. Watschke and J.A. Borger
Department of Agronomy

Introduction

This study was conducted at the State College Elks Country Club, Boalsburg, PA on a mature stand of *Poa annua* and perennial ryegrass (#13 fairway). The objective of this study was to evaluate the control of *Poa annua* when Prograss was applied during the summer growing period.

Methods and Materials

The study was a randomized complete block design with 3 replications. Treatments were applied on June 8, 1998 and were reapplied every 21 days until September 18, 1998 using a three-foot hand held CO_2 powered boom sprayer with two 6504 flat fan nozzles calibrated to deliver 40 GPA at 30 psi.

As a reference, an area was treated using Prograss 1.5EC at a rate of 0.75 lb ai/A on Sept 30, Oct 27 and Nov 19, 1998 using the afore mentioned equipment and application methods.

Results and Discussion

The lowest rate of Prograss tended to increase the amount of *Poa annua* from June 6, 1998 until May 5, 1999. The 0.75 lb ai/A rate appeared to have no effect, while the high rate (1.0 lb ai/A) tended to cause a slight decrease in the amount of *Poa annua* (Table 1). The fall application of 0.75 lb ai/A applied three times (September, October, and November) resulted in a substantial reduction in *Poa annua* when compared to the lower rate, sequential seasonal applications.

Table 1. Ratings for percent control of *Poa annua* in a mixed *Poa annua* and perennial ryegrass fairway. Ratings taken on June 6, 1998 and May 5, 1999.

Treatment	Form	Rate Lb ai/A	Timing	% Control
Prograss	1.5EC	0.25	21DAT	-21.00b[1]
Prograss	1.5EC	0.5	21DAT	-5.56.00ab
Prograss	1.5EC	0.75	21DAT	2.50ab
Prograss	1.5EC	1.0	21DAT	22.87a
Prograss	1.5EC	0.25	21DAT	17.78a
Primo	1EC 0	0.25	21DAT	
Check				-5.05ab
		Reference Only		
Prograss	1.5EC	0.75	Fall	79.30

[1] Negative numbers represent an increase and positive numbers a decrease of *Poa annua*. Means followed by same letter do not significantly differ (P=. 05 Duncan's New MRT)

Late Summer *Poa Annua* Pre-Emergence Application

Dr. T. L. Watschke and J. A. Borger
Department of Agronomy

Introduction

This study was conducted on a mature stand of *Poa annua*/creeping bentgrass (#6 green) at the Nittany Six Hole Golf Course, Penn State University, University Park, PA. The objective of the study was to determine the efficacy of preemergences applied in the late summer for control of *Poa annua* the following growing season.

Methods and Materials

This study was a randomized block design with three replications. All of the treatments were applied on August 26, 1998 using a three foot CO_2 powered boom sprayer calibrated to deliver 80 gpa using two, flat fan, 6504 nozzles at 40 psi.

Results and Discussion

Neither bensulide nor Dimension significantly reduced the amount of *Poa annua* in the treated plots (Table). However, since the amount of *Poa annua* was very low (1%) it would be difficult to attain significant differences. So far in this study there has been no change in the percent of *Poa annua* regardless of treatment. As the study continues with a low population initially of *Poa annua* a good evaluation of these herbicides for encroachment should be made.

Table. Rating of percent cover of *Poa annua* in a *Poa annua*/creeping bentgrass putting green.

Treatment	**Form**	**Rate (LB Ai/A)**	**% Cover 8-26-98**	**% Cover 5-5-99**
Bensulide	4L	12.5	1.0a[1]	1.0a
Dimension	1EC	0.5	0.3a	0.3a
Check			1.0a	1.0a

[1]Means followed by same letter do not significantly differ (P= 0.05 Duncan's New MRT)

Post-Emergence Control of Broadleaf Weeds

Dr. T. L. Watschke and J. A. Borger
Department of Agronomy

Introduction

This study was conducted on a mature stand of perennial ryegrass (*Lolium perenne* L.) at the Landscape Management Research Center, University Park, PA. The objective of the study was to determine the efficacy of broadleaf weed herbicides when applied in early and late summer for control of dandelion, common plantain, and white clover.

Methods and Materials

This study was a randomized complete block design with three replications. All of the treatments were applied on June 7 and August 31, 1999 using a three foot CO_2 powered boom sprayer calibrated to deliver 40 gpa using two, flat fan, 6504 nozzles at 40 psi. Control of the weeds was rated on August 9 and Oct 6, 1999.

Results and Discussion

Applications of the commercial standards Momentum, Trimec Classic, Confront, and Weed-B-Gone resulted in very good to excellent control of white clover and common plantain however, all of the standards had relatively poor control of dandelion when rated on Aug 9 (Table 1). Observation of the dandelions 4 to 6-weeks after application revealed apparent good control. However, by the eight-week rating date, many of the dandelions had resprouted from the taproot. All of the treatments had some level of control of common plantain and white clover, but all had limited control of dandelion. Of the series, NB20334 appeared to have best range of control across the three weed species but still not acceptable on dandelion. The addition of Acclaim Extra to Confront did not appear to antagonize efficacy as Acclaim or Preclaim. Drive provided excellent control of white clover by itself. Combining Drive with Momentum (L0338) improved common plantain control slightly. Tank mixing Drive and Momentum resulted in improved dandelion control compared to Momentum alone, but the control of white clover was decreased. All treatments were reapplied on Aug 31 and a second rating for control was made on Oct 6 (Table 2). All treatments provided acceptable dandelion control except NB30405, and the combination of Preclaim and Confront. All treatments provided acceptable plantain control except L-0337 (Drive G) Drive. Only NB30405 failed to provide acceptable control of white clover.

Table 1. Rating of percent control of three broadleaf weeds taken on Aug. 9, 1999, eight weeks after treatment.

Treatment	**Form**	**Rate (lbs ai/A)**	(---------------% Control-------------) **Dand**[1]	**Plant**	**Clover**
L-0337 (DRIVE)	0.43G	4 LB/M	40.0a-d[2]	8.3de	100.0a
L-0338 (DRIVE/MOMEN)	0.43G	4 LB/M	41.1a-d	37.8cd	100.0a
DRIVE MSO	75DF	0.75 1 % V/V	75.6ab	11.1de	97.8a
DRIVE MSO MOMENTUM	75DF 3.06L	0.75 1% V/V 1.5 OZ/M	87.8a	93.3a	66.7a
CHECK			0.0d	0.0e	0.0b
NB20332	L	4 PT/A	41.7a-d	82.3ab	100.0a
NB30401	L	4 PT/A	8.3d	84.0a	88.9a
NB30402	L	4 PT/A	35.6a-d	75.6ab	65.6a
NB30403	L	4 PT/A	11.1cd	46.7bc	25.0b
NB20334	L	4 PT/A	22.2bcd	88.3a	86.7a
NB30405	L	4 PT/A	1.1cd	75.6ab	0.0b
TRIMEC CLASSIC	L	4 PT/A	32.2a-d	85.0a	100.0a
CONFRONT	3SL	0.75	41.1a-d	85.6a	100.0a
MOMENTUM	3.06L	3.2 PT/A	47.2a-d	80.0ab	100.0a
MOMENTUM	3.06L	4 PT/A	34.4a-d	77.8ab	100.0a
WEED-B-GONE	1.06L	13.6 PT/A	57.8a-d	93.3a	100.0a
ACCLAIM EXTRA CONFRONT	0.57EW 3SL	0.12 0.375	33.3a-d	73.3ab	100.0a
PRECLAIM CONFRONT	3.09EC 3SL	2.06 0.375	67.8abc	27.8cde	100.0a

1 - Dand = dandelion, Plant = broadleaf plantain, Clover = white clover.

2 - Means followed by same letter do not significantly differ (P=.05 Duncan's New MRT)

Table 2. Rating of percent control of three broadleaf weeds taken on Oct 6, 1999.

Treatment	**Form**	**Rate (lb ai/A)**	**Dand[1]**	**Plant**	**Clover**
			(---------------% Control	-------------	------)
L-0337 (DRIVE)	0.43G	4 LB/M	96.7a[2]	33.3d	100.0a
L-0338 (DRIVE/MOMEN)	0.43G	4 LB/M	100.0a	80.0ab	100.0a
DRIVE	75DF	0.75	100.0a	65.6bc	100.0a
MSO		1 % V/V			
DRIVE	75DF	0.75	100.0a	100.0a	100.0a
MSO		1% V/V			
MOMENTUM	3.06L	1.5 OZ/M			
CHECK			0.0c	0.0e	0.0d
NB20332	L	4 PT/A	93.3a	100.0a	100.0a
NB30401	L	4 PT/A	93.3a	100.0a	100.0a
NB30402	L	4 PT/A	88.7a	100.0a	100.0a
NB30403	L	4 PT/A	83.3a	100.0a	100.0a
NB20334	L	4 PT/A	97.8a	100.0a	100.0a
NB30405	L	4 PT/A	64.4ab	100.0a	55.6b
TRIMEC CLASSIC	L	4 PT/A	93.3a	100.0a	100.0a
CONFRONT	3SL	0.75	100.0a	100.0a	100.0a
MOMENTUM	3.06L	3.2 PT/A	100.0a	100.0a	100.0a
MOMENTUM	3.06L	4 PT/A	97.8a	100.0a	100.0a
WEED-B-GONE	1.06L	13.6 PT/A	97.8a	100.0a	100.0a
ACCLAIM EXTRA	0.57EW	0.12	65.3ab	97.8a	100.0a
CONFRONT	3SL	0.375			
PRECLAIM	3.09EC	2.06	100.0a	100.0a	100.0a
CONFRONT	3SL	0.375			

1 - Dand = dandelion, Plant = broadleaf plantain, Clover = white clover.

2 - Means followed by same letter do not significantly differ (P=.05 Duncan's New MRT)

Pre-Emergence Crabgrass Control Study

Dr. T. L. Watschke and J. A. Borger
Department of Agronomy

Introduction

This study was conducted on a mature stand of perennial ryegrass at the Landscape Management Research Center, Penn State University, University Park, PA. The objective of the study was to evaluate the efficacy of herbicides for the preemergence control of smooth crabgrass.

Methods and Materials

This study was a randomized complete block design with three replications. All of the treatments were applied on April 28, 1999 using a three foot CO_2 powered boom sprayer calibrated to deliver 80 gpa using two, flat fan, 6504 nozzles at 40 psi. Granular treatments were applied with a shaker jar. After application the entire test site received approximately 0.5 inch of water.

Crabgrass germination was first noted in the test site on May 12, 1999. Non treated checks were rated to have a minimum of 80 percent crabgrass infestation in all replications.

Results and Discussion

Most of the herbicides used in this study provided commercially acceptable control (at least 85%). Those providing the best control (at least 95%) were the following; prodiamine 65WDG at 0.5 and 0.65 lbs ai/A, dithiopyr 1EC at 0.38, dithiopyr 40WP at 0.25 and 0.38 lbs ai/A, dithiopyr FG AND445 0.164G at 0.38 lbs ai/A, and XF99007 2.32SC at 0.25 and 0.38 lbs ai/A (Table 1). Those providing from 90 to 95% control included; prodiamine 65WDG at 0.38 lbs ai/A, AND672-99 at 3.6 lbs product/M, XF99006 2.32SC at 0.25 and 0.38 lbs ai/A, pendimethalin 60WG at 1.5 lbs ai/A, Team Pro, 0.86G at 2 lbs ai/A, and dithiopyr FG AND445 0.164G. Those materials that did not provide acceptable control were; 011399B, 011399C, 012799E, 012799F, prodiamine at 0.25 lbs ai/A, AND669-99 at 3.6 lbs product/M, AND670-99 at 3.6 lbs product/M, dithiopyr (Crabex) 0.14G at 0.125 lbs ai/A, pendimethalin (Scotts) 0.86G at 1.5 lbs ai/A oxadiazon 2G at 2.0 lbs ai/A and Team 0.87G at 2.0 lbs ai/A.

Table1. Percent control of smooth crabgrass rated on Aug 23, 1999 where 85% and above was considered acceptable.

Treatment	Form	Rate (LB Ai/A)	% Control
011399B	G	3.2 LB/M	68
011399C	G	3.0 LB/M	80
012799E	G	3.4 LB/M	68
012799F	G	3.5 LB/M	75
PRODIAMINE	65WDG	0.25	77
PRODIAMINE	65WDG	0.38	91
PRODIAMINE	65WDG	0.5	97
PRODIAMINE	65WDG	0.65	98
DIMENSION SCOTTS	0.17G	0.5	89
AND669-99	G	3.6 LB/M	78
AND670-99	G	3.6 LB/M	82
AND671-99	G	3.6 LB/M	88
AND672-99	G	3.6 LB/M	90
CHECK LMRC FERT			0
DIMENSION CRABEX	0.14G	0.125	72
DIMENSION CRABEX	0.14G	0.25	86
FERT CHECK 28-3-10	G	3.6 LB/M	0
CHECK NO FERT			0
DIMENSION	1EC	0.25	90
DIMENSION	1EC	0.38	96
DIMENSION	40WP	0.25	96
DIMENSION	40WP	0.38	98
DIMENSION FG AD445	0.164G	0.25	93
DIMENSION FG AD445	0.164G	0.38	97
PENDIMETHALIN SCOTTS	0.86G	1.5	78
XF99006	2.32SC	0.25	91
XF99006	2.32SC	0.38	94
XF99007	2.32SC	0.25	96
XF99007	2.32SC	0.38	96
CHECK LMRC FERT			0
PENDIMETHALIN	60WG	1.5	93
RONSTAR	2G	3	72
BENSULIDE	4EC	10	89
TEAM	0.87G	2	80
TEAM PRO	0.86G	2	91

Post-Emergence Control of Crabgrass at the Two to Three Leaf Growth Stage

Dr. T. L. Watschke and J. A. Borger
Department of Agronomy

Introduction

This study was conducted on a mature stand of perennial ryegrass at the Landscape Management Research Center, Penn State University, University Park, PA. The objective of the study was to evaluate the efficacy of pre/post emergence herbicides for the postemergence control of smooth crabgrass.

Methods and Materials

This study was a randomized complete block design with three replications. All of the treatments were applied on June 18, 1999 using a three foot CO_2 powered boom sprayer calibrated to deliver 40 gpa using two, flat fan, 6504 nozzles at 40 psi. Granular treatments were applied with a shaker jar.

Results and Discussion

Commercially acceptable (85%) postemergence control of smooth crabgrass was attained by applications of the following herbicides; Drive 75DF at 0.75 lbs ai/A with 1%v/v MSO, Drive 75DF at 0.75 lbs ai/A plus 0.375 lbs ai/A of Dimension and MSO at 1% v/v, Drive 75DF at 0.75 lbs ai/A plus 1.5 lbs ai/A of pendimethlin and MSO at 1%v/v, and Acclaim Extra 0.57EW at 0.09 lbs ai/A plus Dimension 40WP at 0.5 lbs ai/A (Table.). All treatments containing granular Drive, Preclaim 3.09EC at 2.06 lbs ai/A, Dimension 40WP at 0.5 and 0.25 lbs ai/A and Puma 1EC at 0.12 lbs ai/A did not provide a commercially acceptable level of control.

Table. Percent control of smooth crabgrass rated on Aug 23, 1999 where 85% and above is considered commercially acceptable.

Treatment	Form	Rate (lb ai/A)	% Control
DRIVE L-0337	G	4 LB/M	68
DRIVE/DIMENSION	G	4 LB/M	70
DRIVE/PREM	G	4 LB/M	68
DRIVE	75DF	0.75	90
MSO	L	1 % V/V	
DRIVE	75DF	0.75	95
MSO	L	1% V/V	
DIMENSION	1EC	0.375	
CHECK			0
DRIVE	75DF	0.75	88
MSO	L	1% V/V	
PENDIMENTHLIN	3.3EC	1.5	
PRECLAIM	3.09EC	2.06	63
ACCLAIN EXTRA	0.57EW	0.09	95
DIMENSION	40WP	0.5	
DIMENSION	40WP	0.5	65
PUMA	1EC	0.12	75
DIMENSION	40WP	0.25	27

Post Emergence Control of Crabgrass at the Two to Three Tiller Growth Stage

Dr. T. L. Watschke and J. A. Borger[1]

Introduction

This study was conducted on a mature stand of perennial ryegrass at the Landscape Management Research Center, Penn State University, University Park, Pa. The objective of the study was to evaluate the efficacy of herbicides for the post emergence control of smooth crabgrass.

Methods and Materials

This study was a randomized complete block design with three replications. All of the treatments were applied on July 19, 1999 using a three foot CO_2 powered boom sprayer calibrated to deliver 40 gpa using two, flat fan, 6504 nozzles at 40 psi.

Results and Discussion

Commercially acceptable postemergence control of smooth crabgrass was attained by the application of Acclaim Extra 0.57EW at 0.12 lbs ai/A, Puma 1EC at 0.12 lbs ai/A, Acclaim Extra 0.57EW at 0.12 lbs ai/A plus Confront 3SL at 0.375 lbs ai/A, and Preclaim 3.09EC at 2.06 lbs ai/A plus Confront 3SL at 0.375 lbs ai/A. All other treatments did not provide commercially acceptable control.

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Table1. Percent control of smooth crabgrass rated on Aug 23, 1999 where 85% and above is considered commercially acceptable.

Treatment	**Form**	**Rate (lbs ai/A)**	**% Control**
ACCLAIM EXTRA	0.57EW	0.12	87
PRECLAIM	3.09EC	2.06	82
PUMA	1EC	0.12	88
CHECK			0
DRIVE	75DF	0.75	75
MSO	L	1 % V/V	
DIMENSION	40WP	0.5	63
DRIVE	0.43G	4 LB/M	42
ACCLAIM EXTRA	0.57EW	0.12	93
CONFRONT	3SL	0.375	
PRECLAIM	3.09EC	2.06	85
CONFRONT	3SL	0.375	

Pre-Stress Conditioning of Perennial Ryegrass with PGRs

Dr. T. L. Watschke and J. A. Borger
Department of Agronomy

Introduction

This study was conducted on a mature stand of perennial ryegrass at the Landscape Management Research Center, Penn State University, University Park, PA. The objective of the study was to evaluate Proxy and Primo for pre-stress conditioning of the turfgrass.

Methods and Materials

This study was a randomized complete block design with three replications. All of the treatments were applied on July 6, 1999 using a three foot CO_2 powered boom sprayer calibrated to deliver 40 gpa using two, flat fan, 6504 nozzles at 40 psi. The test site was only irrigated to prevent turfgrass dormancy.

Results and Discussion

Color was rated six times following the application of the treatments as a means of assessing stress tolerance (Table 1). There were no significant differences found among the treatments on any rating date. Some trends were found to the extent that some generalizations can be made. The highest rate of Proxy (10 oz/M) tended to reduce color until the August third rating date. The two lower rates tended to cause the same effect but caused slightly better color by August third. Adding MacroSorb Foliar to the lowest Proxy rate tended to improve color on the last four rating dates.

The MEC formulation of Primo tended to cause a slightly better color response than the EC formulation (more consistently at the 0.5 oz/M rate). Adding MacroSorb Foliar to Primo treatments did appear to result in color trends. It also appeared that turf treated at the low rate had a similar color response to that treated at the high rate.

On August 17, fresh clipping weights were taken (Table 2). Although Proxy treated turf did not yield significantly different from the check, the yields were significantly lower than those from turf treated with Primo MEC at 0.25 oz/M. By adding MacroSorb Foliar to the 0.25 oz/M rate of Primo MEC, this growth difference was no longer significant.

Table 1. Color ratings taken on six dates in 1999.

Treatment	Form	Rate (oz/M)	Color 7-13	7-20	7-27	8-3	8-10	8-17
PROXY	2SL	3	8.3[1]	8.5	8.7	8.2	8.8	8.7
PROXY	2SL	5	8.0	8.3	8.8	8.2	8.8	8.7
PROXY	2SL	10	8.0	8.0	8.6	7.9	8.8	8.7
CHECK			8.5	8.7	8.9	7.9	8.8	8.6
PRIMO	1EC	0.5	8.5	8.7	9.0	8.1	8.8	8.8
PRIMO	1MEC	0.5	8.5	8.8	8.9	8.5	8.8	8.8
PROXY MACROSORB FOLIAR	2SL L	3 2	8.0	8.2	8.8	8.5	8.8	8.8
PRIMO	1MEC	0.25	8.5	8.8	9.1	8.3	8.8	8.7
PRIMO MACROSORB FOLIAR	1MEC L	0.25 2	8.5	8.7	9.0	8.1	8.8	8.7
PRIMO	1EC	0.25	8.5	8.5	9.1	8.5	8.8	8.8
PRIMO MACROSORB FOLIAR	1EC L	0.25 2	8.5	8.8	9.0	8.3	8.8	8.8

1 – Color ratings where 0 = brown, 7 = acceptable, and 10 = dark green.

Table 2.. Fresh clipping weights (grams) taken Aug 17, 1999.

Treatment	Form	Rate (oz/M)	Weight
PROXY	2SL	3	14.3b[1]
PROXY	2SL	5	12.7b
PROXY	2SL	10	13.0b
CHECK			17.0ab
PRIMO	1EC	0.5	21.7ab
PRIMO	1MEC	0.5	17.7ab
PROXY MACROSORB FOLIAR	2SL L	3 2	17.7ab
PRIMO	1MEC	0.25	23.7a
PRIMO MACROSORB FOLIAR	1MEC L	0.25 2	21.3ab
PRIMO	1EC	0.25	17.7ab
PRIMO MACROSORB FOLIAR	1EC L	0.25 2	17.0ab

[1] Means followed by same letter do not significantly differ
(P= 0.05 Duncan's New MRT)

Evaluation of a New Plant Growth Regulator on Creeping Bentgrass

Dr. T. L. Watschke and J. A. Borger
Department of Agronomy

Introduction

This study was conducted on a mature stand of “Penncross” creeping bentgrass at the Landscape Management Research Center, Penn State University, University Park, PA. The objective of the study was to determine the efficacy and phytotoxicity of an experimental plant growth regulator (EXP310309D).

Methods and Materials

This study was a randomized complete block design with three replications. All of the treatments were applied on June 15 and again on July 13, 1999 using a three foot CO_2 powered boom sprayer calibrated to deliver 40 gpa using two, flat fan, 6504 nozzles at 40 psi. The test site was maintained similar to that of a golf course fairway with respect to irrigation, fertilization and mowing.

Results and Discussion

Color was rated eight times during the course of the experiment (Table 1). No significant differences in color were observed for treated turf.

Height was measured eight times during the course of the experiment (Table 2). On the June 28, July 7, July 12 and July 19 dates there was a slight trend for treated turf to be shorter than non treated, but the differences were not significant.

Fresh clipping weights were harvested seven times during the course of the experiment (Table 3). No significant differences in clipping weights were found in any of the harvest dates.

Table 1. Color ratings on a scale of 0-10 where 0 = brown, 7= acceptable, and 10 = dark green of PGR's applied to "Penncross" creeping bentgrass.

Treatment	**Form**	**Rate Oz/M**	**6-21**	**6-28**	**7-7**	**7-12**	**7-19**	**7-26**	**8-2**	**8-9**
EXP310309D	4SL	2.5	8.0	8.2	8.4	8.5	8.7	8.5	8.7	8.5
EXP310309D	4SL	5	8.0	8.5	8.8	8.5	8.5	8.5	8.8	8.5
CHECK			8.0	8.7	8.6	8.5	9.0	9.0	9.0	8.7
PROXY	2SL	5	8.0	8.6	8.7	8.5	8.8	8.7	8.8	8.6

Table 2. Height ratings (in inches) of PGR's applied to "Penncross" creeping bentgrass.

Treatment	**Form**	**Rate Oz/M**	**6-21**	**6-28**	**7-7**	**7-12**	**7-19**	**7-26**	**8-2**	**8-9**
EXP310309D	4SL	2.5	0.49a[1]	0.40a	0.49a	0.37a	0.43a	0.43a	0.42a	0.39a
EXP310309D	4SL	5	0.52a	0.39a	0.50a	0.41a	0.45a	0.42a	0.44a	0.42a
CHECK			0.50a	0.46a	0.50a	0.41a	0.46a	0.41a	0.40a	0.38a
PROXY	2SL	5	0.53a	0.38a	0.48a	0.38a	0.43a	0.43a	0.39a	0.40a

1 - Means followed by same letter do not significantly differ (P= 0.05 Duncan's New MRT)

Table 3. Fresh weight ratings (in grams) of PGR's applied to "Penncross" creeping bentgrass.

Treatment	**Form**	**Rate Oz/M**	**6-21**	**7-7**	**7-12**	**7-19**	**7-26**	**8-2**	**8-9**
EXP310309D	4SL	2.5	35.7a[1]	0.45a	29.3a	27.0a	30.7a	29.3a	26.3a
EXP310309D	4SL	5	44.0a	46.3a	33.0a	26.0a	29.0a	29.3a	27.0a
CHECK			38.7a	45.3a	33.0a	27.0a	31.7a	28.7a	27.3a
PROXY	2SL	5	43.7a	37.3a	28.0a	27.3a	29.3a	27.3a	25.3a

1 - Means followed by same letter do not significantly differ (P= 0.05 Duncan's New MRT)

Re-Rooting of Four Varieties of Creeping Bentgrass After Applications of Bensulide and Dithiopyr

Dr. T. L. Watschke and J. A. Borger
Department of Agronomy

Introduction

This study was conducted at Penn State University, University Park, PA in the greenhouse at the Agricultural Sciences and Industries Building to evaluate the re-rooting of ‘Penncross’, ‘Seaside’, ‘Penneagle’ and ‘Pennlinks’ creeping bentgrasses. Applications of bensulide and dithiopyr were applied to the bentgrasses for two growing seasons. Samples were taken the spring following the two years of applications for the assessment of re-rooting.

Methods and Materials

This experiment was a completely random design with nine replications. On Feb. 27, 1999, two-inch diameter plugs were collected from the plots in the field that received the herbicide applications. The soil was removed to a depth of 0.5 inch. The plugs were then planted in a sand medium in four-inch pots in a greenhouse.

Bensulide and dithiopyr were applied during two of the three previous growing seasons. All treatments were applied on May 3, 1996 and, with exception of dithiopyr again on May 30, and Aug 26, in 1996. In 1998, all treatments were applied on April 16 and with exception of dithiopyr again on May 20, and Aug 19. All applications were applied using a three-foot hand held CO_2 powered boom sprayer with two 6504 flat fan nozzles calibrated to deliver 80 GPA at 30 psi. After each application the test site received approximately 0.5 inch of water.

Results and Discussion

Color (phytotoxicity) was rated on five consecutive days in March after the plugs were placed in the greenhouse (Table 1). No differences were found in color regardless of treatment during the five day ‘green-up’ phase of the experiment. On March 18, topgrowth was harvested and fresh weights of clippings was recorded (Table 2). No significant differences or trends were found among the treatments. On March 23, roots were harvested, dried, and weighed as a means of assessing re-rooting. No significant differences in re-rooting were found for Penncross, Seaside or Pennlinks varieties. However, Penneagle that had been treated in 1996 and 1998 at the high rate (40, 30, and 30 pts/A) had significantly reduced re-rooting compared to untreated Penneagle. Dithiopyr was not found to cause any significant decrease in re-rooting on any of the varieties when applied at the label rate (0.5 lbs ai/A) with a spring (April) application.

Table 1. Phytotoxicity ratings taken in 1999 on a scale of 1-10 where 1 = brown, 7 = acceptable and 10 = dark green.

Treatment	Form	Rate (pt/a)	Timing	3-2	3-3	3-4	3-5	3-6
			Penncross creeping bentgrass					
BETASAN	4L	20	April	8.6a[1]	9.1a	9.3a	9.2a	9.2a
BETASAN	4L	15	May					
BETASAN	4L	15	Aug					
BETASAN	4L	40	April	8.4a	9.1a	9.2a	9.1ab	9.1a
BETASAN	4L	30	May					
BETASAN	4L	30	Aug					
DIMENSION	1EC	0.5 lb ai/A	April	8.5a	9.1a	8.9ab	8.9ab	8.9a
CHECK				8.4a	8.9a	9.1a	9.0ab	8.9a
			Seaside creeping bentgrass					
BETASAN	4L	20	April	8.5a	9.0a	9.1a	9.0ab	9.0a
BETASAN	4L	15	May					
BETASAN	4L	15	Aug					
BETASAN	4L	40	April	8.6a	9.0a	9.2a	8.9ab	8.9a
BETASAN	4L	30	May					
BETASAN	4L	30	Aug					
DIMENSION	1EC	0.5 lb ai/A	April	8.2a	8.8a	9.1a	8.9ab	8.8a
CHECK				8.5a	9.1a	9.1a	8.9ab	9.0a
			Penneagle creeping bentgrass					
BETASAN	4L	20	April	8.5a	8.8a	9.0a	8.8ab	8.9a
BETASAN	4L	15	May					
BETASAN	4L	15	Aug					
BETASAN	4L	40	April	8.5a	9.0a	9.1a	8.9ab	9.0a
BETASAN	4L	30	May					
BETASAN	4L	30	Aug					
DIMENSION	1EC	0.5 lb ai/A	April	8.6a	8.9a	9.2a	8.8ab	9.1a
CHECK				8.4a	8.7a	8.9ab	8.8ab	9.0a
			Pennlinks creeping bentgrass					
BETASAN	4L	20	April	8.6a	9.1a	9.2a	9.0ab	9.1a
BETASAN	4L	15	May					
BETASAN	4L	15	Aug					
BETASAN	4L	40	April	8.6a	9.0a	9.1a	9.0ab	9.0a
BETASAN	4L	30	May					
BETASAN	4L	30	Aug					
DIMENSION	1EC	0.5 lb ai/A	April	8.5a	8.8a	9.1a	8.7b	9.0a
CHECK				8.7a	9.0a	9.2a	9.1ab	9.0a

[1]Means followed by the same letter do not significantly differ (P = 0.05, Duncan's New MRT).

Table 2. Top growth weights (fresh) and root weights (dry) in grams.

Treatment	Form	Rate (pt/a)	Timing	Top growth 3-18	Root 3-23
			Penncross creeping bentgrass		
BETASAN	4L	20	April	2.94a[1]	0.21ab
BETASAN	4L	15	May		
BETASAN	4L	15	Aug		
BETASAN	4L	40	April	2.64a	0.17ab
BETASAN	4L	30	May		
BETASAN	4L	30	Aug		
DIMENSION	1EC	0.5 lb ai/A	April	2.32a	0.15ab
CHECK				2.65a	0.23ab
			Seaside creeping bentgrass		
BETASAN	4L	20	April	2.59a	0.19ab
BETASAN	4L	15	May		
BETASAN	4L	15	Aug		
BETASAN	4L	40	April	2.58a	0.19ab
BETASAN	4L	30	May		
BETASAN	4L	30	Aug		
DIMENSION	1EC	0.5 lb ai/A	April	2.59a	0.21ab
CHECK				2.36a	0.17ab
			Penneagle creeping bentgrass		
BETASAN	4L	20	April	2.55a	0.23ab
BETASAN	4L	15	May		
BETASAN	4L	15	Aug		
BETASAN	4L	40	April	2.55a	0.14b
BETASAN	4L	30	May		
BETASAN	4L	30	Aug		
DIMENSION	1EC	0.5 lb ai/A	April	2.72a	0.25ab
CHECK				2.45a	0.25a
			Pennlinks creeping bentgrass		
BETASAN	4L	20	April	2.58a	0.17ab
BETASAN	4L	15	May		
BETASAN	4L	15	Aug		
BETASAN	4L	40	April	2.67a	0.19ab
BETASAN	4L	30	May		
BETASAN	4L	30	Aug		
DIMENSION	1EC	0.5 lb ai/A	April	2.55a	0.21ab
CHECK				2.47a	0.24ab

[1]Means followed by the same letter do not significantly differ (P = 0.05, Duncan's New MRT).

Phytotoxicity Screening of Dimension and Different Rates of Bensulide on Four Cultivars of Creeping Bentgrass

Dr. T.L. Watschke and J. A. Borger
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Methods and Materials

This study was conducted at the Valentine Turfgrass Research Center University Park, PA on four mature bentgrass cultivars; ‘ Penncross’, ‘Seaside’, ‘Penneagle’ and ‘Pennlinks’.

The experiment was a split block design with two factors (herbicides and varieties). The turf cultivars were replicated three times. The herbicides (four treatments) were applied across the blocks of varieties. All treatments were applied on April 16, 1998 and, with the exception of Dimension again on May 20, and Aug 19, 1998 using a three-foot hand held CO_2 powered boom sprayer with two 6504 flat fan nozzles calibrated to deliver 80 GPA at 30 psi. After each application the test site received approximately 0.5 inch of irrigation.

The turf was maintained at 1/2 inch every other day using a triplex reel mower with the clippings removed. The turf received irrigation when needed.

Results and Conclusions

The various rate and application schemes of bensulide applied to four creeping bentgrass varieties in 1998 resulted in the same phytotoxicity responses that were found in 1997 (no phytotoxicity on any rating date). Ratings for phytotoxicity were initiated in April and lasted through August. Monthly ratings in the fall of 1998 are not included as no phytotoxicity was observed. Dimension was included as a chemical treatment as creeping bentgrass has a known tolerance to this herbicide. No phytotoxicity was observed from applications of Dimension on any of the creeping bentgrass varieties.

Phytotoxicity rated in the spring of 1999 (Table), revealed that none was present.

Table. Phytotoxicity ratings taken in 1999 on a scale of 1-10 where 1 = brown, 7 = acceptable and 10 = dark green.

Treatment	Form	Rate (pt/a)	Timing	5-5-99
Penncross creeping bentgrass				
BETASAN	4L	20	April	8.0a[1]
BETASAN	4L	15	May	
BETASAN	4L	15	Aug	
BETASAN	4L	40	April	8.0a
BETASAN	4L	30	May	
BETASAN	4L	30	Aug	
DIMENSION	1EC	.5lbai/a	April	8.0a
CHECK				8.0a
Seaside creeping bentgrass				
BETASAN	4L	20	April	8.0a
BETASAN	4L	15	May	
BETASAN	4L	15	Aug	
BETASAN	4L	40	April	8.0a
BETASAN	4L	30	May	
BETASAN	4L	30	Aug	
DIMENSION	1EC	.5lbai/a	April	8.0a
CHECK				8.0a
Penneagle creeping bentgrass				
BETASAN	4L	20	April	8.0a
BETASAN	4L	15	May	
BETASAN	4L	15	Aug	
BETASAN	4L	40	April	8.0a
BETASAN	4L	30	May	
BETASAN	4L	30	Aug	
DIMENSION	1EC	.5lbai/a	April	8.0a
CHECK				8.0a
Pennlinks creeping bentgrass				
BETASAN	4L	20	April	8.0a
BETASAN	4L	15	May	
BETASAN	4L	15	Aug	
BETASAN	4L	40	April	8.0a
BETASAN	4L	30	May	
BETASAN	4L	30	Aug	
DIMENSION	1EC	.5lbai/a	April	8.0a
CHECK				9.0a

[1]Means followed by the same letter do not significantly differ (P = 0.05, Duncan's New MRT).

Web-Accessible Learning Resource Development

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1. Development and evaluation of student-specific courseware for the web.

In cooperation with Heather Shoener, web-accessible learning resources have been designed with "loops" by which information can be added to linear modules for a variety of purposes, including elaboration, clarification, and preparation. An "elaboration" loop simply adds a series of units (graphics, narrative text, and navigation icons) launched from one of the units in the linear series that provide more detailed coverage of a particular subject. For example, the unit on moisture in the climatology module briefly covers the role of moisture in turfgrass growth and quality, but the moisture loop provides detailed information on transpirational cooling, dew formation, and desiccation (see example at: http://www.cas.psu.edu/docs/casdept/turf/Education/shoener/235Lesson05/Climatology/IVA_text20.html). A "clarification" loop attempts to clarify concepts that some students may have difficulty grasping by breaking the concept down into its component parts, explaining each part and the important relationships between parts, and assembling the parts into the whole concept. A "preparation" loop covers prerequisite knowledge that may be needed to fully understand a particular subject. For example, to understand some aspects of nitrogen fertilization, it may be helpful to understand relevant aspects of plant physiology, biochemistry, and organic chemistry. These aspects can be covered in primary, secondary, and tertiary loops, respectively.

Questions can be used to assess each student's understanding of the material prior to each section of an instructional module. If the student is able to correctly answer the questions, he or she is given the option to by-pass the section immediately following the questions and proceed to the next section (an example can be viewed at: http://www.cas.psu.edu/docs/casdept/turf/Education/shoener/235Lesson05/Climatology/Lightprequiz.html).

2. Development and evaluation of solution strategies in case-based learning on the web.

Decision cases are valuable for simulating real-world problematic situations and developing analytical and problem-solving skills. In cooperation with USGA Green Section agronomists, Susan Coleric, David Jonassen, and I are developing a database of "historical" cases as an instructional resource providing students with examples of successful problem-solving as they attempt to develop solution strategies in dealing with the *simulated* problematic situations presented in our "decision" cases. Currently, we have accumulated approximately 40 historical cases and are attempting to expand the database to several hundred covering a broad array of problems encountered in golf turf operations. The agronomists pointed out that the case database has utility as a reference resource for those attempting to deal with *real* problematic situations as well. The case database can be viewed at: http://ide.ed.psu.edu/users/ike/scripts/case-based/turf.idc

3. Courseware development and use for the Penn State World Campus.

Five courses have been completed for use on the World Campus; these are: Turfgrass Pesticides (TURF 230) by Tom Watschke, The Turfgrasses (TURF 235) by Al Turgeon, Turfgrass Pest Management (TURF 236) by Paul Heller and Wakar Uddin, Turfgrass Edaphology (TURF 334) by Andy McNitt, and Case Studies in Turfgrass Management (TURF 436W) by Al Turgeon. Currently under development are:, Weed Control in Turf and Ornamentals (TURF 238) by Tom Watschke and Larry Kuhns, and Turfgrass Cultural Systems (TURF 337) by Tom Watschke. TURF 230, 235, 236, 334, and 436 are currently being taught.

This publication is available in alternative media on request.

Front Cover

Inset photo: Sunrise over the bentgrass plots at the Joseph Valentine Turfgrass Research Center with Beaver Stadium, The Bryce Jordan Center, and Mount Nittany in the background.

Main photo: Flats of individual strains of Annual bluegrass being propagated for use in Penn State's turfgrass breeding program.

Back cover

Clockwise from top left: 1). Students enrolled in the two year Turfgrass Management Program gain hands-on experience in irrigation installation. 2**)**. DNA fingerprints of 13 seedlings of Perennial ryegrass. 3). Laser-grading a USGA spec green under construction for future turfgrass research at the Valentine Research Center. 4). A dandilion grows in the crotch of a tree. 5). Black cutworm & predator. 6). Bentgrass varieties in a National Turfgrass Evaluation Program (NTEP) trial exhibiting susceptibility or resistance to brown patch.