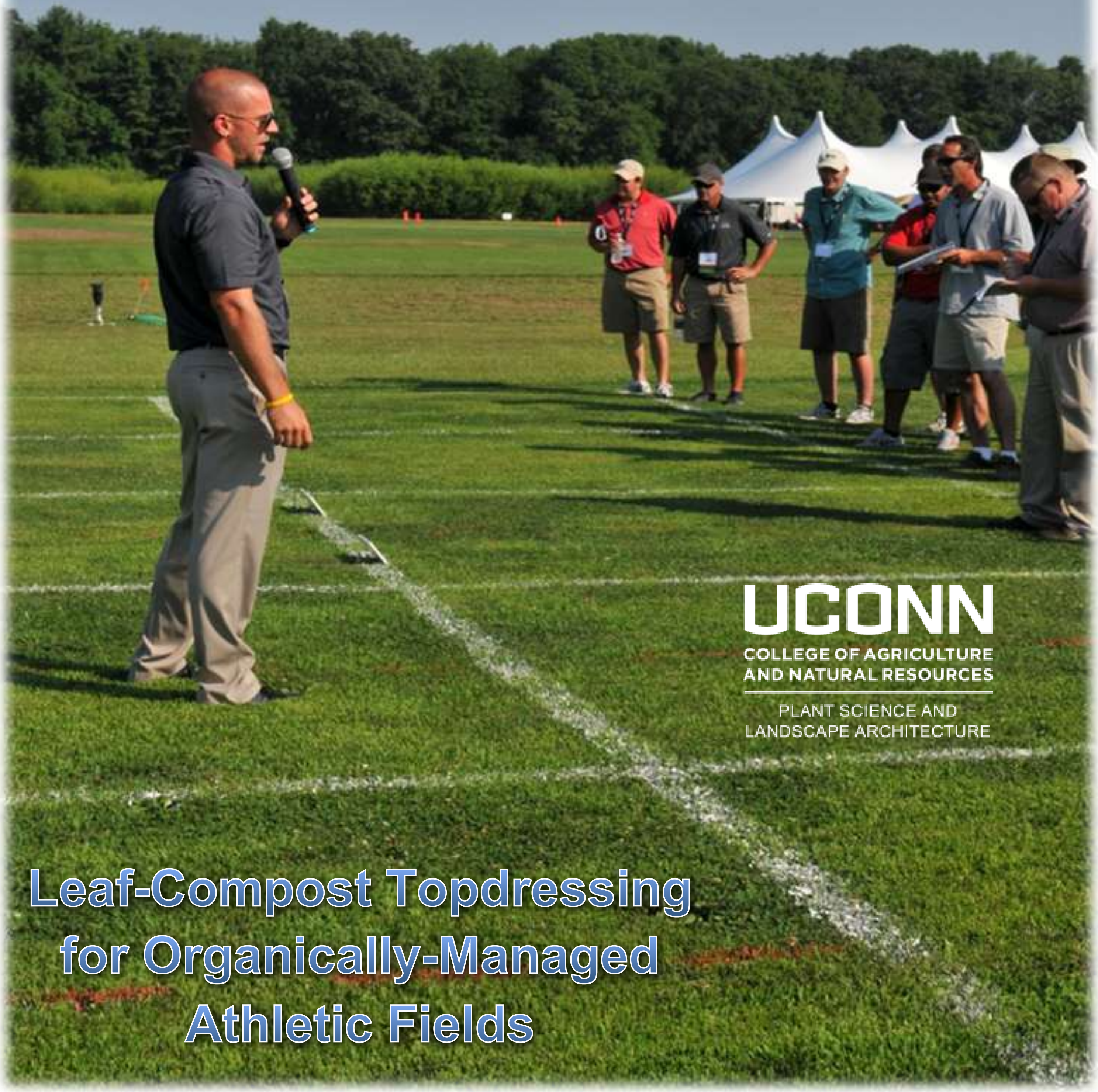
University of Connecticut

College of Agriculture & Natural Resources
2012 Annual Turfgrass Research Report



Leaf-Compost Topdressing for Organically-Managed Athletic Fields

Cover photo: Mr. Brian Tencza, UConn M.S. candidate in Turfgrass Science, discusses the effects of leaf-compost topdressing for organically-managed athletic fields at the 2012 UConn Turf Field Day (read about this exciting research on page 47).

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PLANT SCIENCE AND LANDSCAPE ARCHITECTURE

2012 Annual Turfgrass Research Report Summary

University of Connecticut
College of Agriculture and Natural Resources
Department of Plant Science and Landscape Architecture
Storrs, Connecticut

The University of Connecticut's Annual Turfgrass Research Report is published to provide timely dissemination of current research findings. The purpose of this report is to encourage the exchange of ideas and knowledge between university researchers and members of the turfgrass industry. Research summaries included within this report are designed to provide turfgrass managers, extension specialists, research scientists, and industry personnel with information about current topics related to managing turfgrass.

This report is divided into various sections and includes original research results in the fields of turf pest control (pathology, weed control, entomology), athletic field and golf turf maintenance, cultivar improvement, fertility, and nutrient management. Additionally, abstracts and citations of scientific publications and presentations published in 2012 by University of Connecticut turfgrass researchers are included. This information is presented in the hopes of providing current information on relevant research topics for use by members of the turfgrass industry.

Special thanks are given to those individuals, companies, and agencies that provided support to the University of Connecticut's Turfgrass Research, Extension, and Teaching Programs.

Dr. Karl Guillard, Editor

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PREVENTIVE ANTHRACNOSE CONTROL IN ANNUAL BLUEGRASS PUTTING GREEN TURF WITH VARIOUS FUNGICIDES, 2012

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INTRODUCTION

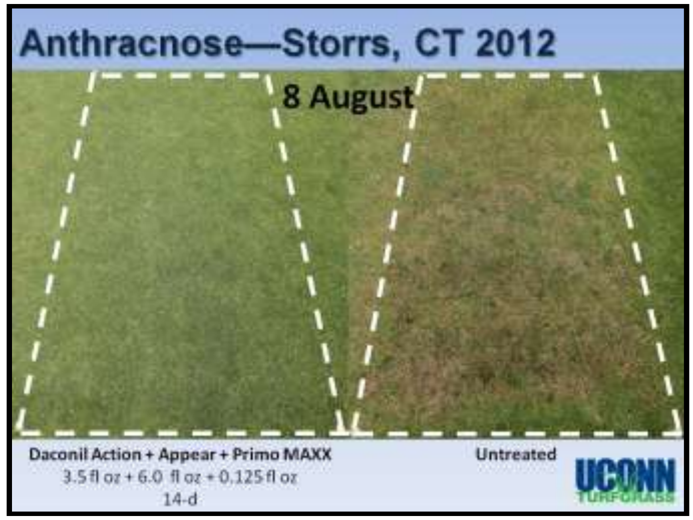
Anthracnose (caused by *Colletotrichum cereale*) is one of the most problematic diseases of annual bluegrass putting greens throughout the Northeastern United States. Recent research has demonstrated that modifications to common cultural practices can reduce anthracnose severity. However, fungicides remain a necessary component of integrated management plans to maintain acceptable anthracnose control.

Several new fungicides have recently become available, or are anticipated to be released for use on turfgrass in the upcoming year. The objective of this study was to evaluate the efficacy of new turfgrass fungicides applied alone or in combination with other products to assess preventive anthracnose control, phytosafety and compatibility of mixtures applied to annual bluegrass putting green turf.

MATERIALS & METHODS

A field study was conducted on annual bluegrass (*Poa annua*) putting green turf grown on a Paxton fine sandy loam at the Plant Science Research Facility in Storrs, CT. The field was established in 2009 from annual bluegrass seed indigenous to the site and contained within aerification cores obtained from Wethersfiled Country Club. Turf was mowed five days wk^{-1} at a height of 0.125-inches. The site was irrigated as necessary to avoid drought stress. Nitrogen was applied at 0.1 lbs N 1000 ft^{-2} every 14-d from May through August with a total of 1.15 lbs N 1000 ft^{-2} applied to the field by the end of the trial. Proxy and Primo MAXX were applied on 22 March and 6 April at 5.0 and 0.125 fl oz 1000-ft^{-2}, respectively to suppress seedhead expression. Dollar spot was controlled from 11 May through 30 June with applications of Curalan or Emerald every 7- to 14-d. Talstar and Dylox were applied on 18 May and 30 June, respectively for control of annual bluegrass weevil.

Treatments consisted of currently available and experimental fungicides applied individually, in combination, or as rotational programs (Table 5). Initial treatment applications were made on 17 May prior to disease development. Subsequent applications were made on 7- or 14-d intervals (dates listed in Tables 1-4) until 17 August. Treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI19508E or AI19504E flat fan nozzle to deliver 2.0 or 1.0 gal water 1000-ft^{-2} at 40 psi, respectively per treatment requirement. Plots measured 3 x 6 ft and were arranged in a randomized complete block design with four replications.



Anthracnose was determined visually as the percent area blighted by *C. cereale* from 11 June through 11 September. Turf quality was visually assessed on a 1-9 scale; where 9 represented the best quality and 6 was the minimum acceptable level. Phytotoxicity was assessed on a 0-5 scale; where 0 represented no turf injury and 2 was the maximum acceptable level. Normalized difference vegetative index was measured with the Field Scout TCM 500 (Spectrum Technologies, Inc) NDVI meter. Ten readings were taken per plot with the mean used for data analysis. Higher NDVI values generally correspond with darker green turf. Data were subjected to an analysis of variance and means were separated using Fisher's protected least significant difference test.

RESULTS AND DISCUSSION

Anthracnose Severity

Anthracnose developed initially throughout the trial on 11 June; although symptoms were limited until 18 July when environmental conditions became more conducive for the disease (Table 1). Disease pressure from July through mid-August was high, with untreated plots sustaining 81% plot area blighted by anthracnose.

As disease increased from 18 July through 9 August, most treatments provided excellent anthracnose control (i.e., $\leq$ 2% plot area blighted). However, plots treated with UC12-1 (0.22 & 0.42 fl oz) and UC12-2 were ineffective at controlling anthracnose at this time, and for the remainder of the trial. The epidemic peaked on 17 August (Table 1). Turf treated with UC12-5, Plant Food Program 2, and chlorothalonil formulations applied alone or as a tank mix with other fungicides provided excellent disease control on this date. Conversely, alternating between Daconil Action and Briskway every 14 d or applications of Velista alone did not provide acceptable anthracnose control. Velista applied as a tank mixture or in a rotational program generally provided good to excellent disease control. By 11 September (33 DAT), several treatments including UC12-5, Daconil Action + Briskway (0.5 fl oz), Daconil Action + Briskway (0.5 fl oz) + Primo MAXX, Syngenta Program, and Daconil Action + Appear + Primo MAXX continued to provide good anthracnose control, maintaining 5% or less plot area blighted.

The effect of reduced carrier volume (i.e., 1.0 vs. 2.0 gal 1000 ft^{-2}) on efficacy of Daconil Action, Briskway and Velista was tested, although no differences were observed in this trial.

Turf Quality, Phytotoxcicty, NDVI

Prior to anthracnose development, turf quality was generally highest in plots treated with the Syngenta and DuPont programs and tank mixes of Daconil Action+Appear+Primo MAXX, and Velista+Chipco Signature (Table 2). Quality of all these treatments was improved in part due to the addition of a green pigment which helped improve turf color. However, tank mixes of Briskway (0.5 fl.oz.)+Daconil Action+Primo MAXX, and Plant Food Programs 1&2 also had improved quality in the absence of a green pigment. Phytotoxicity and reduced turf quality was observed in plots treated every 14-d with UC12-2 and UC12-5 during high temperatures in mid-July. Turf in these plots appeared stunted and canopy uniformity was poor (Table 3). Phytotoxicity was not considered to be unacceptable in any other treatments.

NDVI results were closely associated with turf quality. Treatments with the greatest NDVI values were often the same as those with the highest turf quality (Table 3).

CONCLUSIONS

Anthracnose pressure was high during August of this trial providing a rigorous assessment of fungicide efficacy for anthracnose. Despite high disease pressure many treatments provided excellent disease control. The most effective treatments were generally tank mixes or rotational programs containing chlorothalonil. These results agree with previous studies demonstrating the importance of tank mixing or rotating chemistries for effective anthracnose control. These are also important practices to delay development of fungicide resistance.

Nutritional based programs (i.e., Plant Food Programs) also performed well in this trial. Research has demonstrated that low nitrogen significantly enhances anthracnose. These programs provided an additional 0.1 lb N 1000 ft^{-2} every 7 days; when combined with reduced rates of Phosphite 30 and Daconil WeatherStik, they provided excellent anthracnose control and improved turf quality.

Several new fungicides were evaluated in this trial. Briskway is a combination of the azoxystrobin (QoI) and difenoconazole (DMI). Unlike some other DMI fungicides, difenoconazole appears to have less risk of phytotoxicity when applied to putting green turf throughout the summer. In this trial no phytotoxicity or unacceptable growth regulation was observed when this fungicide was applied with or without Primo MAXX. However, Briskway was only effective in controlling anthracnose when tank mixed with Daconil Action at this site. This is likely due in part to the presence of QoI resistant isolates of the pathogen at the trial site. Velista (penthiopyrad) is a new SDHI fungicide with moderate activity against anthracnose when applied alone at high rates (0.5 oz), but can provide good control when tank mixed with other fungicides with moderate efficacy against anthracnose. Daconil Action is a combination of chlorothalonil and acibenzolar-S-methyl which can activate the plant systemic acquired resistance pathway to help prevent infection. In some trials this fungicide has demonstrated improved activity compared to chlorothalonil alone. However, Daconil Action and other formulations of chlorothalonil provided comparable disease control in this study, regardless of application rate, interval or carrier volume. Appear is a new pigmented phosphite fungicide. In this trial, tank mixes and programs containing Appear provided excellent anthracnose control and improved turf quality.

Table 1. Anthracnose severity in an annual bluegrass putting green turf treated preventively with fungicides at the Plant Science Research Facility, Storrs, CT during 2012.

Treatment	Rate per 1000 ft^2	Int[y]	Anthracnose Severity								
			11 Jun	26 Jun	7 Jul	18 Jul	27 Jul	9 Aug	17 Aug	23 Aug	11 Sep
			------------------------------------- percent plot area blighted -------------------------------------								
Briskway	0.62 fl oz	14-d[w]	1.3 b[v]	1.1 e-h	0.6 b	0.3 de	1.6 f	6.8 ef	26.8 cde	29.8 d	51.8 ab
-Daconil Action	3.5 fl oz										
Briskway	0.5 fl oz	14-d[w]	0.3 bc	1.4 e-h	0.1 b	0.0 e	1.5 f	2.0 fg	22.0 de	20.0 def	46.3 bc
-Daconil Action	3.5 fl oz										
UC12-1	0.22 fl oz	14-d	0.5 bc	1.9 c-f	0.3 b	12.0 b	34.3 b	50.0 b	76.8 a	66.3 b	62.5 a
UC12-1	0.42 fl oz	14-d	1.1 bc	1.5 d-h	0.3 b	3.5 cd	12.5 c	27.8 c	46.3 b	47.5 c	46.3 bc
UC12-2	1.0 fl oz	14-d	0.1 bc	0.8 fgh	0.1 b	4.5 c	8.5 d	24.0 c	36.8 bc	28.8 de	40.0 bcd
UC12-5	0.6 fl oz	14-d	0.1 bc	0.0 h	0.0 b	0.0 e	0.3 f	0.1 g	0.4 g	0.1 j	4.1 klm
Briskway	0.62 fl oz	14-d	0.5 bc	0.8 fgh	0.4 b	0.0 e	0.3 f	0.0 g	0.0 g	0.5 ij	12.5 h-m
+Daconil Action	3.5 fl oz										
Briskway	0.5 fl oz	14-d	0.8 bc	0.8 fgh	0.0 b	0.0 e	0.0 f	0.0 g	0.0 g	0.0 j	4.3 klm
+Daconil Action	3.5 fl oz										
Syngenta Program	[z]	Pgm	0.0 c	0.0 h	0.0 b	0.0 e	0.0 f	0.0 g	0.0 g	0.0 j	0.0 m
Briskway	0.5 fl oz	14-d	0.0 c	0.0 h	0.0 b	0.0 e	0.0 f	0.0 g	0.0 g	0.0 j	1.8 lm
+Daconil Action	3.5 fl oz										
+Primo MAXX	0.125 fl oz										
Daconil Action	3.5 fl oz	14-d	0.0 c	0.0 h	0.0 b	0.1 e	0.0 f	0.0 g	0.3 g	0.0 j	1.6 lm
+Appear	6.0 fl oz										
+Primo MAXX	0.125 fl oz										
Daconil Action	2.0 fl oz	7-d	0.5 bc	3.8 ab	1.3 b	0.0 e	0.0 f	0.0 g	1.6 g	1.5 ij	16.3 f-l
Daconil Action	3.5 fl oz	14-d	0.6 bc	2.4 b-e	0.6 b	0.0 e	1.1 f	0.0 g	0.0 g	2.1 hij	13.0 g-m
EXC948	3.6 fl oz	14-d	0.1 bc	1.6 d-g	0.4 b	0.5 de	1.1 f	2.0 fg	9.8 fg	15.5 fg	27.3 d-g
Daconil Action[x]	3.5 fl oz	14-d	0.6 bc	3.5 ab	1.0 b	0.3 de	0.0 f	0.0 g	0.5 g	2.9 hij	10.1 i-m
Briskway[x]	0.5 fl oz	14-d	0.3 bc	0.4 fgh	0.0 b	0.0 e	0.0 f	0.0 g	0.0 g	0.0 j	1.1 m
+Daconil Action	3.5 fl oz										
+Primo MAXX	0.125 fl oz										
Velista	0.3 oz	14-d	0.3 bc	0.6 fgh	0.3 b	0.0 e	0.8 f	0.0 g	0.3 g	0.3 ij	10.5 i-m
+Daconil Ultrex	3.25 oz										
Velista	0.3 oz	14-d	0.5 bc	0.1 gh	0.0 b	0.0 e	0.0 f	1.9 fg	3.6 g	4.8 g-j	26.3 d-h
+Chipco Signature	4.0 oz										
Velista	0.3 oz	14-d	0.1 bc	1.6 d-g	0.5 b	0.0 e	0.0 f	2.1 fg	6.3 g	11.5 f-i	23.3 e-i
+Medallion	0.5 oz										
Velista	0.3 oz	14-d	0.0 c	1.0 e-h	0.3 b	0.0 e	0.0 f	2.9 fg	6.9 g	2.6 hij	29.5 def
+Endorse	4.0 oz										
DuPont Program	[z]	Pgm	0.1 bc	0.1 gh	0.0 b	0.0 e	0.0 f	0.0 g	0.0 g	1.0 ij	8.8 i-m
Velista	0.3 oz	14-d	0.1 bc	1.1 e-h	0.1 b	0.0 e	0.6 f	9.3 e	23.8 de	21.5 def	45.0 bc
Velista	0.5 oz	14-d	0.1 bc	1.3 e-h	0.1 b	0.0 e	0.0 f	3.3 efg	18.5 ef	18.0 ef	36.5 cde
Velista[x]	0.5 oz	14-d	0.1 bc	1.4 e-h	0.5 b	0.0 e	0.0 f	5.3 efg	20.5 def	13.3 fgh	37.5 b-e
Daconil Ultrex	3.25 oz	14-d	0.5 bc	3.0 a-d	1.4 b	0.3 de	0.0 f	1.0 fg	1.0 g	2.6 hij	12.3 h-m
Daconil WeatherStik	2.0 fl oz	7-d	0.4 bc	1.5 d-h	0.4 b	0.3 de	0.3 f	0.3 g	0.4 g	1.1 ij	16.5 f-k
Daconil WeatherStik	3.6 fl oz	14-d	1.3 b	3.3 abc	0.9 b	1.0 de	3.0 ef	1.0fg	3.3 g	3.4 hij	21.3 f-j
Plant Food Program 1	[z]	Pgm	0.3 bc	0.3 gh	0.0 b	0.5 de	6.5 de	15.5 d	30.0 cd	29.8 d	28.3 def
Plant Food Program 2	[z]	Pgm	0.0 c	0.0 h	0.0 b	0.1 e	0.0 f	0.0 g	0.0 g	1.0 ij	8.0 j-m
Untreated Check			3.0 a	4.0 a	13.0 a	41.3 a	68.8 a	67.5 a	81.3 a	78.8 a	61.8 a
ANOVA: Treatment (P > F)			0.0026	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		7-d	4	5	2	6	2	7	8	14	33
		14-d	12	12	9	6	2	14	8	14	33

[z] See Table 5 for program details.

[y] Treatments were applied on a 7- or 14-d interval from 17 May through 9 Aug.

[x] Select treatments applied with a carrier volume of 1.0 gal 1000ft^{-2}; all other treatments applied in 2.0 gal 1000 ft^{-2}.

[w] Briskway and Daconil Action were alternated every 14-d. Briskway was applied on 17 May, 14 Jun, 12 Jul and 9 Aug. Daconil Action was applied on 31 May, 28 Jun, and 25 Jul.

[v] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test (α = 0.05).

Table 2. Turf quality of an annual bluegrass putting green turf treated preventively with fungicides at the Plant Science Research Facility, Storrs, CT during 2012.

Treatment	Rate per 1000 ft^2	Int	28 May	11 Jun	26 Jun	9 Jul	18 Jul	9 Aug	11 Sep
			Turf Quality						
			1-9; 6=minimum acceptable						
Briskway	0.62 fl oz	14-d[w]	7.0 a-d[v]	6.5 c-f	6.0 e-h	5.8 gh	6.8 e-h	5.8 fg	3.5 jkl
-Daconil Action	3.5 fl oz								
Briskway	0.5 fl oz	14-d[w]	7.5 ab	6.8 b-e	6.5 d-g	6.5 efg	6.8 e-h	5.8 fg	3.3 kl
-Daconil Action	3.5 fl oz								
UC12-1	0.22 fl oz	14-d	6.8 bcd	6.3 def	6.0 e-h	5.8 gh	4.8 l	2.5 j	2.0 m
UC12-1	0.42 fl oz	14-d	6.5 cd	6.0 efg	6.0 e-h	5.8 gh	6.0 h-k	4.0 i	3.0 l
UC12-2	1.0 fl oz	14-d	7.5 ab	7.0 a-e	6.3 efg	4.3 ij	4.8 l	4.0 i	3.8 i-l
UC12-5	0.6 fl oz	14-d	7.0 a-d	7.0 a-e	6.3 efg	4.3 ij	5.3 kl	5.8 fg	7.0 ab
Briskway	0.62 fl oz	14-d	7.3abc	6.5 c-f	6.3 efg	6.0 fgh	6.3 g-j	6.5 def	5.8 cde
+Daconil Action	3.5 fl oz								
Briskway	0.5 fl oz	14-d	7.5 ab	6.8 b-e	6.3 efg	6.5 efg	7.0 d-g	7.8 bc	6.5 bc
+Daconil Action	3.5 fl oz								
Syngenta Program	[z]	Pgm	6.5 cd	7.8 ab	7.5 bcd	9.0 a	8.8 a	9.0 a	7.5 a
Briskway	0.5 fl oz	14-d	6.8 bcd	7.3 a-d	7.5 bcd	7.3 cde	7.3 c-f	7.8 bc	7.0 ab
+Daconil Action	3.5 fl oz								
+Primo MAXX	0.125 fl oz								
Daconil Action	3.5 fl oz	14-d	6.8 bcd	7.8 ab	7.8 abc	8.3 abc	8.0 abc	8.0 b	7.0 ab
+Appear	6.0 fl oz								
+Primo MAXX	0.125 fl oz								
Daconil Action	2.0 fl oz	7-d	6.5 cd	5.0 g	5.0 h	5.3 hi	5.8 ijk	6.5 def	5.3 def
Daconil Action	3.5 fl oz	14-d	6.8 bcd	6.0 efg	5.5 gh	5.3 hi	6.0 h-k	6.5 def	5.8 cde
EXC948	3.6 fl oz	14-d	7.3 abc	6.8 b-e	6.3 efg	6.3 e-h	5.8 ijk	5.8 fg	4.3 g-j
Daconil Action[x]	3.5 fl oz	14-d	7.0 a-d	6.0 efg	5.5 gh	5.5 gh	5.5 jkl	6.0 efg	6.0 cd
Briskway[x]	0.5 fl oz	14-d	6.3 d	6.8 b-e	7.0 b-e	7.3 cde	7.0 d-g	8.0 b	7.0 ab
+Daconil Action	3.5 fl oz								
+Primo MAXX	0.125 fl oz								
Velista	0.3 oz	14-d	7.3 abc	7.0 a-e	6.3 efg	5.8 gh	6.3 g-j	6.8 de	6.3 bc
+Daconil Ultrex	3.25 oz								
Velista	0.3 oz	14-d	7.3 abc	7.0 a-e	6.8 c-f	7.0 def	7.3 c-f	6.8 de	5.0 efg
+Chipco Signature	4.0 oz								
Velista	0.3 oz	14-d	7.0 a-d	6.3 def	5.8 fgh	6.3 e-h	6.5 f-i	5.8 fg	4.5 f-i
+Medallion	0.5 oz								
Velista	0.3 oz	14-d	7.8 a	7.5 abc	6.5 d-g	6.3 e-h	6.8 e-h	6.3 d-g	4.8 fgh
+Endorse	4.0 oz								
DuPont Program	[z]	Pgm	6.8 bcd	7.3 a-d	7.8 abc	7.8 bcd	7.8 bcd	7.8 bc	6.5 bc
Velista	0.3 oz	14-d	7.5 ab	6.5 c-f	6.5 d-g	6.3 e-h	7.3 c-f	4.8 hi	4.0 h-k
Velista	0.5 oz	14-d	7.3 abc	6.8 b-e	6.5 d-g	6.5 efg	6.8 e-h	6.3 d-g	4.3 g-j
Velista[x]	0.5 oz	14-d	7.0 a-d	6.5 c-f	6.0 e-h	5.5 gh	6.5 f-i	5.5 gh	4.0 h-k
Daconil Ultrex	3.25 oz	14-d	6.5 cd	5.5 fg	5.0 h	5.5 gh	6.3 g-j	6.3 d-g	6.0 cd
Daconil WeatherStik	2.0 fl oz	7-d	7.3 abc	6.3 def	5.5 gh	6.0 fgh	6.5 f-i	7.0 cd	5.3 def
Daconil WeatherStik	3.6 fl oz	14-d	6.8 bcd	6.3 def	5.5 gh	5.5 gh	6.0 h-k	5.8 fg	5.0 efg
Plant Food Program 1	[z]	Pgm	7.8 a	7.5 abc	8.0 ab	8.0 a-d	7.5 b-e	4.8 hi	4.3 g-j
Plant Food Program 2	[z]	Pgm	7.8 a	8.0 a	8.8 a	8.5 ab	8.3 ab	9.0 a	5.8 cde
Untreated Check			6.8 bcd	5.0 g	5.0 h	4.0 j	2.8 m	2.3 j	2.0 m
ANOVA: Treatment (P > F)			0.0073	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		7-d	4	4	5	4	6	7	33
		14-d	11	12	12	11	6	14	33

[z] See Table 5 for program details.

[y] Treatments were applied on a 7- or 14-d interval from 17 May through 9 Aug.

[x] Select treatments applied with a carrier volume of 1.0 gal 1000ft^{-2}; all other treatments applied in 2.0 gal 1000 ft^{-2}.

[w] Briskway and Daconil Action were alternated every 14-d. Briskway was applied on 17 May, 14 Jun, 12 Jul and 9 Aug. Daconil Action was applied on 31 May, 28 Jun, and 25 Jul.

[v] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test ($\alpha = 0.05$).

Table 3. Phytotoxicity of annual bluegrass putting green turf treated preventively with fungicides at the Plant Science Research Facility, Storrs, CT during 2012.

Treatment Rate per 1000 ft^2	Int	Phytotoxicity					
		28 May	11 Jun	26 Jun	9 Jul	18 Jul	9 Aug
		----------------------- 0-5; 2=maximum acceptable -----------------------					
Briskway .... 0.62 fl oz -Daconil Action........ 3.5 fl oz	14-d[w]	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Briskway .... 0.5 fl oz -Daconil Action........ 3.5 fl oz	14-d[w]	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
UC12-1.................. 0.22 fl oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
UC12-1.................. 0.42 fl oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
UC12-2.................... 1.0 fl oz	14-d	0.5 ab	0.0	2.8 a	4.0 a	3.5 a	0.8 a
UC12-5.................... 0.6 fl oz	14-d	0.0 c	0.0	1.5 db	3.3 b	3.0 b	1.0 a
Briskway .... 0.62 fl oz +Daconil Action....... 3.5 fl oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.8 c	0.0 b
Briskway .... 0.5 fl oz +Daconil Action....... 3.5 fl oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.3 d	0.0 b
Syngenta Program .... [z]	Pgm	0.8 a	0.0	0.5 cd	0.5 c	0.0 d	0.0 b
Briskway .... 0.5 fl oz +Daconil Action....... 3.5 fl oz +Primo MAXX .... 0.125 fl oz	14-d	0.8 a	0.0	0.3 d	0.0 d	0.3 d	0.0 b
Daconil Action .... 3.5 fl oz +Appear .... 6.0 fl oz +Primo MAXX .... 0.125 fl oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Daconil Action .... 2.0 fl oz	7-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Daconil Action .... 3.5 fl oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
EXC948 .... 3.6 fl oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Daconil Action[x]........ 3.5 fl oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Briskway[x]................ 0.5 fl oz +Daconil Action....... 3.5 fl oz +Primo MAXX .... 0.125 fl oz	14-d	0.5 ab	0.0	0.3 d	0.0 d	1.0 c	0.0 b
Velista ....0.3 oz +Daconil Ultrex ....3.25 oz	14-d	0.3 bc	0.0	0.0 d	0.0 d	0.0 d	0.3 b
Velista ....0.3 oz +Chipco Signature ....4.0 oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Velista ....0.3 oz +Medallion...................0.5 oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Velista ....0.3 oz +Endorse ....4.0 oz	14-d	0.0 c	0.0	0.3 d	0.0 d	0.0 d	0.0 b
DuPont Program.................. [z]	Pgm	0.8 a	0.0	1.0 bc	0.0 d	0.0 d	0.0 b
Velista ....0.3 oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Velista ....0.5 oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Velista[x]........................0.5 oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Daconil Ultrex...........3.25 oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Daconil WeatherStik 2.0 fl oz	7-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Daconil WeatherStik 3.6 fl oz	14-d	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Plant Food Program 1 .... [z]	Pgm	0.3 bc	0.0	0.0 d	0.8 c	0.0 d	0.0 b
Plant Food Program 2 .... [z]	Pgm	0.0 c	0.0	0.0 d	0.0 d	0.0 d	0.0 b
Untreated Check		0.5 ab	0.0	0.0 d	0.0 d	0.0 d	0.3 b
ANOVA: Treatment (P > F)		0.0001	1.000	0.0001	0.0001	0.0001	0.0001
Days after treatment	7-d	4	4	5	4	6	7
	14-d	11	12	12	11	6	14

[z] See table 5 for program details.
[y] Treatments were applied on a 7- or 14-d interval from 17 May through 9 Aug.
[x] Select treatments applied with a carrier volume of 1.0 gal 1000ft^{-2}; all other treatments applied in 2.0 gal 1000 ft^{-2}.
[w] Briskway and Daconil Action were alternated every 14-d. Briskway was applied on 17 May, 14 Jun, 12 Jul and 9 Aug. Daconil Action was applied on 31 May, 28 Jun, and 25 Jul.
[v] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test (α = 0.05).

Table 4. NDVI rating on annual bluegrass putting green turf treated preventively with fungicides at the Plant Science Research Facility, Storrs, CT during 2012.

Treatment	Rate per 1000 ft^2	Int	28 May	14 Jun	21 Jun	28 Jun	12 Jul	31 Jul	8 Aug
			NDVI						
			canopy reflectance index						
Briskway -Daconil Action	0.62 fl oz 3.5 fl oz	14-d[w]	0.792 b-f[v]	0.769 c-k	0.761 b-i	0.767 e-i	0.765 e-h	0.777 c-g	0.766 f-i
Briskway -Daconil Action	0.5 fl oz 3.5 fl oz	14-d[w]	0.797 bcd	0.778 b-e	0.769 bcd	0.775 c-f	0.771 d-g	0.777 c-g	0.784 b-g
UC12-1	0.22 fl oz	14-d	0.796 bcd	0.769 c-k	0.760 c-i	0.760 hij	0.763 e-h	0.730 h	0.677 j
UC12-1	0.42 fl oz	14-d	0.787 b-f	0.764 f-l	0.759 c-i	0.763 f-j	0.770 d-g	0.774 efg	0.757 i
UC12-2	1.0 fl oz	14-d	0.792 b-f	0.772 c-i	0.775 b	0.746 k	0.754 h	0.769 g	0.764 hi
UC12-5	0.6 fl oz	14-d	0.788 b-f	0.768 d-l	0.762 b-g	0.751 jk	0.761 fgh	0.782 b-g	0.783 b-h
Briskway +Daconil Action	0.62 fl oz 3.5 fl oz	14-d	0.792 b-f	0.776 b-f	0.762 b-g	0.770 e-i	0.774 c-g	0.788 a-g	0.785 b-f
Briskway +Daconil Action	0.5 fl oz 3.5 fl oz	14-d	0.792 b-f	0.774 b-g	0.761 b-i	0.774 c-g	0.783 a-d	0.785 a-g	0.800 ab
Syngenta Program	[z]	Pgm	0.787 b-f	0.779 bcd	0.768 b-e	0.780 b-e	0.796 a	0.793 a-e	0.807 a
Briskway +Daconil Action +Primo MAXX	0.5 fl oz 3.5 fl oz 0.125 fl oz	14-d	0.787 b-f	0.785 ab	0.770 bc	0.787 abc	0.790 ab	0.791 a-f	0.799 abc
Daconil Action +Appear +Primo MAXX	3.5 fl oz 6.0 fl oz 0.125 fl oz	14-d	0.801 bc	0.774 b-h	0.770 bc	0.772 d-h	0.788 abc	0.782 b-g	0.795 a-d
Daconil Action	2.0 fl oz	7-d	0.778 f	0.760 jkl	0.752 ghi	0.764 f-j	0.764 e-h	0.780 b-g	0.776 d-i
Daconil Action	3.5 fl oz	14-d	0.780 ef	0.762 g-l	0.747 i	0.763 f-j	0.769 d-h	0.772 fg	0.783 b-h
EXC948	3.6 fl oz	14-d	0.790 b-f	0.772 c-j	0.766 b-g	0.773 c-h	0.775 b-g	0.779 b-g	0.779 c-h
Daconil Action[x]	3.5 fl oz	14-d	0.786 b-f	0.759 kl	0.754 e-i	0.769 e-i	0.767 e-h	0.780 b-g	0.782 b-h
Briskway[x] +Daconil Action +Primo MAXX	0.5 fl oz 3.5 fl oz 0.125 fl oz	14-d	0.784 def	0.780 bc	0.766 b-g	0.783 a-d	0.790 ab	0.788 a-g	0.799 abc
Velista +Daconil Ultrex	0.3 oz 3.25 oz	14-d	0.793 b-f	0.771 c-k	0.755 d-i	0.762 f-j	0.777 b-e	0.783 b-g	0.782 b-h
Velista +Chipco Signature	0.3 oz 4.0 oz	14-d	0.788 b-f	0.767 e-l	0.762 b-g	0.766 e-i	0.771 d-g	0.792 a-e	0.784 b-g
Velista +Medallion	0.3 oz 0.5 oz	14-d	0.793 b-f	0.770 c-k	0.761 b-h	0.758 ijk	0.767 e-h	0.798 ab	0.791 a-d
Velista +Endorse	0.3 oz 4.0 oz	14-d	0.799 bcd	0.773 b-h	0.762 b-g	0.761 g-j	0.770 d-g	0.796 a-d	0.784 b-h
DuPont Program	[z]	Pgm	0.786 c-f	0.774 b-h	0.767 b-f	0.775 c-f	0.787 abc	0.794 a-e	0.789 a-e
Velista	0.3 oz	14-d	0.800 bcd	0.773 b-h	0.762 b-g	0.770 d-i	0.776 b-f	0.794 a-e	0.780 b-h
Velista	0.5 oz	14-d	0.799 bcd	0.774 b-g	0.761 b-i	0.765 f-i	0.770 d-g	0.797 abc	0.785 b-f
Velista[x]	0.5 oz	14-d	0.795 b-e	0.766 f-l	0.759 c-i	0.760 hij	0.760 gh	0.794 a-e	0.764 ghi
Daconil Ultrex	3.25 oz	14-d	0.784 def	0.761 i-l	0.748 hi	0.766 e-i	0.775 b-g	0.776 d-g	0.784 b-g
Daconil WeatherStik	2.0 fl oz	7-d	0.789 b-f	0.768 d-l	0.762 b-g	0.765 f-i	0.775 b-g	0.785 a-g	0.784 b-g
Daconil WeatherStik	3.6 fl oz	14-d	0.787 b-f	0.762 h-l	0.753 f-i	0.766 f-i	0.767 d-h	0.786 a-g	0.789 a-e
Plant Food Program 1	[z]	Pgm	0.802 b	0.781 bc	0.790 a	0.791 ab	0.783 a-d	0.785 a-g	0.770 e-i
Plant Food Program 2	[z]	Pgm	0.828 a	0.794 a	0.795 a	0.797 a	0.794 a	0.804 a	0.792 a-d
Untreated Check			0.793 b-f	0.756 l	0.753 f-i	0.761 g-j	0.712 i	0.695 i	0.659 j
ANOVA: Treatment ($P > F$)			0.0005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		7-d	4	7	7	7	7	6	6
		14-d	11	14	7	14	14	6	14

[z] See table 5 for program details.

[y] Treatments were applied on a 7- or 14-d interval from 17 May through 9 Aug.

[x] Select treatments applied with a carrier volume of 1.0 gal 1000ft^{-2}; all other treatments applied in 2.0 gal 1000 ft^{-2}.

[w] Briskway and Daconil Action were alternated every 14-d. Briskway was applied on 17 May, 14 Jun, 12 Jul and 9 Aug. Daconil Action was applied on 31 May, 28 Jun, and 25 Jul.

[v] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least [v] significant difference test ($\alpha = 0.05$).

Table 5. Anthracnose fungicide programs evaluated on an annual bluegrass putting green turf at the Plant Science Research and Education Facility in Storrs, CT during 2012.

Application Date	Syngenta Program		DuPont Program		Plant Food Program 1 [z]		Plant Food Program 2 [z]	
	Treatment	Rate 1000 ft^{-2}	Treatment	Rate 1000 ft^{-2}	Treatment	Rate 1000 ft^{-2}	Treatment	Rate 1000 ft^{-2}
17 May	Headway	2.25 fl oz	Chipco Signature	4.0 oz	16-2-7, 25% SRN	6.0 fl oz	16-2-7, 25% SRN	6.0 fl oz
	Daconil Action	3.5 fl oz	QP Tebuconazole	0.6 fl oz	Phosphite 30	3.0 fl oz	Phosphite 30	3.0 fl oz
	Appear	6.0 fl oz	Primo MAXX	0.125 fl oz	Impulse	6.0 fl oz	Impulse	6.0 fl oz
	Primo MAXX	0.125 fl oz					Flo Thru	3.0 fl oz
							Daconil WeatherStik	0.9 fl oz
31 May	Appear	6.0 fl oz	Chipco Signature	4.0 oz				
	Daconil Action	3.5 fl oz	Velista	0.5 oz				
	Medallion	0.33 oz	Primo MAXX	0.125 fl oz				
	Primo MAXX	0.125 fl oz						
14 Jun	Headway	2.25 fl oz	Chipco Signature	4.0 oz				
	Daconil Action	3.5 fl oz	Daconil Ultrex	3.25 oz				
	Appear	6.0 fl oz	Primo MAXX	0.125 fl oz				
	Secure	0.5 fl oz						
	Primo MAXX	0.125 fl oz						
28 Jun	Appear	6.0 fl oz	Chipco Signature	4.0 oz				
	Daconil Action	3.5 fl oz	Velista	0.5 oz				
	Medallion	0.33 oz	Primo MAXX	0.125 fl oz				
	Secure	0.5 fl oz						
	Primo MAXX	0.125 fl oz						
12 Jul	Appear	6.0 fl oz	Chipco Signature	4.0 oz				
	Daconil Action	3.5 fl oz	Daconil Ultrex	3.25 oz				
	Secure	0.5 fl oz	Primo MAXX	0.125 fl oz				
	Briskway	0.5 fl oz						
	Primo MAXX	0.125 fl oz						
25 Jul	Appear	6.0 fl oz	Chipco Signature	4.0 oz				
	Daconil Action	3.5 fl oz	Velista	0.5 oz				
	Briskway	0.5 fl oz	Primo MAXX	0.125 fl oz				
	Primo MAXX	0.125 fl oz						
9 Aug	Appear	6.0 fl oz	Velista	0.5 oz				
	Daconil Action	3.5 fl oz	Daconil Ultrex	3.25 oz				
	Briskway	0.5 fl oz	Primo MAXX	0.125 fl oz				
	Primo MAXX	0.125 fl oz						

[z] Treatments applied every 7-d from 17 May through 9 Aug.

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PREVENTIVE BROWN PATCH CONTROL WITH VARIOUS FUNGICIDES ON COLONIAL BENTGRASS FAIRWAY TURF, 2012

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INTRODUCTION

Brown patch (caused by *Rhizoctonia solani*) commonly affects high-maintenance turfgrasses. Symptoms appear as blighted patches (4-12 inch diam.) with a thin margin of dark, water-soaked plants, or "smoke ring," at the leading edge of the patch. This disease is particularly severe on colonial bentgrass fairway turf. Avoiding excessive nitrogen fertility and minimizing leaf wetness period are effective practices to reduce the incidence and severity of brown patch. However, repeat fungicide applications may be required to control the disease. Over the past few years, systemic fungicides have become increasingly available in granular formulations. Traditionally, granular fungicide formulations have provided less effective control of foliar diseases due to their reduced coverage of the turf canopy compared to spray applications. However, newer technology has developed prills which rapidly breakdown in the presence of water, improving dispersion of the fungicide in the lower turf canopy. The objective of this trial was to evaluate the efficacy of currently available and experimental fungicides, applied with liquid or granular carriers, for preventative brown patch control in fairway turf.

MATERIALS & METHODS

A field study was conducted on an 'Alister' colonial bentgrass (*Agrostis capillaris*) fairway turf grown on a Paxton fine sandy loam at the Plant Science Research and Education Facility in Storrs, CT. Turf was mowed three times a week at 0.5 inches and the area was irrigated three times a week at 1800 hrs to extend leaf wetness period. Nitrogen was applied at 1.0 lb N 1000 ft^{-2} on 16 June and 0.25 lbs N 1000 ft^{-2} on 30 June and 14 July as urea to encourage disease development.

Treatments consisted of currently available fungicides applied individually or in combination at either 14-d or 21-d intervals. Initial applications were made on 12 June. Spray treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI9504E flat fan nozzle calibrated to deliver 1 gal 1000-ft^{-2} at 40 psi. Granular treatments were applied by hand using a shaker jar. Immediately following application 0.1 inch of irrigation was applied to individual plots receiving granular treatments with a watering can. Plots measured 3 x 6 ft and were arranged in a randomized complete block design with four replications.

Brown patch was assessed visually as a percentage of the plot area blighted by *R. solani*. Turf quality was visually assessed on a 1 to 9 scale; where 9 represented the best quality turf and 6 was the minimum acceptable level. Phytotoxicity was visually assessed on a 0-5 scale; where 0 represented no phytotoxicity observed and 2 was the maximum acceptable rating. Data were subjected to an analysis of variance and means separated using Fisher's protected least significant difference test.

RESULTS

Brown patch pressure was low during the trial, with maximum disease in untreated plots reaching only 28% (Table 1). Most treatments provided excellent brown patch control under the limited disease pressure. Banner MAXX (1.0 oz) was slightly less effective compared to other treatments, but still provided good control. Turf quality was good among all treatments, and no phytotoxicity was observed (Table 2).

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Table 1. Brown patch severity on ‘Alister’ colonial bentgrass fairway turf treated preventively with various fungicides at the Plant Science Research Facility in Storrs, CT during 2012.

			Brown Patch				
Treatment	Rate per $1000ft^{-2}$	Int.[y]	13 Jul	19 Jul	29-Jul	9-Aug	23 Aug
			---------------- % plot area blighted ----------------				
Contend	0.96 fl oz	14-d	0.0 c[z]	0.0 b	0.0 c	0.3 b	0.0 b
Runway	0.51 fl oz	14-d	0.0 c	0.0 b	0.3 bc	0.0 b	0.5 b
Velista	0.3 oz	14-d	0.0 c	0.0 b	0.0 c	0.0 b	0.0 b
+Daconil Ultrex	3.25 oz						
Velista	0.3 oz	14-d	0.0 c	0.0 b	0.0 c	0.0 b	0.0 b
Velista	0.3 oz	21-d	0.0 c	0.0 b	0.0 c	0.0 b	0.0 b
Velista	0.5 oz	14-d	0.0 c	0.0 b	0.0 c	0.0 b	0.0 b
Velista	0.5 oz	21-d	0.0 c	0.0 b	0.0 c	0.0 b	0.3 b
Disarm G[x]	73.6 oz	21-d	0.0 c	0.0 b	0.0 c	0.0 b	0.0 b
Pillar G[x]	48.0 oz	21-d	0.0 c	0.0 b	0.0 c	0.0 b	0.3 b
Heritage G[x]	64.0 oz	21-d	0.0 c	0.0 b	0.5 bc	0.0 b	0.5 b
Insignia SC	0.7 fl oz	21-d	0.0 c	0.0 b	0.0 c	0.0 b	0.0 b
+Trinity	0.972 fl oz						
Heritage TL	2.0 fl oz	21-d	0.0 c	0.0 b	0.0 c	0.0 b	0.0 b
Disarm 480SC	0.363 fl oz	21-d	0.0 c	0.0 b	0.0 c	0.0 b	0.3 b
Compass	0.15 fl oz	21-d	0.0 c	0.0 b	0.5 bc	0.0 b	0.0 b
Banner MAXX	1.0 fl oz	14-d	0.4 bc	1.0 b	1.3 b	1.8 b	3.8 b
QP Tebuconazole	0.6 fl oz	14-d	0.0 c	0.0 b	0.0 c	0.0 b	0.3 b
Trinity	0.75 fl oz	14-d	0.0 c	0.0 b	0.0 c	0.0 b	0.0 b
QP Myclobutanil	1.2 fl oz	14-d	0.0 c	0.0 b	0.3 bc	0.0 b	0.5 b
Tourney	0.28 oz	14-d	1.5 b	0.4 b	0.0 c	0.0 b	0.8 b
Untreated			5.3 a	10.3 a	26.3 a	16.3 a	28.8 a
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		14 d	2	8	4	15	29
		21 d	10	16	4	15	29

[x] Individual plots received 0.1 inches of irrigation with a watering can immediately after fungicide application

[y] All treatments were initiated on 12 Jun. Subsequent 14 d treatments were applied on 27 Jun, 11 Jul and 25 Jul; 21 d treatments were applied on 3 Jul and 25 Jul.

[z] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher’s protected least significant difference test ($\alpha = 0.05$).

Table 2. Turf quality and phytotoxicity of an 'Alister' colonial bentgrass fairway turf treated preventively with various fungicides at the Plant Science Research Facility in Storrs, CT during 2012.

Treatment	Rate per $1000ft^{-2}$	Int.[y]	Turf Quality				Phytotoxicity	
			20 Jun	13 Jul	9-Aug	23 Aug	20 Jun	13 Jul
			--------------1-9; 6=min--------------				-0-5; 2=max-	
Contend	0.96 fl oz	14-d	8.0	7.0 cde[z]	7.0 cd	7.3 abc	0.0	0.0
Runway	0.51 fl oz	14-d	8.3	7.0 cde	7.0 cd	7.3 abc	0.0	0.0
Velista	0.3 oz	14-d	8.5	8.3 a	8.3 a	7.8 a	0.0	0.0
+Daconil Ultrex	3.25 oz							
Velista	0.3 oz	14-d	8.0	8.0 ab	7.8 abc	7.5 ab	0.0	0.0
Velista	0.3 oz	21-d	8.0	7.3 bcd	7.3 bcd	7.8 a	0.0	0.0
Velista	0.5 oz	14-d	8.5	8.0 ab	7.8 abc	7.8 a	0.0	0.0
Velista	0.5 oz	21-d	8.5	8.3 a	8.0 ab	7.5 ab	0.0	0.0
Disarm G[x]	73.6 oz	21-d	8.0	7.5 a-d	7.0 cd	6.8 cd	0.0	0.0
Pillar G[x]	48.0 oz	21-d	8.3	7.3 bcd	7.5 abc	7.0 bcd	0.0	0.0
Heritage G[x]	64.0 oz	21-d	8.0	7.5 a-d	7.8 abc	7.3 abc	0.0	0.0
Insignia SC	0.7 fl oz	21-d	8.0	7.3 bcd	7.0 cd	7.0 bcd	0.0	0.0
+Trinity	0.972 fl oz							
Heritage TL	2.0 fl oz	21-d	8.8	7.8 abc	7.5 abc	7.0 bcd	0.0	0.0
Disarm 480SC	0.363 fl oz	21-d	8.0	7.3 bcd	7.0 cd	7.3 abc	0.0	0.0
Compass	0.15 fl oz	21-d	8.5	7.5 a-d	7.5 abc	7.5 ab	0.0	0.0
Banner MAXX	1.0 fl oz	14-d	8.3	7.8 abc	6.5 d	6.5 d	0.0	0.0
QP Tebuconazole	0.6 fl oz	14-d	8.0	7.8 abc	7.8 abc	6.8 cd	0.0	0.0
Trinity	0.75 fl oz	14-d	8.3	7.3 bcd	7.5 abc	7.0 bcd	0.0	0.0
QP Myclobutanil	1.2 fl oz	14-d	8.3	7.5 a-d	7.0 cd	6.8 cd	0.0	0.0
Tourney	0.28 oz	14-d	8.3	6.8 de	7.3 bcd	7.0 bcd	0.0	0.0
Untreated			8.0	6.3 e	5.0 e	5.8 a	0.0	0.0
ANOVA: Treatment (P > F)			0.4665	0.0018	0.0001	0.0002	1.0000	1.0000
Days after treatment		14-d	8	2	15	29	8	15
		21-d	8	10	37	51	8	37

[x] Individual plots received 0.1 inches of irrigation with a watering can immediately after fungicide application

[y] All treatments were initiated on 12 Jun. Subsequent 14 d treatments were applied on 27 Jun, 11 Jul and 25 Jul; 21 d treatments were applied on 3 Jul and 25 Jul.

[z] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test ($\alpha = 0.05$).

PREVENTIVE DOLLAR SPOT CONTROL IN CREEPING BENTGRASS FAIRWAY TURF WITH RECENTLY REGISTERED AND EXISTING FUNGICIDES, 2012

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INTRODUCTION

Dollar spot (caused by *Sclerotinia homoeocarpa*) is one of the most common diseases affecting golf course fairways throughout New England from May to October. Symptoms of the disease appear small (1 to 2 inch diam.) light tan colored spots of desiccated turf, that eventually coalesce during prolonged favorable conditions. Individual leaf symptoms initiate as a light tan lesion extending the width the leaf blade bordered by a dark reddish-brown margin. On humid mornings, white filamentous mycelium may be observed in the spots, and on infected leaf blades.

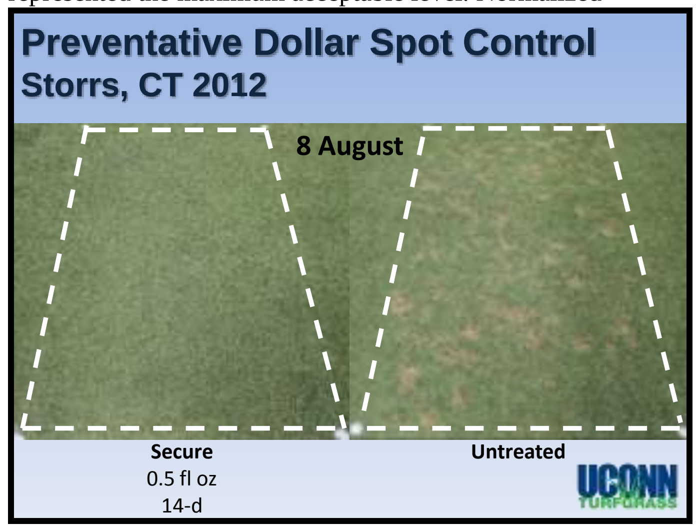
An integrated approach employing cultural practices and preventive fungicide applications is typically required to provide season-long control of this disease. Several new fungicides have recently become available, or are anticipated to be released for use on turfgrass in the upcoming year. The objective of this study was to evaluate the efficacy of new turfgrass fungicides for preventive dollar spot control on creeping bentgrass fairway turf.

MATERIALS & METHODS

A field study was conducted on a 'Putter' creeping bentgrass (*Agrostis stolonifera*) turf grown on a Paxton fine sandy loam at the Plant Science Research and Education Facility in Storrs, CT. Turf was mowed three days wk^{-1} at a bench setting of 0.5-inches. Nitrogen applied at 0.25 lbs N 1000 ft^{-2}as urea each month from April to August. Carbaryl (Sevin) was applied on 21 July and 25 August for the control of cutworms. Overhead irrigation was applied every other night to prolong leaf wetness period and enhance disease.

Treatments consisted of currently available and experimental fungicides applied individually or as combination and programmatic treatments every 14-, 21-, or 28-d. Initial treatments were applied on 18 May prior to disease developing in the trial area. Subsequent applications were made at the specified intervals (dates listed in Tables 1 – 3) until 8 August. All treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 1 gal 1000-ft^{-2} at 40 psi. Plots measured 3 x 6 ft and were arranged in a randomized complete block design with four replications.

Dollar spot was assessed as a count of individual disease foci within each plot from 23 May to 7 September. Turf quality was visually assessed on a 1 to 9 scale; where 9 represented the best quality turf and 6 was the minimum acceptable level. Phytotoxicity was also assessed visually on a 0 to 5 scale; where 0 was equal to no discoloration and 2 represented the maximum acceptable level. Normalized difference vegetative index (NDVI) was determined using the FieldScout TCM 500 NDVI meter (Spectrum Technologies, Inc.). Ten readings were taken per plot with the mean used for data analysis. Data were subjected to an analysis of variance and means were separated using Fisher's protected least significant difference test.



RESULTS AND DISCUSSION

Dollar Spot

Dollar spot pressure was moderate to high throughout the trial during 2012, although conditions were particularly conducive in late-May and late-July. Initial symptoms developed throughout the trial on 23 May, 5 days after the initial application (Table 1a & 1b). All treatments failed to provide complete dollar spot control at this time, although disease was not considered to be unacceptable in any treatment on this date. No significant treatment effects were apparent at this time. Control failures among all treatments on this date may be due to extremely favorable conditions preceding this date. It is also possible that asymptomatic infection may have occurred before the initial preventive applications (18 May), and preventive rates applied in this trial were too low to provide complete curative control.

Disease incidence was reduced 9 days later (1 June) in nearly all treatments, except UC12-8, Velista (applied alone) Insignia, and the Plant Food program. Several treatments provided excellent control (i.e., ≤ 5 dollar spot foci) on this date: Secure + Contend, Xzemplar (0.211 fl oz), Lexicon Intrinsic, Honor Intrinsic, Encartis, Interface, and tank mixes with QP Enclave. Many of these treatments are new fungicides that should be available in Fall 2012 or 2013. Similar treatment responses were observed throughout June. By 7 July, all treatments provided excellent dollar spot control except UC12-8, Encartis (28-d), Insignia, and Curalan (0.66 oz.).

Dollar spot pressure increased during late-July and early-August. Many treatments continued to provide excellent dollar spot control during this time; however, several important differences became apparent by 9 August (Table 1a & 1b). Secure, a new contact fungicide, applied on a 14-d interval provided excellent dollar spot control, although this material applied every 21-d alone or tank-mixed with Heritage TL or Primo MAXX did not provide acceptable control under increased disease pressure. Encartis is a new pre-mix of boscalid and chlorothalonil which provided good (5-10 dollar spot foci) dollar spot control on a 21-d interval, but was unacceptable when applied at the same rate every 28-d. Velista, a new carboximide fungicide, provided excellent control when applied alone every 14-d at 0.5 oz 1000 ft^{-2} or at 0.3 oz 1000 ft^{-2} tank mixed with Daconil Ultrex; whereas Velista applied every 21-d did not provide acceptable dollar spot control under increased disease pressure.

Turf Quality, Phytotoxicity, and NDVI

Turf quality was generally good among all treatments in the trial (Table 2a & 2b). Reductions in quality were associated with increased dollar spot incidence. Improved quality was consistently observed in turf treated with Interface and tank mixes containing QP Enclave and Foursome. These treatments contain a green pigment that improves quality by enhancing turf color. Secure (14-d) also had improved turf quality during the latter half of the trial.

No phytotoxicity was observed in any treatment throughout the study (Table 3a & 3b).

Normalized difference vegetative index values were consistently highest for turf treated with Secure, Velista, Xzemplar (14-d), and Encartis (28-d) (Table 3a & 3b).

CONCLUSIONS

New fungicides being introduced to the turfgrass market should provide superintendents additional options for dollar spot control in addition to effective materials currently available. However, data from the current trial suggests that the application rate and interval of some of these materials are important factors influencing dollar spot control, particularly under high disease pressure and curative control.

The emergence of dollar spot early in this trial demonstrated that fungicides applied at preventive rates may not provide complete disease control during very favorable environmental conditions. Moreover, once disease symptoms are apparent, increased rates or shorter intervals are often required to control disease and reduce recovery time.

Table 1a. Dollar spot incidence in a ‘Putter’ creeping bentgrass fairway turf treated preventively with fungicides at the Plant Science Research and Education Facility in Storrs, CT during 2012.

			Dollar Spot Incidence											
Treatment	Rate per 1000 ft^2	Int.[y]	23 May	1 Jun	7 Jun	18 Jun	27 Jun	7 Jul	18 Jul	27 Jul	9 Aug	17 Aug	23 Aug	7 Sep
			number of foci per $18ft^2$											
Secure	0.5 fl oz	14-d	17.0	7.8 e-h[x]	4.5 g-j	2.8 g	0.3 e	0.3 d	0.0 g	0.3 e	0.5 i	0.0 d	0.0 c	1.8 de
Secure	0.5 fl oz	21-d	19.3	9.3 e-h	7.8 f-j	1.3 g	3.5 de	0.0 d	27.5 d	9.0 de	45.3 de	0.3 cd	0.0 c	0.8 e
UC12-8	2.0 fl oz	14-d	15.3	16.5 c-g	12.5 c-h	34.0 cd	38.5 b	15.5 bc	12.5 ef	67.0 b	57.5 d	6.8 c	4.5 c	14.3 cd
Secure	0.5 fl oz	21-d	13.5	6.3 fgh	4.0 g-j	0.5 g	0.8 e	0.0 d	4.5 efg	1.8 e	12.0 ghi	0.8 cd	0.5 c	2.5 de
+Heritage TL	1.0 fl oz													
Secure	0.5 fl oz	21-d	17.3	5.8 gh	3.3 g-j	0.5 g	0.0 e	0.0 d	0.0 g	0.0 e	0.8 i	0.5 cd	0.0 c	0.8 e
+UC12-7	0.236 fl oz													
Contend	0.96 fl oz	21-d	20.5	8.8 e-h	10.8 d-i	4.0 g	4.8 de	0.0 d	0.3 g	0.3 e	0.5 i	0.0 d	0.0 c	1.8 de
Secure	0.5 fl oz	21-d	8.3	2.5 h	2.5 hij	0.5 g	0.0 e	0.0 d	0.0 g	0.0 e	0.0 i	0.0 d	0.3 c	0.3 e
+Contend	0.96 fl oz													
Syngenta Program	[z]	14-d	9.3	5.8 gh	5.8 g-j	9.3 fg	2.3 de	0.0 d	0.0 g	0.0 e	0.5 i	2.3 cd	1.3 c	0.0 e
-Contend	0.6 fl oz													
-Daconil Action	1.6 fl oz													
-Secure	0.5 fl oz													
-Appear	3.0 fl oz													
Secure	0.5 fl oz	21-d	22.3	9.3 e-h	8.5 e-j	1.5 g	0.8 e	0.3 d	8.0 efg	16.5 d	30.3 ef	0.3 cd	1.0 c	0.8 e
+Primo MAXX	0.2 fl oz													
Xzemplar	0.157 fl oz	14-d	16.3	5.8 gh	4.0 g-j	7.8 g	0.5 e	0.0 d	0.0 g	0.0 e	0.0 i	0.0 d	0.3 c	1.0 e
Xzemplar	0.211 fl oz	21-d	16.8	4.5 h	2.8 hij	0.8 g	0.0 e	0.3 d	0.0 g	0.3 e	0.0 i	0.3 cd	0.3 c	0.3 e
Emerald	0.18 oz	21-d	12.3	8.3 e-h	7.0 f-j	4.5 g	6.5 de	0.8 d	0.0 g	0.5 e	0.0 i	0.0 d	0.0 c	1.0 e
Xzemplar	0.262 fl oz	28-d	17.3	6.5 fgh	3.0 g-j	3.3 g	0.3 e	0.0 d	0.0 g	0.3 e	5.0 ghi	0.0 d	0.3 c	5.3 cde
Lexicon Intrinsic	0.34 fl oz	21-d	12.0	2.3 h	1.0 ij	0.5 g	0.3 e	0.0 d	0.0 g	0.0 e	1.0 i	0.0 d	0.0 c	0.8 e
Honor Intrinsic	0.84 oz	21-d	11.0	3.3 h	3.3 g-j	2.0 g	1.5 de	0.3 d	0.5 fg	0.0 e	1.0 i	0.8 cd	0.0 c	0.3 e
Lexicon Intrinsic	0.472 fl oz	28-d	9.8	1.8 h	1.3 ij	4.3 g	0.0 e	0.0 d	0.0 g	0.0 e	0.5 i	0.0 d	0.0 c	1.3 e
Encartis	3.0 fl oz	28-d	9.8	2.5 h	6.3 f-j	30.8 cd	8.5 de	12.8 c	0.3 g	7.3 de	41.0 de	1.5 cd	0.3 c	1.3 e
Encartis	3.0 fl oz	21-d	12.3	5.5 gh	9.3 e-j	4.5 g	4.8 de	0.0 d	1.8 fg	0.5 e	5.3 ghi	1.0 cd	0.0 c	0.5 e
Xzemplar	0.26 fl oz	21-d	15.5	3.0 h	3.5 g-j	1.0 g	0.0 e	0.0 d	0.0 g	0.3 e	0.0 i	0.0 d	0.0 c	1.0 e
Velista	0.5 oz	21-d	15.3	21.5 cd	18.0 b-e	12.5 efg	14.3 cd	1.0 d	12.5 ef	10.0 de	34.3 ef	0.8 cd	0.8 c	6.5 cde
Velista	0.5 oz	21-d	12.8	8.5 e-h	12.5 c-h	2.0 g	7.5 de	0.3 d	15.3 e	7.3 de	43.8 de	0.5 cd	0.0 c	5.3 cde
+Daconil Weatherstik	3.0 fl oz													
Interface	3.0 fl oz	21-d	14.8	4.3 h	2.8 hij	0.8 g	2.0 de	0.0 d	0.3 g	0.5 e	2.8 i	0.5 cd	0.0 c	6.8 cde
Interface	4.0 fl oz	21-d	6.8	1.3 h	1.3 ij	0.3 g	0.0 e	0.0 d	0.3 g	0.3 e	0.8 i	0.0 d	0.0 c	12.3 cde
Honor	0.83 oz	21-d	17.8	9.8 e-h	7.8 f-j	4.0 g	3.3 de	0.0 d	0.0 g	0.0 e	2.5 i	0.0 d	0.0 c	1.0 e
Insignia	0.9 oz	21-d	17.0	19.0 cde	20.0 bcd	25.8 d	39.3 b	8.0 cd	55.3 c	41.3 c	83.0 c	0.8 cd	0.0 c	1.0 e
Iprodione Pro 2SE	4.0 fl oz	21-d	17.5	9.5 e-h	6.3 f-j	0.8 g	1.5 de	0.3 d	1.5 fg	2.5 e	22.5 fg	1.8 cd	0.8 c	16.8 c

Table continues on next page

Table 1b. Dollar spot incidence in a ‘Putter’ creeping bentgrass fairway turf treated preventively with fungicides at the Plant Science Research and Education Facility in Storrs, CT during 2012.

Treatment	Rate per 1000 ft^2	Int.[y]	Dollar Spot Incidence											
			23 May	1 Jun	7 Jun	18 Jun	27 Jun	7 Jul	18 Jul	27 Jul	9 Aug	17 Aug	23 Aug	7 Sep
			number of foci per 18ft^2											
Velista	0.3 oz	14-d	26.5	11.5 d-h[x]	7.5 f-j	21.3 def	5.5 de	0.0 d	0.5 fg	0.3 e	0.0 i	2.0 cd	1.8 c	1.8 de
+Daconil Ultrex	3.25 oz													
Velista	0.3 oz	14-d	15.0	39.8 b	22.8 b	61.5 b	21.8 c	3.5 d	0.3 g	6.5 de	21.8 fgh	0.3 cd	0.0 c	9.8 cde
Velista	0.5 oz	14-d	11.0	25.0 c	13.0 b-g	43.0 c	11.8 cde	0.5 d	0.0 g	0.8 e	2.5 i	0.5 cd	0.0 c	5.5 cde
QP Enclave	3.0 fl oz	14-d	9.3	2.5 h	1.5 ij	10.5 fg	0.8 e	0.3 d	0.0 g	0.3 e	2.3 i	0.5 cd	0.0 c	3.5 de
+Foursome	0.4 fl oz													
QP Enclave	4.0 fl oz	21-d	6.5	1.8 h	3.8 g-j	1.0 g	1.8 de	2.8 d	0.8 fg	0.0 e	8.8 ghi	0.3 cd	0.0 c	7.8 cde
+Foursome	0.4 fl oz													
QP Enclave	3.0 fl oz	14-d	4.0	1.8 h	0.5 j	3.5 g	0.8 e	0.0 d	0.0 g	0.0 e	0.0 i	0.0 d	1.0 c	3.8 de
+QP Fosetyl-Al	4.0 oz													
+Foursome	0.4 fl oz													
QP Enclave	4.0 fl oz	21-d	8.0	4.8 h	4.3 g-j	1.0 g	1.5 de	0.5 d	1.3 fg	0.5 e	4.5 hi	0.0 d	0.5 c	2.3 de
+QP Fosetyl-Al	4.0 oz													
+Foursome	0.4 fl oz													
Plant Food Program		14-d	13.0	17.3 c-f	16.0 b-f	33.3 cd	10.5 cde	3.5 d	0.0 g	2.5 e	9.8 ghi	0.0 d	0.0 c	7.0 cde
+20-3-3, 25% SRN	6.0 fl oz													
+6 Iron	1.5 fl oz													
+Impulse	3.0 fl oz													
+Banner MAXX	0.5 fl oz													
Curalan	.0.66 oz	21-d	23.5	12.5 d-h	21.8 bc	25.0 de	47.0 b	22.8 b	76.5 b	49.3 c	122.8 b	34.5 b	24.0 b	44.8 b
Untreated Check			14.0	53.0 a	55.8 a	79.5 a	109.0 a	112.5 a	158.5 a	212.0 a	191.5 a	163.0 a	111.5 a	222.8 a
ANOVA: Treatment (P > F)			0.2764	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		14-d	5	1	8	4	13	10	7	2	1	9	15	30
		21-d	5	15	1	8	20	10	21	8	1	9	15	30
		28-d	5	15	22	4	13	23	7	16	1	9	15	30

[z] Applications were made every 14-d. Contend was applied on 18 May and 14 Jun; Secure on 31 May, 27 Jun, 11 Jul, 25 Jul and 8 Aug; Appear on 14 Jun, 27 Jun, 11 Jul, 25 Jul, and 8 Aug. Daconil Action was applied in combination with each treatment on all dates.

[y] All treatments were initiated on 18 May, prior to disease development. Subsequent 14-d treatments were applied on 31 May, 14 Jun, 27 Jun, and 11 Jul, 25 Jul and 8 Aug; 21-d treatments were applied on 6 Jun, 27 Jun, 19 Jul and 8 Aug; 28-d treatments were applied on 14 Jun, 11 Jul and 8 Aug.

[x] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher’s protected least significant difference test ($\alpha = 0.05$).

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Table 2a. Turf quality of a 'Putter' creeping bentgrass fairway turf treated preventively with fungicides at the Plant Science Research and Education Facility in Storrs, CT during 2012.

Treatment	Rate per 1000ft²	Int[y]	Turf Quality 23 May	8 Jun	7 Jul	9 Aug
			1-9;6=min acceptable			
Secure	0.5 fl oz	14-d	6.3	7.3 c-f [x]	8.0 a-d	8.8 a
Secure	0.5 fl oz	21-d	6.8	7.0 d-g	7.3 d-g	4.8 hi
UC12-8	2.0 fl oz	14-d	6.5	7.3 c-f	6.3 hij	4.0 hij
Secure	0.5 fl oz	21-d	6.3	7.0 d-g	7.3 d-g	7.0 d-g
+Heritage TL	1.0 fl oz					
Secure	0.5 fl oz	21-d	6.8	7.5 b-e	7.8 b-e	8.8 a
+UC12-7	0.236 fl oz					
Contend	0.96 fl oz	21-d	6.5	6.5 fgh	6.5 ghi	6.3 g
Secure	0.5 fl oz	21-d	6.8	7.3 c-f	6.3 hij	7.3 c-g
+Contend	0.96 fl oz					
Syngenta Program	[z]	Pgm	6.5	6.8 e-h	7.8 b-e	7.5 b-f
-Contend	0.6 fl oz					
-Daconil Action	1.6 fl oz					
-Secure	0.5 fl oz					
-Appear	3.0 fl oz					
Secure	0.5 fl oz	21-d	6.5	6.8 e-h	7.3 d-g	5.0 h
+Primo MAXX	0.2 fl oz					
Xzemplar	0.157 fl oz	14-d	6.5	7.3 c-f	7.8 b-e	8.0 a-d
Xzemplar	0.211 fl oz	21-d	6.5	7.5 b-e	7.8 b-e	6.8 efg
Emerald	0.18 oz	21-d	6.5	7.0 d-g	7.5 c-f	7.8 a-e
Xzemplar	0.262 fl oz	28-d	6.5	7.8 a-d	7.3 d-g	7.3 c-g
Lexicon Intrinsic	0.34 fl oz	21-d	6.3	7.3 c-f	7.8 b-e	7.5 b-f
Honor Intrinsic	0.84 oz	21-d	6.3	7.0 d-g	8.0 a-d	7.0 d-g
Lexicon Intrinsic	0.472 fl oz	28-d	7.0	7.3 c-f	7.5 c-f	7.0 d-g
Encartis	3.0 fl oz	28-d	6.8	7.3 c-f	6.0 ij	4.8 hi
Encartis	3.0 fl oz	21-d	6.5	6.8 e-h	7.3 d-g	7.0 d-g
Xzemplar	0.26 fl oz	21-d	6.8	7.0 d-g	7.3 d-g	7.5 b-f
Velista	0.5 oz	21-d	6.5	6.3 gh	7.3 d-g	5.0 h
Velista	0.5 oz	21-d	6.8	7.0 d-g	8.0 a-d	4.8 hi
+Daconil Weatherstik	3.0 fl oz					
Interface	3.0 fl oz	21-d	7.0	8.3 ab	8.5 ab	8.0 a-d
Interface	4.0 fl oz	21-d	7.3	8.3 ab	8.3 abc	8.8 a
Honor	0.83 oz	21-d	6.3	6.3 gh	7.5 c-f	7.3 c-g
Insignia	0.9 oz	21-d	6.5	6.3 gh	6.8 f-i	4.0 hij
Iprodione Pro 2SE	4.0 fl oz	21-d	6.3	7.3 c-f	7.0 e-h	6.3 g

Table continues on next page

Table 2a. Turf quality of a 'Putter' creeping bentgrass fairway turf treated preventively with fungicides at the Plant Science Research and Education Facility in Storrs, CT during 2012.

Treatment	Rate per 1000ft^2	Int[y]	Turf Quality			
			23 May	8 Jun	7 Jul	9 Aug
			------------------- 1-9;6=min acceptable -------------------			
Velista	0.3 oz	14-d	6.8	7.3 c-f[x]	7.3 d-g	7.3 c-g
+Daconil Ultrex	3.25 oz					
Velista	0.3 oz	14-d	6.8	6.5 fgh	7.5 c-f	6.3 g
Velista	0.5 oz	14-d	6.8	6.5 fgh	7.8 b-e	7.8 a-e
QP Enclave	3.0 fl oz	14-d	7.0	8.5 a	8.8 a	8.3 abc
+Foursome	0.4 fl oz					
QP Enclave	4.0 fl oz	21-d	7.8	8.0 abc	8.8 a	7.0 d-g
+Foursome	0.4 fl oz					
QP Enclave	3.0 fl oz	14-d	7.3	8.3 ab	8.8 a	8.5 ab
+QP Fosetyl-Al	4.0 oz					
+Foursome	0.4 fl oz					
QP Enclave	4.0 fl oz	21-d	7.5	7.8 a-d	8.5 ab	7.3 c-g
+QP Fosetyl-Al	4.0 oz					
+Foursome	0.4 fl oz					
20-3-3, 25% SRN	6.0 fl oz	14-d	7.0	7.0 d-g	7.3 d-g	6.5 fg
+6 Iron	1.5 fl oz					
+Impulse	3.0 fl oz					
+Banner MAXX	0.5 fl oz					
Curalan	.0.66 oz	21-d	6.5	6.0 h	5.5 j	3.8 ij
Untreated Check			6.3	5.0 i	4.0 k	3.0 j
ANOVA: Treatment (P > F)			0.0757	0.0001	0.0001	0.0001
Days after treatment		14-d	5	9	10	1
		21-d	5	2	10	1
		28-d	5	22	24	1

[z] Applications were made every 14-d. Contend was applied on 18 May and 14 Jun; Secure on 31 May, 27 Jun, 11 Jul, 25 Jul and 8 Aug; Appear on 14 Jun, 27 Jun, 11 Jul, 25 Jul, and 8 Aug. Daconil Action was applied in combination with each treatment on all dates.

[y] All treatments were initiated on 18 May, prior to disease development. Subsequent 14- d treatments were applied on 31 May, 14 Jun, 27 Jun, and 11 Jul, 25 Jul and 8 Aug; 21-d treatments were applied on 6 Jun, 27 Jun, 19 Jul and 8 Aug; 28-d treatments were applied on 14 Jun, 11 Jul and 8 Aug.

[x] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test (α = 0.05).

Table 3a. Phytotoxicity and NDVI of a 'Putter' creeping bentgrass fairway turf treated preventively with fungicides at the Plant Science Research and Education Facility in Storrs, CT during 2012.

Treatment Rate per 1000ft^2	Int.^{y}	Phytotoxicity 23 May	Phytotoxicity 8 Jun	NDVI 18 Jun	NDVI 28 Jun	NDVI 30 Jul	NDVI 17 Aug
		0-5; 2=max acceptable		-------------- canopy reflectance index --------------			
Secure.........................0.5 fl oz	14-d	0.0 b^x	0.0 c	0.762 a-h	0.758 d-n	0.801 a-d	0.785 a-h
Secure.........................0.5 fl oz	21-d	0.0 b	0.0 c	0.762 a-h	0.757 d-n	0.797 a-h	0.784 b-h
UC12-8.......................2.0 fl oz	14-d	0.0 b	0.0 c	0.765 a-g	0.751 j-n	0.786 jk	0.788 a-g
Secure.........................0.5 fl oz	21-d	0.0 b	0.0 c	0.770 a-d	0.764 a-j	0.795 a-j	0.786 a-h
+Heritage TL.............1.0 fl oz							
Secure.........................0.5 fl oz	21-d	0.0 b	0.0 c	0.769 a-e	0.771 abc	0.794 a-j	0.790 a-d
+UC12-7................0.236 fl oz							
Contend ....0.96 fl oz	21-d	0.0 b	0.3 b	0.745 i	0.753 h-n	0.782 k	0.774 j
Secure.........................0.5 fl oz	21-d	0.0 b	0.0 c	0.760 a-i	0.762 c-l	0.788 h-k	0.775 ij
+Contend.................0.96 fl oz							
Syngenta Program ....^{z}	14-d	0.0 b	0.0 c	0.757 b-i	0.754 g-n	0.795 a-j	0.782 d-j
-Contend.....................0.6 fl oz							
-Daconil Action..........1.6 fl oz							
-Secure........................0.5 fl oz							
-Appear.......................3.0 fl oz							
Secure.........................0.5 fl oz	21-d	0.5 a	0.8 a	0.753 e-i	0.775 ab	0.803 a	0.793 a
+Primo MAXX...........0.2 fl oz							
Xzemplar................0.157 fl oz	14-d	0.0 b	0.0 c	0.766 a-g	0.755 f-n	0.798 a-g	0.790 a-e
Xzemplar................0.211 fl oz	21-d	0.0 b	0.0 c	0.757 b-i	0.756 e-n	0.791 e-k	0.781 f-j
Emerald .... 0.18 oz	21-d	0.0 b	0.0 c	0.762 a-h	0.758 d-n	0.791 e-k	0.789 a-e
Xzemplar................0.262 fl oz	28-d	0.0 b	0.0 c	0.752 f-i	0.763 b-k	0.798 a-f	0.787 a-g
Lexicon Intrinsic ......0.34 fl oz	21-d	0.0 b	0.0 c	0.767 a-f	0.747 mno	0.795 a-i	0.775 ij
Honor Intrinsic .... 0.84 oz	21-d	0.0 b	0.0 c	0.767 a-f	0.765 a-i	0.791 e-k	0.784 b-h
Lexicon Intrinsic ....0.472 fl oz	28-d	0.0 b	0.0 c	0.763 a-h	0.763 a-j	0.792 d-j	0.782 d-j
Encartis.......................3.0 fl oz	28-d	0.0 b	0.0 c	0.766 a-g	0.767 a-f	0.802 ab	0.784 c-i
Encartis.......................3.0 fl oz	21-d	0.0 b	0.0 c	0.767 a-f	0.761 c-l	0.797 a-h	0.784 b-h
Xzemplar..................0.26 fl oz	21-d	0.0 b	0.0 c	0.756 c-i	0.752 i-n	0.793 c-j	0.785 a-h
Velista .... 0.5 oz	21-d	0.0 b	0.0 c	0.768 a-f	0.766 a-g	0.796 a-i	0.792 abc
Velista .... 0.5 oz	21-d	0.0 b	0.0 c	0.767 a-f	0.769 a-d	0.799 a-f	0.792 ab
+Daconil Weatherstik.3.0 fl oz							
Interface......................3.0 fl oz	21-d	0.0 b	0.0 c	0.750 ghi	0.749 lmn	0.791 e-k	0.781 e-j
Interface......................4.0 fl oz	21-d	0.0 b	0.0 c	0.764 a-h	0.756 d-n	0.791 e-k	0.784 b-h
Honor .... 0.83 oz	21-d	0.0 b	0.3 b	0.756 c-i	0.756 d-n	0.793 c-j	0.788 a-g
Insignia.......................... 0.9 oz	21-d	0.0 b	0.0 c	0.761 a-h	0.760 c-m	0.790 f-k	0.781 f-j
Iprodione Pro 2SE......4.0 fl oz	21-d	0.0 b	0.0 c	0.748 hi	0.746 no	0.788 ijk	0.786 a-g

Table continues on next page

Table 3b. Phytotoxicity and NDVI of a ‘Putter’ creeping bentgrass fairway turf treated preventively with fungicides at the Plant Science Research and Education Facility in Storrs, CT during 2012.

Treatment	Rate per 1000ft[2]	Int.[y]	Phytotoxicity 23 May	Phytotoxicity 8 Jun	NDVI 18 Jun	NDVI 28 Jun	NDVI 30 Jul	NDVI 17 Aug
			0-5; 2=max acceptable		------------- canopy reflectance index -------------			
Velista	0.3 oz	14-d	0.0 b	0.0 c	0.767 a-f [x]	0.750 k-n	0.800 a-e	0.786 a-h
+Daconil Ultrex	3.25 oz							
Velista	0.3 oz	14-d	0.0 b	0.0 c	0.758 b-i	0.750 k-n	0.796 a-i	0.789 a-f
Velista	0.5 oz	14-d	0.0 b	0.0 c	0.759 b-i	0.768 a-e	0.802 abc	0.790 a-e
QP Enclave	3.0 fl oz	14-d	0.0 b	0.0 c	0.776 a	0.765 a-i	0.793 b-j	0.785 b-h
+Foursome	0.4 fl oz							
QP Enclave	4.0 fl oz	21-d	0.0 b	0.0 c	0.761 a-h	0.767 a-g	0.789 g-k	0.785 b-h
+Foursome	0.4 fl oz							
QP Enclave	3.0 fl oz	14-d	0.0 b	0.0 c	0.771 abc	0.776 a	0.791 e-k	0.780 g-j
+QP Fosetyl-Al	4.0 oz							
+Foursome	0.4 fl oz							
QP Enclave	4.0 fl oz	21-d	0.0 b	0.0 c	0.773 ab	0.761 c-l	0.790 f-k	0.783 d-i
+QP Fosetyl-Al	4.0 oz							
+Foursome	0.4 fl oz							
20-3-3, 25% SRN	6.0 fl oz	14-d	0.0 b	0.0 c	0.760 a-i	0.766 a-h	0.785 jk	0.777 hij
+6 Iron	1.5 fl oz							
+Impulse	3.0 fl oz							
+Banner MAXX	0.5 fl oz							
Curalan	0.66 oz	21-d	0.0 b	0.0 c	0.754 d-i	0.746 no	0.788 ijk	0.781 f-j
Untreated Check			0.0 b	0.3 b	0.749 hi	0.736 o	0.761 l	0.745 k
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0308	0.0001	0.0001	0.0001
Days after treatment		14-d	5	9	4	1	5	9
		21-d	5	2	12	1	11	9
		28-d	5	21	4	14	19	9

[z] Applications were made every 14-d. Contend was applied on 18 May and 14 Jun; Secure on 31 May, 27 Jun, 11 Jul, 25 Jul and 8 Aug; Appear on 14 Jun, 27 Jun, 11 Jul, 25 Jul, and 8 Aug. Daconil Action was applied in combination with each treatment on all dates.

[y] All treatments were initiated on 18 May, prior to disease development. Subsequent 14-d treatments were applied on 31 May, 14 Jun, 27 Jun, and 11 Jul, 25 Jul and 8 Aug; 21-d treatments were applied on 6 Jun, 27 Jun, 19 Jul and 8 Aug; 28-d treatments were applied on 14 Jun, 11 Jul and 8 Aug.

[x] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher’s protected least significant difference test (α = 0.05).

PREVENTATIVE DOLLAR SPOT CONTROL WITH NEW CONTACT FUNGICIDES IN VARIOUS CARRIER VOLUMES ON CREEPING BENTGRASS FAIRWAY TURF, 2012

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INTRODUCTION

Dollar spot (caused by *Sclerotinia homoeocarpa*) is a common disease of golf course fairway turf occurring from May to October throughout New England. Control of this disease is achieved through integrated management plans utilizing improved bentgrass varieties, cultural, and chemical approaches. Contact fungicides with multi-site modes of action are an important tool for managing dollar spot and development of fungicide resistance. The volume of the spray solution (i.e., carrier volume) can be an important factor affecting efficacy of contact fungicides. Low carrier volumes may not provide acceptable control due to inadequate leaf coverage, and higher volumes may dilute the active ingredient or move the fungicide past the foliage into the thatch where it will not protect foliage from infection. The effect of carrier volume on efficacy of two new commercially available contact fungicides was evaluated.

MATERIALS & METHODS

A field study was conducted on a 'Crenshaw' creeping bentgrass (*Agrostis stolonifera*) turf grown on a Paxton fine sandy loam at the Plant Science Research and Education Facility in Storrs, CT. Turf was mowed three days wk^{-1} at a bench setting of 0.5-inches. A total of 1.15 lbs. of N was applied to the site from 26 April to 23 August. Sevin was applied on 21 July and 25 August for the control of cutworms. Overhead irrigation was applied every other night to prolong leaf wetness period and enhance disease.

Treatments consisted of experimental and currently available fungicides applied every 14-d. Initial treatments were made on 8 May prior to disease development. Subsequent applications were made every 14-d (dates listed in tables 1-4). All treatments were applied using a hand held CO_2 powered spray boom outfitted with a single flat fan nozzle. Treatments were applied with an AI9504E or AI9508E spray nozzle calibrated to deliver 1 or 2 gal 1000-ft^{-2} at 40 psi, respectively.

Dollar spot was assessed as a count of individual disease foci within each plot between 26 May and 18 July and then as a percentage of the plot area blighted by *S. homoeocarpa* once disease severity increased on 27 July. Turf quality was visually assessed on a 1 to 9 scale; where 9 represented the best quality turf and 6 was the minimum acceptable level. Phytotoxicity was visually assessed on a 0-5 scale; where 2 represented the maximum acceptable level. Turf color was visually assessed on a 1-9 scale; where 9 represented dark green turf. Canopy reflective index was determined using the FieldScout TCM 500 NDVI meter (Spectrum Technologies, Inc.). Ten readings were taken per plot with the mean used for data analysis. Plots measured 3 x 6 ft and were arranged in a split plot design with four replications. Data were subjected to an analysis of variance and means were separated using Fisher's protected least significant difference test.

RESULTS & DISCUSSION

Dollar spot pressure was moderate to high throughout the trial, although conditions were particularly conducive during July. Initial symptoms developed throughout the trial by 26 May (Table 1). All treatments reduced disease compared to untreated throughout the trial. However, the lowest rate of UC12-8 (1.28 fl oz) and UC12-6 (1.3 fl oz) failed to provide acceptable dollar spot control (i.e., ≤ 20 foci per plot) by 7 June (Table 1). No statistical differences in dollar spot control were observed between rates of UC12-8 or UC12-6 ranging from 2.0 to 1.56 fl oz throughout the trial (Tables 1 & 2). Differences between UC12-8 and UC12-6 were observed on 9 and 23 August. In early August, the lowest rate of UC12-8 reduced dollar spot severity 4% compared to the lowest rate of UC12-6 (Table 2). Later in the month, the two highest rates of UC12-8 reduced dollar spot 12% compared to similar rates of UC12-6, 23 days after the last application. These data suggest that UC12-8 may occasionally provide extended duration of control and improved control at lower rates compared to UC12-6.

Secure provided excellent dollar spot control, limiting disease to less than one foci per plot throughout the trial (Tables 1 & 2). Daconil Action provided acceptable dollar spot control (≤ 20 foci per plot) on most observation dates; except on 18 July, and 23 August, 23 days after the last application. Dollar spot incidence and severity did not differ between carrier volumes of 1.0 and 2.0 gal 1000-ft^{-2} for Secure or Daconil Action.

Turf quality was good for all treatments in May before disease developed in the trial. Thereafter, reductions in turf quality were largely influenced by poor disease control (Table 3). No phytotoxicity was observed among any of the treatments evaluated in the trial.

CONCLUSIONS

Secure is a new multi-site contact fungicide that provides excellent dollar spot control when applied on a 14-d interval. Daconil Action also provided acceptable dollar spot control under high disease pressure. Carrier volume did not affect efficacy of Secure or Daconil Action when applied to fairway height turf at 1.0 to 2.0 gal 1000-ft^{-2}. Few differences were observed between comparable rates of UC12-8 and UC12-6 during the first half of the epidemic. However, UC12-8 did provide improved disease control at the lowest rate later in the epidemic (9 Aug) and improved control at higher rates 23 days after the last application. These data suggest that UC12-8 may provide occasional improvements in dollar spot control over UC12-6.

Table 1. Dollar spot incidence in a 'Crenshaw' creeping bentgrass fairway turf treated preventively with fungicides at the Plant Science Research and Education Facility in Storrs, CT during 2012.

Treatment Rate per $1000ft^2$	Carrier Volume	Int.[y]	Dollar Spot Incidence 26 May	1 Jun	7 Jun	18 Jun	29 Jun	7 Jul	18 Jul
	gal $1000ft^{-2}$		--------------------------- number of foci per $18ft^2$ -----------------------------						
UC12-8 .... 1.98 fl oz	1.0	14-d	8.8 b[x]	6.8 b	10.0 b	11.5 b	8.3 c	12.5 de	43.8 def
UC12-8 .... 1.80 fl oz	1.0	14-d	8.3 b	6.3 b	9.3 b	7.5 b	5.8 c	7.0 de	34.0 ef
UC12-8 .... 1.56 fl oz	1.0	14-d	7.5 b	6.0 b	9.5 b	10.0 b	13.0 c	19.0 cde	69.0 cde
UC12-8 .... 1.28 fl oz	1.0	14-d	13.3 b	13.0 b	22.8 b	31.5 b	34.5 bc	49.8 bc	109.8 bc
UC12-6 .... 2.00 fl oz	1.0	14-d	17.0 b	14.0 b	24.0 b	30.0 b	28.5 bc	38.3 bcd	97.5 cd
UC12-6 .... 1.82 fl oz	1.0	14-d	9.0 b	9.0 b	14.8 b	15.0 b	18.3 bc	24.8 cde	85.0 cde
UC12-6 .... 1.59 fl oz	1.0	14-d	11.0 b	8.0 b	14.0 b	19.0 b	25.0 bc	30.3 cde	85.8 cde
UC12-6 .... 1.30 fl oz	1.0	14-d	17.0 b	14.0 b	25.5 b	35.3 b	52.5 b	73.5 b	166.0 b
Secure .... 0.5 fl oz	1.0	14-d	0.8 b	0.0 b	0.0 b	0.0 b	0.0 c	0.0 e	0.0 f
Secure[z] .... 0.5 fl oz	2.0	14-d	0.5 b	0.8 b	0.0 b	0.3 b	0.0 c	0.0 e	0.0 f
Daconil Action...... 2.0 fl oz	1.0	14-d	8.3 b	4.5 b	9.8 b	7.5 b	7.3 c	13.3 cde	52.0 c-f
Daconil Action[z]..... 2.0 fl oz	2.0	14-d	12.0 b	8.3 b	16.8 b	17.0 b	12.8 c	18.0 cde	72.3 cde
Untreated Check			42.5 a	59.3 a	80.5 a	112.5 a	167.3 a	186.5 a	272.5 a
Untreated Check			46.0 a	71.8 a	84.3 a	126.0 a	191.3 a	211.0 a	280.3 a
ANOVA: Treatment (P > F)			0.0126	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment			3	9	2	13	10	5	2

[z] Select treatments applied with a carrier volume of 2.0 gal $1000ft^{-2}$; all other treatments applied in 1.0 gal $1000ft^{-2}$.

[y] All treatments were initiated on 8 May, prior to symptom development. Subsequent 14 d treatments were applied on 23 May, 5 Jun, 19 Jun, 2 Jul, 16 Jul, and 31 Jul.

[x] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test ($\alpha = 0.05$).

Table 2. Dollar spot severity in a 'Crenshaw' creeping bentgrass fairway turf treated preventively with fungicides at the Plant Science Research and Education Facility in Storrs, CT during 2012.

Treatment Rate per $1000ft^2$	Carrier Volume	Int.[y]	Dollar Spot Severity 27 Jul	9 Aug	23 Aug
	gal $1000ft^{-2}$		----- percent plot area blighted -----		
UC12-8 .... 1.98 fl oz	1.0	14-d	2.3 de[x]	2.1 ef	10.5 e
UC12-8 ....1.80 fl oz	1.0	14-d	1.9 de	1.9 ef	12.0 e
UC12-8 ....1.56 fl oz	1.0	14-d	4.8 cde	3.8 c-f	14.3 de
UC12-8 ....1.28 fl oz	1.0	14-d	10.3 bc	7.3 c	25.8 bc
UC12-6 ....2.00 fl oz	1.0	14-d	7.0 cd	5.4 cde	22.3 cd
UC12-6 ....1.82 fl oz	1.0	14-d	5.8 cd	4.0 c-f	23.8 cd
UC12-6 ....1.59 fl oz	1.0	14-d	7.3 cd	6.5 cd	22.5 cd
UC12-6 ....1.30 fl oz	1.0	14-d	13.3 b	11.5 b	34.3 b
Secure ....0.5 fl oz	1.0	14-d	0.0 e	0.0 f	0.0 f
Secure[z] ....0.5 fl oz	2.0	14-d	0.0 e	0.0 f	0.2 f
Daconil Action........2.0 fl oz	1.0	14-d	2.4 de	2.4 def	11.5 e
Daconil Action[z].......2.0 fl oz	2.0	14-d	3.5 de	3.0 def	10.3 e
Untreated Check			40.5 a	36.3 a	63.8 a
Untreated Check			43.5 a	37.5 a	65.0 a
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001
Days after treatment			11	9	23

[z] Select treatments applied with a carrier volume of 2.0 gal $1000ft^{-2}$; all other treatments applied in 1.0 gal $1000ft^{-2}$.

[y] All treatments were initiated on 8 May. Subsequent 14 d treatments were applied on 23 May, 5 Jun, 19 Jun, 2 Jul, 16 Jul, and 31 Jul.

[x] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test ($\alpha = 0.05$).

Table 3. Turf quality and phytotoxicity of a 'Crenshaw' creeping bentgrass fairway turf treated preventively with fungicides at the Plant Science Research and Education Facility in Storrs, CT during 2012.

Treatment	Rate per $1000ft^2$	Int.[y]	Turf Quality				Phytotoxicity	
			26 May	8 Jun	9 Jul	9 Aug	26 May	8 Jun
			----- 1-9; 6=minimum acceptable -----				-0-5; 2=max acceptable-	
UC12-8	1.98 fl oz	14-d	6.5 abc[x]	5.8 b	7.8 abc	6.5 b	0.0	0.0
UC12-8	1.80 fl oz	14-d	6.8 abc	6.3 ab	7.8 abc	6.3 bc	0.0	0.0
UC12-8	1.56 fl oz	14-d	6.5 abc	6.0 ab	5.8 de	5.0 d	0.0	0.0
UC12-8	1.28 fl oz	14-d	6.5 abc	5.5 b	5.3 e	4.8 de	0.0	0.0
UC12-6	2.00 fl oz	14-d	6.0 bcd	5.8 b	5.8 de	5.3 d	0.0	0.0
UC12-6	1.82 fl oz	14-d	7.3 a	6.0 ab	5.8 de	4.8 de	0.0	0.0
UC12-6	1.59 fl oz	14-d	6.5 abc	6.3 ab	5.3 e	4.0 ef	0.0	0.0
UC12-6	1.30 fl oz	14-d	6.0 bcd	5.5 b	4.5 e	3.8 f	0.0	0.0
Secure	0.5 fl oz	14-d	6.8 abc	7.0 a	8.8 a	9.0 a	0.0	0.0
Secure[z]	0.5 fl oz	14-d	7.0 ab	7.0 a	8.3 ab	9.0 a	0.0	0.0
Daconil Action	2.0 fl oz	14-d	7.3 a	6.5 ab	7.3 bc	6.3 bc	0.0	0.0
Daconil Action[z]	2.0 fl oz	14-d	6.8 abc	6.0 ab	6.8 cd	5.5 cd	0.0	0.0
Untreated Check			5.8 cd	4.3 c	2.8 f	2.8 g	0.0	0.0
Untreated Check			5.3 d	4.3 c	2.5 f	2.5 g	0.0	0.0
ANOVA: Treatment (P > F)			0.0248	0.0005	0.0001	0.0001	1.0000	1.0000
Days after treatment			3	3	7	9	3	3

[z] Select treatments applied with a carrier volume of 2.0 gal $1000ft^{-2}$; all other treatments applied in 1.0 gal $1000ft^{-2}$.

[y] All treatments were initiated on 8 May. Subsequent 14 d treatments were applied on 23 May, 5 Jun, 19 Jun, 2 Jul, 16 Jul, and 31 Jul.

[x] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test (α = 0.05).

Table 4. Turf color and NDVI of a 'Putter' creeping bentgrass fairway turf treated preventively with fungicides at the Plant Science Research and Education Facility in Storrs, CT during 2012.

Treatment	Rate per $1000ft^2$	Int.[y]	Turf Color		NDVI		
			26 May	9 Jul	18 Jun	28 Jul	23 Aug
			- 1-9; 9= dark green -		---- canopy reflectance index ----		
UC12-8	1.98 fl oz	14-d	6.3	7.8 ab[x]	0.771	0.778 ab	0.794 ab
UC12-8	1.8 fl oz	14-d	7.0	7.5 abc	0.773	0.787 ab	0.796 ab
UC12-8	1.56 fl oz	14-d	6.8	7.5 abc	0.770	0.785 ab	0.791 abc
UC12-8	1.28 fl oz	14-d	6.8	7.0 b-e	0.757	0.778 ab	0.777 cd
UC12-6	2.0 fl oz	14-d	6.8	7.3 a-d	0.757	0.785 ab	0.786 bcd
UC12-6	1.82 fl oz	14-d	6.5	6.8 cde	0.769	0.784 ab	0.793 abc
UC12-6	1.59 fl oz	14-d	6.5	6.8 cde	0.780	0.789 a	0.790 abc
UC12-6	1.3 fl oz	14-d	6.5	6.8 cde	0.758	0.775 b	0.774 d
Secure	0.5 fl oz	14-d	6.3	6.3 e	0.772	0.786 ab	0.803 a
Secure[z]	0.5 fl oz	14-d	6.0	6.5 de	0.755	0.780 ab	0.802 a
Daconil Action	2.0 fl oz	14-d	6.5	8.0 a	0.769	0.783 ab	0.798 ab
Daconil Action[z]	2.0 fl oz	14-d	6.5	7.3 a-d	0.770	0.779 ab	0.793 abc
Untreated Check			5.8	2.8 f	0.754	0.757 c	0.733 e
Untreated Check			6.0	2.8 f	0.760	0.749 c	0.722 e
ANOVA: Treatment (P > F)			0.1644	0.0001	0.2701	0.0001	0.0001
Days after treatment			3	7	13	12	23

[z] Select treatments applied with a carrier volume of 2.0 gal $1000ft^{-2}$; all other treatments applied in 1.0 gal $1000ft^{-2}$.

[y] All treatments were initiated on 8 May. Subsequent 14 d treatments were applied on 23 May, 5 Jun, 19 Jun, 2 Jul, 16 Jul, and 31 Jul.

[x] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test (α = 0.05).

PREVENTIVE DOLLAR SPOT CONTROL IN CREEPING BENTGRASS FAIRWAY TURF WITH EXTENDED FUNGICIDE APPLICATION INTERVALS, 2012

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INTRODUCTION

Dollar spot (caused by *Sclerotinia homoeocarpa*) is a common disease of golf course fairway turf occurring from May to October throughout New England. Control of this disease is achieved through integrated management plans utilizing improved bentgrass varieties, cultural and chemical approaches. However, acceptable control often still requires fungicide applications every 21 to 28 days with currently available materials. New fungicides with greater efficacy may permit turf managers to achieve acceptable control with extended application intervals (i.e., 35 days). Use of new materials with extended intervals could reduce the total number of chemical applications required to control dollar spot as well as reduce labor costs. The objective of this study was to evaluate the efficacy of extended application intervals of experimental and commercially available fungicides for preventive control of dollar spot in fairway turf.

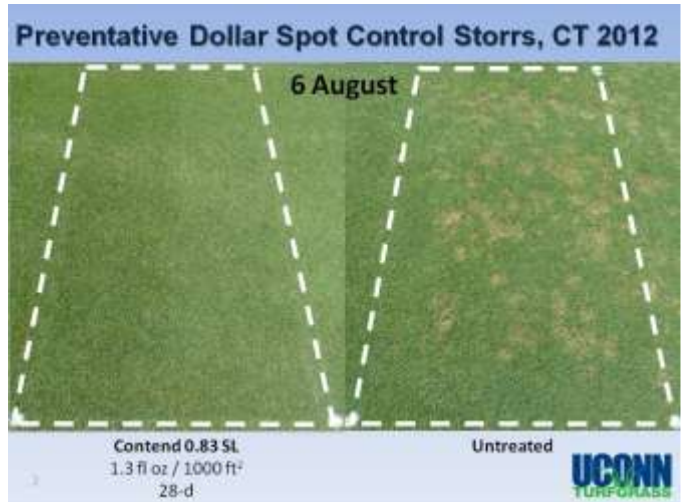
MATERIALS AND METHODS

A field study was conducted on a 'Putter' creeping bentgrass (*Agrostis stolonifera*) turf grown on a Paxton fine sandy loam at the Plant Science Research and Education Facility in Storrs, CT. Turf was mowed three days wk^{-1} at a bench setting of 0.5-inches. Nitrogen was applied monthly from April through August at approximately 0.25 lbs N 1000-ft^{-2} for a total of 1.15 lbs N 1000-ft^{-2}

nitrogen from 3 April and 25 August. Sevin was applied on 21 July and 25 August for the control of cutworms. Overhead irrigation was applied every other night to prolong leaf wetness period and enhance disease.

Treatments consisted of experimental and currently available fungicides applied individually every 21, 28, or 35-days. Initial treatment applications were made on 8 May prior to disease developing in the trial area. Subsequent applications were made at the specified intervals (dates listed in Tables 1 – 4) until 12 August. All treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI9504E flat fan nozzle calibrated to deliver 1 gal 1000-ft^{-2} at 40 psi. Plots measured 3 x 6 ft and were arranged in a randomized complete block design with four replications.

Dollar spot was assessed as a count of individual disease foci within each plot from 26 May to 23 August. Turf quality was visually assessed on a 1 to 9 scale; where 9 represented the best quality turf and 6 was the minimum acceptable level. Phytotoxicity was also assessed visually where 0 was equal to no discoloration and 2 represented the maximum acceptable level. Turf color was visually assessed on a 1-9 scale where 9



represented dark green color. Canopy reflective index was determined using the FieldScout TCM 500 (Spectrum Technologies, Inc.) NDVI meter. Ten readings were taken per plot with the mean used for data analysis. Data were subjected to an analysis of variance and means were separated using Fisher's protected least significant difference test.

RESULTS AND DISCUSSION

Dollar Spot

Dollar spot pressure was high to moderate throughout the trial, although conditions were particularly conducive in late-May. Initial symptoms developed on 26 May, 18 days after the initial application (Table 1). All treatments failed to provide complete dollar spot control on this date, although disease was not considered to be unacceptable in any treatment. No significant treatment effects were apparent at this time, although UC12-3 and Contend (1.3 fl oz; 35-d int) maintained excellent dollar spot control (i.e., ≤ 5 foci per plot) during the initial outbreak. Control failures among all treatments were likely due to extremely favorable conditions at this time.

Disease continued to increase in most treatments by 1 Jun. Although, treatments applied on a 21-d int appeared to slow disease development on this date, following a second application on 29 May. Similarly, disease was arrested by the initial application (i.e., single application) of an increased rate of Contend (1.3 fl oz) and Runway (0.68 fl oz), and UC12-3. Interestingly, Contend applied at the low rate of 0.96 fl oz every 28-d did not appear to slow disease development on 1 Jun compared the same rate applied on a 21-d int, although the two treatments were not statistically different. Turf treated with UC12-5 failed to control dollar spot on this date.

The epidemic continued to worsen by 7 Jun, particularly in plots treated at 28- and 35-d application intervals. Shorter application intervals are generally required to completely arrest disease once infection has occurred. Therefore, treatments applied on a 28- or 35-d int failed to control disease 30 DAT, since repeat applications had not been made by this date, or had only been made 2 days previously in the case of the 28-d int. Regardless, Contend (1.3 fl oz) applied on a 28- and 35-d int and Contend (0.96 fl oz) and Runway (0.507 fl oz) applied every 21-d maintained the lowest levels of disease on 7 Jun, albeit not statistically different from most other treatments.

Improved dollar spot control began to develop by 18 Jun, in some 28-d and 35-d interval treatments after 2 applications. Contend (1.3 fl oz), UC12-3, and UC12-4 applied every 28-d provided excellent (≤ 5 foci per plot) to good (10 – 6 foci per plot) control on this date, and throughout the remainder of the trial. Whereas, Contend (0.96 fl oz), Runway (0.507 fl oz), UC12-2, and UC12-5 applied every 28-d did not provide acceptable dollar spot control until 7 Jul after 3 applications, although these treatments were not statistically different from the best treatments. Contend (1.3 fl oz) applied every 35-d provided good dollar spot control by 18 Jun. Runway (0.68 fl oz), UC12-2, UC12-4 and UC12-5 also applied every 35-d, did not provide acceptable dollar spot control until late-July or August when disease declined in all plots including the untreated control.

Dollar spot in 21-d interval treatments (Contend 0.96 fl oz and Runway 0.507 fl oz) increased on 18 Jun, 20 DAT, but began to consistently reduce disease, by 29 Jun, after 3 applications.

Turf quality, Phytotoxicity, NDVI and Turf Color.

Turf quality was largely influenced by dollar spot incidence throughout the trial. By 9 Aug, most treatments provided complete dollar spot control; turf quality in these plots was good with no statistical differences among them. (Table 2). Only, the control and treatments that did not control disease were had reduced turf quality. Few turf quality differences were observed on the final observation date (23 Aug), although quality was greatest in turf treated with Runway (0.507) every 21-d. No treatments resulted in unacceptable phytotoxicity throughout this trial (Table 2). Most treatments were associated with dark green color throughout the trial, although UC12-2 applied every 28-d and UC12-4 applied every 35-d generally had lighter green color than other treated turf (Table 3). Similarly, NDVI readings were fairly uniform among all treatments throughout the trial (Table 3).

CONCLUSIONS

This trial provided a rigorous evaluation of the treatments' potential to provide preventive and curative dollar spot control. Few statistical treatment differences were observed in the trial; however several treatments maintained numerically better disease control. Lowest disease was typically associated with 28-d applications of Contend (1.3 fl oz), UC12-3 (3.4 fl oz), UC12-4 (0.37 oz) and Contend (1.3 fl oz) applied every 35-d. Increased rates of Contend (i.e., 1.3 vs. 0.96 fl oz) appeared to control dollar spot more effectively regardless of interval. Whereas, Runway seemed to provide better control when applied at lower rates (0.507 fl oz) more frequently (i.e., 21-d) compared to 28- or 35-d.

Previous studies have demonstrated that DMI fungicides are less effective curative treatments compared to other classes of fungicides. Curative control of dollar spot in this trial would likely have been improved if treatments were applied on a 14 – 21 d int to rapidly arrest disease development. Despite, initial breakthrough in all treatments, increased rates of Contend provided excellent to good dollar spot control at 28- to 35-d.

Table 1. Dollar spot incidence in a 'Putter' creeping bentgrass fairway turf treated preventively with fungicides at extended application intervals at the Plant Science Research and Education Facility in Storrs, CT during 2012.

			Dollar Spot Incidence										
Treatment	Rate per $1000ft^2$	Int.[z]	26 May	1 Jun	7 Jun	18 Jun	29 Jun	7 Jul	18 Jul	27 Jul	9 Aug	17 Aug	23 Aug
			number of foci per $18ft^{-2}$										
Contend	0.96 fl oz	21-d	8.3	12.5 cd[y]	12.8 d	22.8 bcd	6.0 e	9.3 de	1.8 e	3.3 cd	0.0 d	3.5 b	1.5 b
Runway	0.507 fl oz	21-d	9.3	10.3 cd	11.8 d	23.8 bcd	11.5 e	13.8 cde	2.3 e	5.8 bcd	0.5 d	0.8 b	0.0 b
Contend	0.96 fl oz	28-d	11.5	20.5 bcd	30.0 a-d	23.3 bcd	23.5 b-e	16.3 cde	0.3 e	1.3 cd	0.0 d	0.0 b	0.0 b
Contend	1.3 fl oz	28-d	6.3	5.8 d	11.3 d	5.0 d	7.3 e	4.0 e	0.0 e	0.3 d	0.0 d	0.0 b	0.0 b
Runway	0.507 fl oz	28-d	10.0	15.0 cd	24.0 bcd	28.8 bc	31.8 bcd	21.0 cde	2.8 e	2.8 cd	0.0 d	0.8 b	0.5 b
UC12-3	3.4 fl oz	28-d	3.8	4.3 d	14.3 cd	4.0 d	2.3 e	3.0 e	0.5 e	0.5 d	0.3 d	2.3 b	0.5 b
UC12-2	2.0 fl oz	28-d	8.0	14.3 cd	20.8 bcd	16.0 cd	21.0 cde	13.3 cde	1.0 e	3.3 cd	0.5 d	0.0 b	0.3 b
UC12-4	0.37 oz	28-d	5.3	12.5 cd	13.8 cd	5.5 d	7.8 e	5.5 e	1.8 e	4.5 bcd	0.0 d	3.0 b	1.5 b
UC12-5	0.6 fl oz	28-d	17.8	33.8 ab	42.5 ab	27.8 bc	37.0 bc	20.8 cde	2.8 e	7.3 bcd	0.3 d	7.3 b	5.5 b
Contend	1.3 fl oz	35-d	4.5	7.3 d	9.3 d	8.3 cd	5.0 d	5.3 e	9.3 de	1.0 cd	1.0 d	0.0 b	0.3 b
Runway	0.68 fl oz	35-d	8.5	9.3 cd	24.5 bcd	21.0 bcd	15.5 de	16.8 cde	14.5 de	1.5 cd	3.8 cd	0.0 b	0.0 b
UC12-2	2.0 fl oz	35-d	6.0	14.5 cd	24.3 bcd	20.8 bcd	20.0 cde	24.3 cd	26.3 cd	18.3 bc	13.0 bcd	0.0 b	1.0 b
UC12-4	0.37 oz	35-d	10.0	25.8 abc	36.8 abc	22.8 bcd	20.5 cde	30.5 bc	41.3 bc	11.8 bcd	19.0 bc	0.3 b	0.0 b
UC12-5	0.6 fl oz	35-d	19.0	39.8 a	52.8 a	39.8 ab	42.8 b	43.3 b	56.0 b	21.0 b	23.3 b	1.0 b	0.5 b
Untreated Control			23.8	41.5 a	42.3 ab	55.5 a	78.8 a	75.8 a	107.0 a	126.3 a	124.8 a	54.0 a	38.3 a
ANOVA: Treatment (P > F)			0.0830	0.0008	0.0060	0.0007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0023
Days after treatment		21-d	18	2	9	20	10	17	7	16	9	17	23
		28-d	18	23	2	13	24	5	16	25	9	17	23
		35-d	18	23	30	6	17	24	2	11	24	32	36

[z] All treatments were initiated on 8 May, prior to symptom development. Subsequent 21-d treatments were applied on 29 May, 19 Jun, 11 Jul, and 31 Jul; 28-d treatments were applied on 5 Jun, 2 Jul, and 31 Jul; 35-d treatments were applied on 12 Jun and 16 Jul.

[y] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test (α = 0.05).

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Table 2. Turf quality and phytotoxicity of a ‘Putter’ creeping bentgrass fairway turf treated preventively with fungicides at different application intervals at the Plant Science Research and Education Facility in Storrs, CT during 2012.

Treatment	Rate per 1000ft^2	Int.[z]	Turf Quality 26 May	8 Jun	29 Jun	9 Aug	23 Aug	Phytotoxicity 26 May	8 Jun	9 Aug
			------------- 1-9; 6=min acceptable -------------					- 0-5; 2=max acceptable -		
Contend	0.96 fl oz	21-d	6.0	6.0	6.5 ab[y]	8.0 a	7.0 bcd	0.0	0.8	0.0
Runway	0.507 fl oz	21-d	5.8	6.3	6.5 ab	7.8 a	8.0 a	0.0	0.5	0.0
Contend	0.96 fl oz	28-d	6.0	5.5	5.8 abc	7.3 ab	7.0 bcd	0.0	0.3	0.0
Contend	1.3 fl oz	28-d	6.5	6.3	6.5 ab	7.5 a	7.0 bcd	0.0	1.0	0.0
Runway	0.507 fl oz	28-d	6.0	5.8	5.3 c	7.5 a	7.5 abc	0.0	0.5	0.0
UC12-3	3.4 fl oz	28-d	6.8	6.0	6.5 ab	7.0 ab	6.8 cd	0.0	0.0	0.0
UC12-2	2.0 fl oz	28-d	6.5	5.5	5.8 abc	7.5 a	7.5 abc	0.0	0.3	0.0
UC12-4	0.37 oz	28-d	6.8	6.0	6.3 abc	7.8 a	7.0 bcd	0.0	0.3	0.0
UC12-5	0.6 fl oz	28-d	6.5	5.3	5.8 abc	7.3 ab	7.3 a-d	0.0	0.3	0.0
Contend	1.3 fl oz	35-d	6.3	5.8	6.8 a	7.5 a	7.3 a-d	0.0	0.8	0.0
Runway	0.68 fl oz	35-d	6.5	5.8	5.8 abc	7.0 ab	7.8 ab	0.0	0.3	0.0
UC12-2	2.0 fl oz	35-d	6.3	5.8	5.5 bc	6.3 bc	6.5 d	0.0	0.3	0.0
UC12-4	0.37 oz	35-d	6.3	5.3	6.3 abc	5.3 cd	7.0 bcd	0.0	0.3	0.0
UC12-5	0.6 fl oz	35-d	6.0	4.8	5.3 c	5.0 d	7.3 a-d	0.0	0.0	0.0
Untreated Control			5.8	4.8	4.0 d	2.8 e	5.3 e	0.0	0.0	0.0
ANOVA: Treatment (P > F)			0.4708	0.2430	0.0011	0.0001	0.0002	1.0000	0.1833	1.0000
Days after treatment		21-d	18	7	10	9	23	18	7	9
		28-d	18	3	24	9	23	18	3	9
		35-d	18	31	17	24	37	18	31	24

[z] All treatments were initiated on 8 May, prior to symptom development. Subsequent 21-d treatments were applied on 29 May, 19 Jun, 11 Jul, and 31 Jul; 28-d treatments were applied on 5 Jun, 2 Jul, and 31 Jul; 35-d treatments were applied on 12 Jun and 16 Jul.

[y] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher’s protected least significant difference test ($\alpha = 0.05$).

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Table 3. NDVI and turf color of a ‘Putter’ creeping bentgrass fairway turf treated preventively with fungicides at different application intervals at the Plant Science Research and Education Facility in Storrs, CT during 2012.

Treatment	Rate per 1000ft^2	Int.[z]	NDVI				Turf Color		
			18 Jun	28 Jun	30 Jul	17Aug	8 Jun	9 Aug	23 Aug
			---------- canopy reflectance index ----------				----- 1-9; 9= dark green -----		
Contend	0.96 fl oz	21-d	0.738	0.743	0.778 bc[y]	0.759	8.0 a	7.3 bcd	7.5
Runway	0.507 fl oz	21-d	0.747	0.746	0.786 ab	0.763	8.0 a	7.8 abc	7.3
Contend	0.96 fl oz	28-d	0.744	0.736	0.788 a	0.764	7.8 ab	7.0 cd	7.0
Contend	1.3 fl oz	28-d	0.744	0.740	0.789 a	0.768	8.0 a	7.5 a-d	7.8
Runway	0.507 fl oz	28-d	0.747	0.748	0.789 a	0.769	8.0 a	8.3 a	7.8
UC12-3	3.4 fl oz	28-d	0.745	0.748	0.790 a	0.769	7.3 abc	8.0 ab	7.3
UC12-2	2.0 fl oz	28-d	0.743	0.751	0.784 ab	0.762	6.8 c	6.0 ef	6.3
UC12-4	0.37 oz	28-d	0.735	0.747	0.786 ab	0.761	7.8 ab	7.0 cd	7.3
UC12-5	0.6 fl oz	28-d	0.739	0.751	0.787 ab	0.770	6.8 c	7.0 cd	6.8
Contend	1.3 fl oz	35-d	0.739	0.737	0.790 a	0.765	7.8 ab	7.8 abc	6.8
Runway	0.68 fl oz	35-d	0.737	0.750	0.785 ab	0.762	8.0 a	7.3 bcd	7.8
UC12-2	2.0 fl oz	35-d	0.740	0.740	0.783ab	0.762	7.3 abc	7.0 cd	7.0
UC12-4	0.37 oz	35-d	0.751	0.753	0.790 a	0.766	6.8 c	6.8 de	6.5
UC12-5	0.6 fl oz	35-d	0.752	0.753	0.786 ab	0.763	7.3 abc	6.8 de	6.8
Untreated Control			0.746	0.749	0.768 c	0.755	7.0 bc	5.8 f	6.5
ANOVA: Treatment (P > F)			0.3996	0.1059	0.0059	0.2865	0.0150	0.0001	0.1058
Days after treatment		21-d	20	9	19	17	7	9	23
		28-d	13	23	28	17	3	9	23
		35-d	6	16	14	33	31	24	37

[z] All treatments were initiated on 8 May, prior to symptom development. Subsequent 21-d treatments were applied on 29 May, 19 Jun, 11 Jul, and 31 Jul; 28-d treatments were applied on 5 Jun, 2 Jul, and 31 Jul; 35-d treatments were applied on 12 Jun and 16 Jul.

[y] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher’s protected least significant difference test ($\alpha = 0.05$).

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PREVENTIVE DOLLAR SPOT CONTROL AFFECTED BY A BIOSTIMULANT AND FUNGICIDES ON CREEPING BENTGRASS FAIRWAY TURF, 2012

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INTRODUCTION

Dollar spot (caused by *Sclerotinia homoeocarpa*) is a common disease of golf course fairway turf occurring from May to October throughout New England. Integrated management approaches are often more effective at providing season-long control compared to fungicide applications alone. Biostimulants are commonly used to provide essential nutrients and other plant health promoting compounds. Proactin is a new biostimulant containing amino acids and vitamans. This trial was designed to assess the effect of Proactin on fungicide efficacy for dollar spot control of creeping bentgrass fairway turf.

MATERIALS & METHODS

A field study was conducted on a 'Crenshaw' creeping bentgrass (*Agrostis stolonifera*) turf grown on a Paxton fine sandy loam at the Plant Science Research and Education Facility in Storrs, CT. Turf was mowed three days wk^{-1} at a bench setting of 0.5-inches. Nitrogen in the form of urea was applied monthly for a total of 1.15 pounds nitrogen between 26 April and 23 August. Sevin was applied on 21 July and 25 August for the control of cutworm. Overhead irrigation was applied every other night to prolong leaf wetness period and enhance disease.

Treatments consisted of currently available fungicides and a biostimulant applied individually or in combination every 14 or 28-days. Initial treatment applications were made on 11 Jun. Subsequent applications were made at the specified intervals (dates listed in Tables 1 & 2) until 9 July. All treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI9504E flat fan nozzle calibrated to deliver 1 gal 1000-ft^{-2} at 40 psi. Plots measured 3 x 6 ft and were arranged in a randomized complete block design with four replications.

Dollar spot was assessed as a count of individual disease foci within each plot from 21 Jun to 9 August and then as a percentage of the plot area blighted by *S. homoeocarpa* once disease severity increased on 23 August. Turf quality was visually assessed on a 1 to 9 scale; where 9 represented the best quality turf and 6 was the minimum acceptable level. Canopy reflective index was determined using the FieldScout TCM 500 NDVI meter (Spectrum Technologies, Inc.). Ten readings were taken per plot with the mean used for data analysis. Data were subjected to an analysis of variance and means were separated using Fisher's protected least significant difference test.

RESULTS & DISCUSSION

Dollar spot developed throughout the trial by 21 June and intensified rapidly during favorable conditions in late-June and July (Table 1). All treatments reduced dollar spot compared to the untreated control except Proactin applied alone (Table 1). Proactin applied as a tank mix with QP Chlorothalonil (1.75 fl oz) or QP Tebuconazole (0.60 fl oz) also had no effect on dollar spot incidence or severity compared to the same rate of each fungicide applied alone. No significant differences were observed between QP Chlorothalonil treatments applied alone at high (3.5 fl oz) and low (1.75 fl oz) rates. However, only the high rate of QP Chlorothalonil and Daconil Action provided acceptable dollar spot control (i.e., ≤ 20 foci per plot) and turf quality (Table 2) throughout the trial. No differences in dollar spot efficacy were observed between Daconil Action and QP Chlorothalonil applied alone. QP Tebuconazole applied alone or as a tank mix with Proactin every 28-d failed to provide acceptable dollar spot control. A shorter application interval would likely have improved control with this treatment.

Table 1. Dollar spot incidence in ‘Crenshaw’ creeping bentgrass fairway turf treated preventively with fungicides at the Plant Science Research Facility in Storrs, CT during 2012.

Treatment	Rate per 1000ft^2	Int.[z]	Dollar Spot Incidence					Percent Dollar Spot
			21 Jun	29 Jun	7 Jul	27 Jul	9 Aug	23 Aug
			-------------------- number of foci 18 ft^{-2} --------------------					% plot area blighted
Proactin	0.14 fl oz	14-d	12.8 a[y]	55.3 a	86.8 a	154.0 b	153.3 a	45.8 b
QP Chlorothalonil	1.75 fl oz	14-d	1.3 b	16.3 b	8.8 cd	20.8 def	50.3 c	8.8 de
QP Chlorothalonil	3.50 fl oz	14-d	0.0 b	2.5 b	0.0 d	1.0 ef	11.8 d	1.9 de
QP Chlorothalonil +Proactin	1.75 fl oz 0.14 fl oz	14-d	0.5 b	23.0 b	16.5 cd	29.0 de	64.8 c	11.0 d
QP Chlorothalonil +Proactin	3.50 fl oz 0.14 fl oz	14-d	0.0 b	2.5 b	0.0 d	0.3 f	6.8 d	1.4 e
QP Tebuconazole	0.60 fl oz	28-d	0.5 b	8.8 b	31.8 bc	42.5 cd	82.0 bc	21.3 c
QP Tebuconazole +Proactin	0.60 fl oz 0.14 fl oz	28-d	0.5 b	10.8 b	49.8 b	57.8 c	111.8 b	28.8 c
QP Chlorothalonil +Foursome	3.50 fl oz 0.40 fl oz	14-d	0.0 b	3.5 b	0.0 d	0.5 f	5.8 d	1.8 de
Daconil Action	3.50 fl oz	14-d	0.5 b	6.3 b	0.8 d	1.5 ef	3.3 d	1.6 de
Untreated Check			21.5 a	75.8 a	105.0 a	193.8 a	188.0 a	57.5 a
ANOVA: Treatment (P > F)			0.0027	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment:		14-d	10	2	12	4	18	32
		28-d	10	18	28	18	31	45

[z] Treatments were initiated on 11 Jun. Subsequent 14 d applications were made on 27 Jun, 9 Jul, and 23 Jul; 28 d applications were made on 9 Jul.

[y] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher’s protected least significant difference test ($\alpha = 0.05$).

Table 2. Turf quality and NDVI of ‘Crenshaw’ creeping bentgrass fairway turf preventatively treated with fungicides at the Plant Science Research Facility in Storrs, CT during 2012.

Treatment	Rate per 1000ft^2	Int.[z]	Turf Quality		NDVI	
			21 Jun	9 Aug	29 Jun	30 Jul
			- 1-9; 6=min acceptable-		- reflectance index -	
Proactin	0.14 fl oz	14-d	6.8 cd[y]	2.5 d	0.768	0.754 b
QP Chlorothalonil	1.75 fl oz	14-d	7.5 bc	5.3 bc	0.780	0.809 a
QP Chlorothalonil	3.50 fl oz	14-d	7.0 bc	6.8 ab	0.770	0.813 a
QP Chlorothalonil +Proactin	1.75 fl oz 0.14 fl oz	14-d	7.3 bc	4.5 c	0.777	0.805 a
QP Chlorothalonil +Proactin	3.50 fl oz 0.14 fl oz	14-d	7.8 b	8.0 a	0.774	0.812 a
QP Tebuconazole	0.60 fl oz	28-d	7.5 bc	4.3 c	0.781	0.797 a
QP Tebuconazole +Proactin	0.60 fl oz 0.14 fl oz	28-d	7.3 bc	3.8 cd	0.780	0.796 a
QP Chlorothalonil +Foursome	3.50 fl oz 0.40 fl oz	14-d	8.8 a	7.5 a	0.777	0.806 a
Daconil Action	3.50 fl oz	14-d	7.0 bc	7.8 a	0.771	0.805 a
Untreated Check			6.0 d	2.5 d	0.778	0.756 b
ANOVA: Treatment (P > F)			0.0012	0.0001	0.7491	0.0001
Days after treatment:		14-d	10	18	2	7
		28-d	10	31	18	21

[z] Treatments were initiated on 11 Jun, prior to disease development. Subsequent 14-d applications were made on 27 Jun, 9 Jul, and 23 Jul; 28-d applications were made on 9 Jul.

[y] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher’s protected least significant difference test ($\alpha = 0.05$).

ANNUAL BLUEGRASS CONTROL WITH SELECTIVE HERBICIDES IN CREEPING BENTGRASS FAIRWAY TURF, 2012

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INTRODUCTION

Annual bluegrass (*Poa annua*) is a common component of golf course fairways throughout the northern United States. The species is capable of forming a dense, fine-textured, turf under low mowing which makes it well adapted for fairway and putting green areas. However, annual bluegrass possesses only fair tolerance to high temperatures and medium tolerance to low temperatures. Poor tolerance to environmental stress limits survival of this turf species either directly or indirectly by predisposing ABG to diseases such as dollar spot, summer patch and anthracnose.

Management inputs required to maintain healthy annual bluegrass playing surfaces are generally greater than turfgrass species such as creeping bentgrass which benefit from breeding programs intended to improve disease resistance and environmental stress tolerance. Despite costly efforts to maintain annual bluegrass this species commonly declines under severe environmental conditions causing a disruption in play and requiring renovation of playing surfaces.

Selective herbicides to reduce annual bluegrass in established creeping bentgrass fairways would help turf managers transition fairways to more sustainable turfgrass species with improved environmental stress tolerance and disease resistance, thus reducing water and chemical applications necessary to maintain acceptable playing surfaces. Two recently indentified herbicides have been purported to have selectivity to control annual bluegrass in established creeping bentgrass fairways. The objective of the current trial was to evaluate the efficacy of Xonerate (amicarbazone) and PoaCure (methiozolin) in controlling annual bluegrass in a newly established creeping bentgrass fairway turf and assess their phytosafety on creeping bentgrass.

MATERIALS AND METHODS

This field study was initiated in 2012 on 'Mackenzie' creeping bentgrass (*Agrostis stolonifera*) turf established on a Paxton sandy loam in August 2011. Turf was mowed three days wk^{-1} at a bench setting of 0.5 inches. Xonerate treatments were applied at 7 to 14 day intervals at rates ranging 1.0 to 4.0 oz. per arce. PoaCure treatments were applied as a single application of 27.4 fl. oz. per acre or two applications of 55.0 fl. oz. per acre on a 14 day interval. Cutless was applied at 8.0 oz per acre every 21 days. All treatments were applied on days when the maximum air temperature was less than 85 F, except Cutless. Treatments were applied using a single AI9504E flat fan nozzle at 40 psi to 1.0 gal. of water per 1000ft^2. Plots measuring 3 x 6 feet were arranged in a randomized complete block design with 4 replications. Annual bluegrass populations were determined by counting the number of annual bluegrass plants present per 1 ft^2. Three 1 ft^2 evaluations were made per plot on each observation. Turf quality was assessed visually on a 1-9 scale where 9 is the best quality turf, and 6 represents the minimum level of turf quality. Data were subjected to an analysis of variance and means were separated using Fisher's protected least significant difference test.

RESULTS AND DISCUSSION

Two applications of Xonerate applied at 2 to 4 oz. per acre to 9 month old fairway turf resulted in severe injury to creeping bentgrass. Complete loss of creeping bentgrass cover occurred following the second application of both rates. Applications of Xonerate at 1.0 oz per acre were arrested after 3 applications due to severe damage to creeping bentgrass. According to label recommendations Xonerate should not be applied when air temperatures exceed 85 F, or immediately prior to or after high temperatures are forecast. In Storrs, temperatures did not exceed 85 F during the trial until 28 May, 12 days after the last application. In other studies Xonerate has provided effective annual bluegrass control without significant injury to bentgrass. Label recommendations also suggest that Xonerate should not be applied to bentgrass that has not been established for less than 6 months. It may be possible that maturity of the 9 month old bentgrass fairway was a factor in the injury observed on bentgrass in the current trial. Use caution if considering using Xonerate, it is advisable to test this herbicide for phytosafety on a small area before making broadcast applications.

PoaCure provided little annual bluegrass control at the time of printing. Previous research with this material suggests that up to four applications in the spring and early summer may be required to control annual bluegrass. No phytotoxicity to creeping bentgrass was observed with PoaCure treatments, and turf quality remained high throughout the trial (Table 2). Cutless initially discolored creeping bentgrass reducing turf quality, although following continued applications turf eventually became darker green and quality improved.

Table 1. Annual bluegrass stand composition and injury in 'Mackenzie' creeping bentgrass fairway turf treated with herbicides to control annual bluegrass at the Plant Science Research Center, Storrs, CT during 2012.

Treatment	Rate per Acre	App code[z]	Poa Count 3 May	Poa Count 4 Jun	Percent Poa 13 Jul	Poa Injury 23 May	Poa Injury 8 Jun
			# of plants sq.ft.		% of stand	--0-5; 2=min--	
Poacure	27.4 fl oz	A	5.1	3.1 ab[y]	1.5	0.5 cd	0.5 c
Poacure	55.0 fl oz	AC	9.9	3.4 a	3.0	1.5 b	1.0 c
Xonerate	2.0 oz	AC	8.4	1.2 bc	2.3	0.8 c	4.0 b
Xonerate	4.0 oz	AC	6.9	0.0 c	0.0	4.0 a	5.0 a
Xonerate	1.0 oz	ACD	9.3	0.1 c	0.0	0.0 d	5.0 a
Cutless	8.0 oz	ADE	10.3	4.0 a	1.4	1.5 b	1.3 c
Untreated		--	6.2	2.8 ab	1.6	0.3 cd	0.5 c
ANOVA: Treatment (P > F)		-	0.1086	0.0026	0.1061	0.0001	0.0001
Days after treatment:		A	--	31	--	20	35
		C	--	18	48	7	22
		D	--	9	28	--	--
		E	--	--	29		

[z] Initial treatment (A) was applied on 3 May. Subsequent application dates correspond to respective letter: C=16 May, D=25 May, E=15 Jun.

[y] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test ($\alpha = 0.05$).

Table 2. Turf quality and NDVI in 'Mackenzie' creeping bentgrass fairway turf treated with herbicides to control annual bluegrass at the Plant Science Research Center, Storrs, CT during 2012.

Treatment	Rate per Acre	App code[z]	Turf Quality 16 May	Turf Quality 23 May	Turf Quality 8 Jun	Turf Quality 13 Jul	NDVI 17 May	NDVI 18 Jun
			----1-9; 6=maximum acceptable----				--reflectance index--	
Poacure	27.4 fl oz	A	5.8 a[y]	7.0 ab	7.0 b	6.3 ab	0.760 bc	0.760 a
Poacure	55.0 fl oz	AC	5.8 a	7.0 ab	7.0 b	7.0 a	0.767 b	0.748 a
Xonerate	2.0 oz	AC	4.8 b	4.8 c	2.8 c	5.8 b	0.742 d	0.697 b
Xonerate	4.0 oz	AC	3.0 c	1.0 d	1.0 d	2.0 c	0.721 e	0.334 c
Xonerate	1.0 oz	ACD	5.3 ab	6.3 b	1.0 d	1.0 c	0.753 c	0.290 d
Cutless	8.0 oz	ADE	4.8 b	7.0 ab	6.8 b	6.8 ab	0.783 a	0.755 a
Untreated			6.0 a	7.5 a	8.0 a	7.3 a	0.753 c	0.759 a
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment:		A	13	20	35	--	14	45
		C	--	7	22	48	1	33
		D	--	--	--	28	--	25
		E				29		

[z] Initial treatment (A) was applied on 3 May. Subsequent application dates correspond to respective letter: C=16 May, D=25 May, E=15 Jun.

[y] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test ($\alpha = 0.05$).

ANNUAL BLUEGRASS CONTROL WITH POACURE IN CREEPING BENTGRASS PUTTING GREEN TURF, 2012

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INTRODUCTION

Annual bluegrass (*Poa annua*) is a common component of golf course putting greens throughout the northern United States. The species is capable of forming a dense, fine-textured, turf under low mowing which makes it well adapted for putting greens. However, annual bluegrass possesses only fair tolerance to high temperatures and medium tolerance to low temperatures. Poor tolerance to environmental stress limits survival of this turf species either directly or indirectly by predisposing ABG to diseases such as dollar spot, summer patch and anthracnose.

Management inputs required to maintain healthy annual bluegrass playing surfaces are generally greater than turfgrass species such as creeping bentgrass which benefit from breeding programs intended to improve disease resistance and environmental stress tolerance. Despite costly efforts to maintain annual bluegrass this species commonly declines under severe environmental conditions causing a disruption in play and requiring renovation of playing surfaces.

Selective herbicides to reduce annual bluegrass in established creeping bentgrass putting greens would help turf managers transition these areas to more sustainable turfgrass species with improved environmental stress tolerance and disease resistance, thus reducing water and chemical applications necessary to maintain acceptable playing surfaces. A new herbicide has been purported to selectivity control annual bluegrass in established creeping bentgrass. The objectives of the current trial were to, i.) evaluate the efficacy of PoaCure (methiozolin) in controlling annual bluegrass in a mixed creeping bentgrass and annual bluegrass putting green turf; ii.) compare efficacy of multiple low rate applications to fewer applications at increased rates and; iii.) assess phytosafety on creeping bentgrass.

MATERIALS AND METHODS

This field study was initiated in 2012 on a mixed stand of 'Penn A-4' creeping bentgrass (*Agrostis stolonifera*) and annual bluegrass turf established on a Paxton sandy loam. Turf was mowed five days wk^{-1} at a bench setting of 0.125 inches. PoaCure treatments were applied 1, 2, 4 or 6 times at 0.6 fl. oz. 1000 ft^{-2} or 2 applications at 1.2 fl. oz. 1000 ft^{-2} on a 14 day interval. Plots measuring 3 x 6 feet were arranged in a randomized complete block design with 4 replications. Annual bluegrass cover was determined as a visual estimation of the population within each plot. Turf quality was assessed visually on a 1-9 scale where 9 is the best quality turf, and 6 represents the minimum level of turf quality.

RESULTS AND DISCUSSION

The field contained approximately 15% annual bluegrass at the initiation of the trial. The greatest reduction of annual bluegrass occurred when PoaCure was applied 4 or 6 times at 0.62 fl.oz.; or 2 applications at 1.26 fl. oz. One or two spring applications at 0.62 fl.oz. did not reduce annual bluegrass compared to untreated.

During this trial, 6 applications did not improve annual bluegrass control compared to 4 applications at the same rate. Two applications at the 1.26 fl.oz. rate also provided statistically similar annual bluegrass control.

No phytotoxcicty was observed with any treatments, and turf quality was good throughout the trial (Table 1). However, in a separate study conducted simultaneously in Greenwich, CT, unacceptable bentgrass injury was observed when PoaCure was applied 6 times at 0.6 fl.oz. or 2 times at 1.2 fl.oz. In that study, bentgrass injury developed shortly after the second application of 1.2 fl.oz., and not until the 6th application of PoaCure applied at 0.6 fl.oz. Injury at the lower rate seemed to develop as treatments continued into July during increased summer temperatures.

Based on these data, spring PoaCure applications for annual bluegrass control in creeping bentgrass putting green turf should be limited to 4 applications on a 14-d interval completed before air temperatures exceed 85F.

Table 1. Annual bluegrass cover and turf quality in a mixed creeping bentgrass and annual bluegrass putting green turf treated with PoaCure at the Plant Science Research and Education Facility, Storrs, CT during 2012.

Treatment	Rate per 1000 ft^2	App. code[z]	Annual Bluegrass Cover		Turf Quality		
			9 Jul	23 Aug	23 May	11 Jun	9 Jul
			--- percent area covered ---		-- 1-9; 6=minimum acceptable --		
PoaCure	0.62 fl oz	AB	10.5 a[y]	7.4 a	6.5	6.8 c	6.8 bc
PoaCure	0.62 fl oz	ABCD	3.4 b	3.0 abc	6.5	7.0 bc	6.8 bc
PoaCure	0.62 fl oz	ABCDEF	3.3 b	2.1 bc	6.8	7.3 abc	6.5 c
PoaCure	1.26 fl oz	AB	1.0 b	0.6 c	6.3	7.0 bc	7.3 ab
PoaCure	0.62 fl oz	A	8.3 a	6.3 ab	6.5	7.8 a	7.0 abc
Untreated			11.5 a	5.6 ab	7.0	7.5 ab	7.5 a
ANOVA: Treatment ($P > F$)			0.0003	0.0450	0.0866	0.0328	0.0495

[z] Treatments were applied on the corresponding dates: A= 3 May, B = 14 May, C = 31 May, D= 15 Jun, E= 28 Jun, F = 12 Jul 2012.

[y] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test ($\alpha = 0.05$).

ANALYSIS OF PREOVIPOSITIONAL BEHAVIORS OF SUMMER TIPHIA (*Tiphia popilliavora*) ON LARVAE OF JAPANESE AND ORIENTAL BEETLES

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INTRODUCTION

Two important scarab beetle species, the Japanese beetle (*Popillia japonica*) and oriental beetle (*Anomala orientalis*) are considered invasive species and have been reported as key pests of urban landscapes and of various other agricultural settings in the Northeast. The larvae of Japanese beetles primarily feed on the roots of a wide variety of plants, including all cool season grasses and most weeds that are commonly found in turfgrass sites. The root-feeding larvae of oriental beetles, are a major pest of blueberries, ornamental nurseries, and turfgrass. *Tiphia popilliavora* Rohwer (summer Tiphia), was introduced as part of the biological control effort against *P. japonica*. Adult *T. popilliavora* emerge in August and September. Female summer Tiphia wasps burrow into the soil and search for grubs. When a host is found, the wasp paralyzes it momentarily and attaches an egg in the crease between the fifth and sixth abdominal segments (Clausen et al. 1927, Legrand 2009). The resulting parasitic larva feeds externally by piercing the grub's integument and imbibing host body fluids. The full-grown larva spins a silken cocoon and passes the winter within the cocoon (Rogers and Potter 2002).

T. popilliavora attacks both *P. japonica* and *A. orientalis* grubs in older stages of development (second or third instars) during late summer. Recent surveys indicated that *T. popilliavora* is present in Connecticut and the collected wasps readily oviposited on *P. japonica* and *A. orientalis* larvae (Legrand 2009). In a previous study, Rogers and Potter (2002) described and compared the oviposition process of *T. vernalis* and *T. pygidialis* on their respective host species based upon the videotaped oviposition events. No recent studies have examined the preovipositional behaviors of *T. popilliavora* (Rogers and Potter 2004). Further, it is not clear whether *T. popilliavora* wasps prefer one host species over the other. No empirical studies have examined the field parasitism rates of *P. japonica* and *A.orientalis* by *T. popilliavora*. Therefore, the objectives of this study were: 1) to examine the oviposition process of *T. popilliavora* on *P. japonica* and *A.orientalis* based upon videotaped oviposition events; and 2) to determine whether the sequence, duration, and frequency of preovipositional behaviors of *T. popilliavora* vary when the wasp attacks *P. japonica* versus *A. orientalis*.

MATERIALS & METHODS

An observation chamber was used to simulate below-ground conditions and view the preovipositional behaviors of the wasp while in the soil. Two panes of glass (bottom, 27 × 30 cm; top, 20 × 20 cm), positioned horizontally, were separated by an outline of modeling clay. The gap between the glass panes (~ 0.75 cm) was filled with autoclaved, moist sifted soil. A 10-cm long piece of flexible plastic tubing was inserted through a break in the modeling clay at one end of the observation chamber to allow for introduction of wasps. A previous study on preovipositional behaviors of *T. vernalis*, and preliminary observations on *T. popilliavora* showed that the oviposition process is lengthy, requiring a mean of 4 hrs. Therefore, a color video camera (Panasonic WV– CP504) was used to record each oviposition event. The camera was positioned 0.3 m above the observation chamber and the recordings were made under low-light conditions with only a red bulb (40 W) as a light source. For each oviposition event recorded, a host-grub and a wasp were introduced to the soil-filled observation chamber. Later the recordings were played back for scoring and analysis. Sequence, frequency, and duration of behaviors before oviposition were scored and analyzed using the 'Noldus Observer' behavior recording software. Ten separate oviposition events were recorded for *T. popilliavora* ovipositing on *P. japonica* and on *A. orientalis*.

The sequence of preovipositional behaviors on *P. japonica* and *A. orientalis* was developed based on lag sequential analysis using the Observer® XT (version 10.5) software. Lag-sequential analysis begins by designating one behavior as the 'criterion' behavior. Then a set of probability profiles was constructed one for each of the other behaviors. Each profile graphs the conditional probabilities for the particular behavior immediately following the criterion behavior (lag 1). Peaks of the probabilities indicates sequential positions following the criterion at which a given behavior is more likely to occur, whereas valleys indicate positions at which it is less likely to occur (Lehner 1996). Duration and frequency of each behavior performed *by T. popilliavora* ovipositing on *P. japonica* and *A. orientalis* were compared using Mann- Whitney U test (Wilcoxon rank sum test) and two-sample t-test respectively, using SAS 9.3.

RESULTS & DISCUSSION

Pre-ovipositional behaviors of *T. popilliavora*.

Naïve female wasps of *T. popilliavora* performed six distinct behaviors when they attack both *P. japonica* and *A. orientalis* third-instar larvae. These pre-ovipositional behaviors include, stinging, examining, moving soil, kneading, host-feeding, and host scraping. Before oviposition *T. popilliavora* locate the host using species specific kairomones present in grub frass and body ordor trails (Obeysekara and Legrand 2011).

Stinging. As soon as the wasp makes antennal contact with the host, it advances onto the region of the grub's thorax, and then wraps her abdomen around the ventral-side of the body.

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Then it inserts the stinger in the area of thoracic ganglia usually between the first and second segments resulting in temporary paralysis of the host (Figure 1A). This stinging behavior was repeated up to five separated stinging acts (Fig. 3), each directed at the first and second segments of the thorax and lasts for average of 0.63 min for *P. japonica* and 1 min for *A. orientalis*. Several studies have shown that paralysis caused by stinging may serve to protect the parasitoid from the defensive responses from the relatively larger host and facilitate long lasting oviposition events (Rogers and Potter, 2004, Steiner 1986).

Examining. Upon stinging, the wasp was observed examining the host by walking in circles over and around the grub while antennating it and the surrounding soil (Figure 1B). Each examining event was brief and lasted up to 0.40 min. Brunson (1938) reported that *T. popilliavora* have the ability to control the sex of its offspring. When they lay eggs on the second-instar *P. japonica* the eggs will develop into males whereas when the eggs are laid on third-instars they develop in to females. Thus, host examination may help the parasitoid to gauge the size of the host when determining the sex of offspring to allocate to a host. Other species of parasitoids have been shown to determine host size in similar manners (Rogers and Potter, 2002, Sandlan 1979, Schmidt and Smith 1985).

Moving soil. Wasps were observed moving soil away from the grubs to facilitate the orientation of the grub during the process of oviposition. Wasps use their forelegs to dig the soil from around the grub and push soil away with the abdomen.

Kneading. The wasp firmly grasps each body segment of the grub using its mandibles (Figure 1C). This starts at the mid-abdominal region of the grub, with the wasp working its way to the posterior region and then back to the host's head. Upon, kneading the segments with the mandibles, the wasp uses her abdomen to push against the segment that she recently kneaded. After several bouts of kneading the wasp moves the grub in to a C-shape position.

Host Feeding. The wasps were observed to feed on the paralyzed grubs on the area of the grub's thorax near the head capsule. They use their mouthparts to pierce grub's body and imbibe the hemolymph exuding from the wound. Host feeding has been observed for many other Tiphiid parasitoids (Clausen et al. 1927, Rogers and Potter 2004). It is shown that through feeding on the hosts wasps gain proteins and other nutrients for development of the eggs and other metabolic needs of the adult female (Rogers and Potter 2004, Quicke 1997).

Host scraping. During the oviposition process, scraping occurs just before the oviposition. The wasp coils itself transversely about the body in the mid-abdominal region and the sheath of ovipositor is applied to the crease between the fifth and sixth abdominal segments and worked back and forth for up to ~ 9 min. (Figure 1D and Figure 4). Scraping is the most time consuming pre-ovipositional behavior and is known to enlarge the crevices which facilitate easier perforation by the young larvae.

Sequence of pre-ovipositional behaviors

The sequence of pre-ovipositional behaviors by *T. popilliavora* on *P. japonica* and *A. orientalis*, including the conditional probabilities of behavioral transitions, is shown in Figure 2. The sequence of wasp behaviors did not show a difference between *P. japonica* and *A. orientalis*. Roger and Potter (2004) also recorded similar sequences and conditional probabilities of event transition for *T. vernalis* and *T. pygidialis* on their respective hosts.

Frequency and duration of behaviors

There was a trend for *T. popilliavora* to perform all six behaviors more often on *A. orientalis* than on *P. japonica* (Figure 3). However, there was no significant difference between the two host species on total number of acts for each behavior. Of the six behaviors leading to oviposition, *T. popilliavora* spent significantly longer time stinging *A. orientalis* compared to *P. japonica* (df = 1, $\chi^2 = 5.6743$, $P = 0.0172$, Figure 4) In contrast, the wasp spent significantly more time scraping on *P. japonica* than *A. oreintalis* (df = 1, $\chi^2 = 6.6057$, $P = 0.0102$). However, the total time the wasp spent on each host species was not significantly different (df = 1, $\chi^2 = 0.0514$, $P = 0.8206$). Based on our observations, *A. orientalis* grubs showed a higher frequency of vigorous movements with initial contact with the wasps' antennae than did *P.japonica* grubs. This could explain the longer time the wasp spent on stinging *A. orientalis* compared to *P. japonica*. Scraping using the ovipositor sheath and abdominal rasping may enlarge and roughen the crease between fifth and sixth abdominal segments by wearing away the integument (Clausen et al., 1927). No empirical studies have examined the textures of integuments between different white grub species. If the integuments of *P. japonica* and *A. orientalis* are texturally different, then it might explain why the duration of host scraping by *T. popilliavora* varies between two host species.

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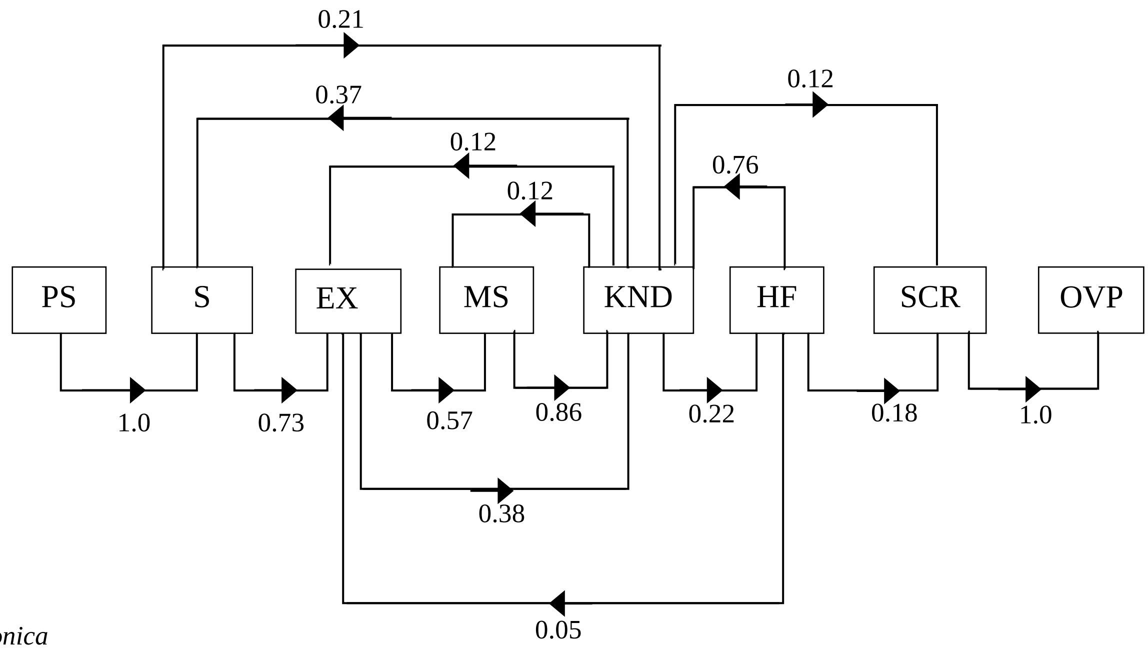
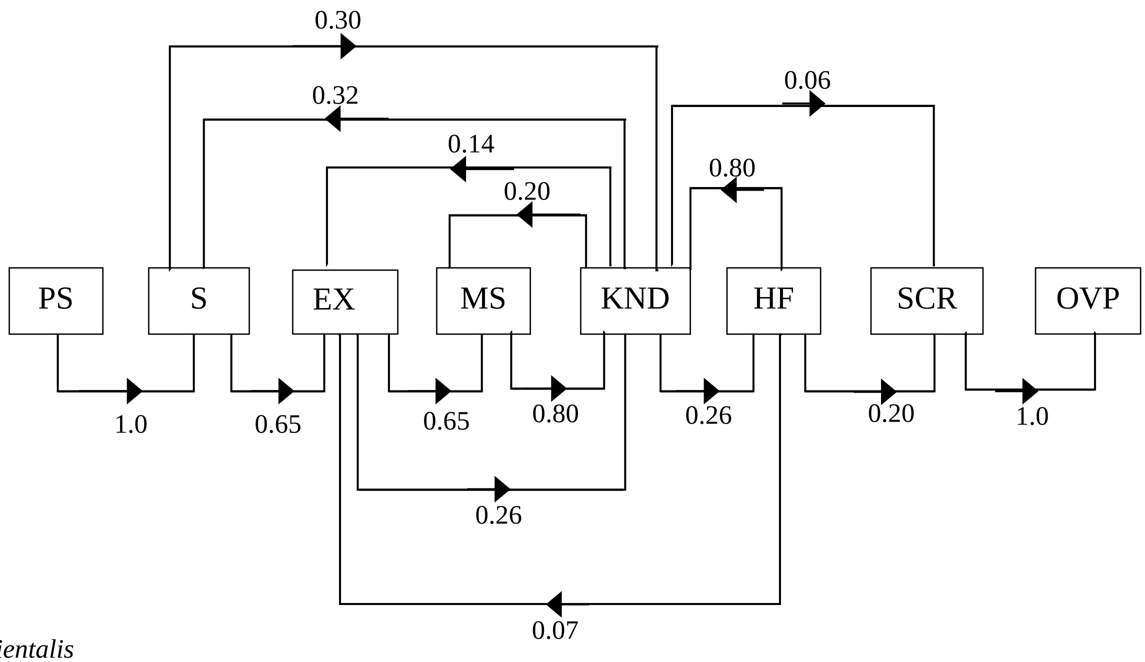
Figure 1. Behavioral acts performed by *T. popilliavora* ovipositing on *P. japonica*. (A) Host stinging. (B) Host examining. (C) Host kneading using it’s mandibles. (D) Host scraping.



Popillia japonica



Anomala orientalis

Figure 2. Flow charts of the behavioral activities of *T. popilliavora* ovipositing on *P. japonica* (upper chart) and on *A. orientalis* (lower chart). Numbers associated with arrows are the conditional probabilities of an indicated transition. PS, pre-stinging behaviors; S, stinging; EXM, examining host; MS, moving soil around the host; KND, Kneading host; HF, host feeding; SCR, scraping; OVP, oviposition.

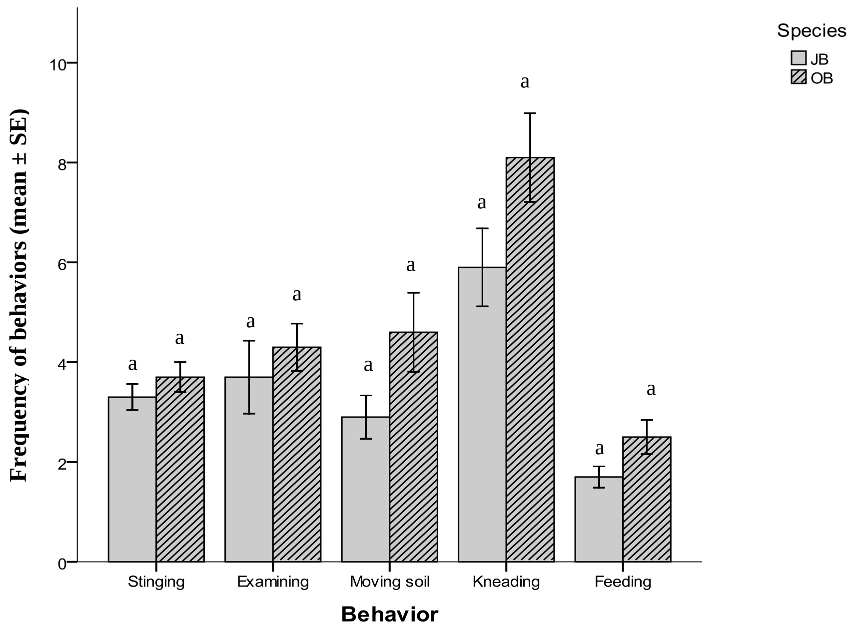


Figure 3. Frequency of behaviors (mean ± SE) performed by *T. popilliavora* on *A. orientalis* and *P. japonica* during each oviposition trial (n=10). JB, *P. japonica*; OB, *A. orientalis*. For each behavior, means with the same letter do not differ significantly (two-sample *t* test; $P \geq 0.05$).

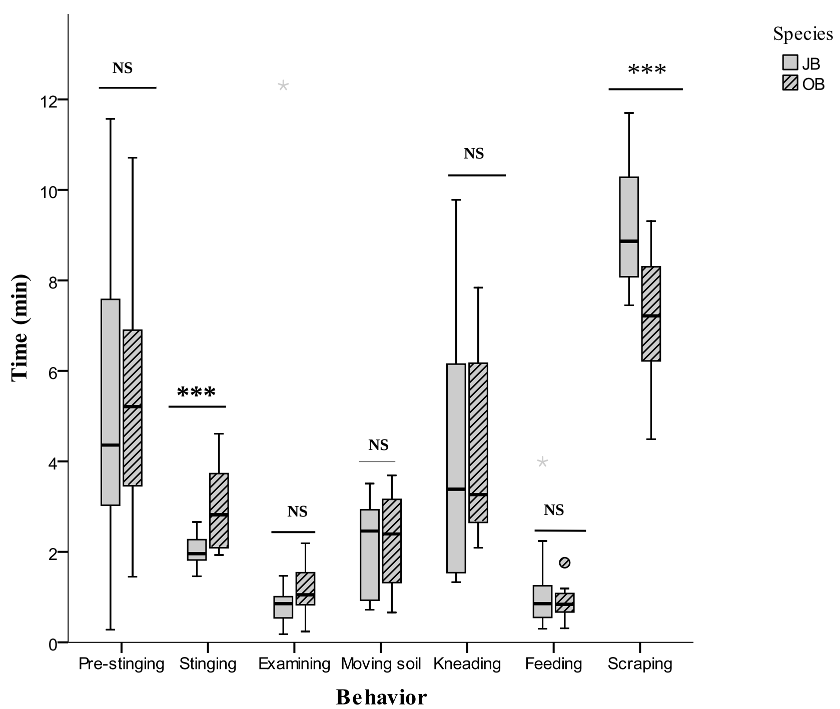


Figure 4. Total time that *T. popilliavora* performed each behavior during the process of oviposition. JB, *P. japonica*; OB, *A. orientalis*. (Mann- Whitney U test *** $P < 0.05$, illustrating medians, 25th and, 75th percentiles).

BEHAVIORAL DEFENSES OF JAPANESE AND ORIENTAL BEETLE LARVAE AGAINST TIPHIID WASPS

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INTRODUCTION

During the late 1920s and early 1930s, the US Department of Agriculture (USDA) introduced several parasitoid wasp species in order to control the outbreak of Japanese beetles, *Popillia japonica* (Ramoutar and Legrand 2007). Of these, two species of tiphiid wasps, *Tiphia vernalis* Rohwer and *Tiphia popilliavora* Rohwer were successfully established as biocontrol agents against Japanese beetle grubs (Ramoutar and Legrand 2007). *T. vernalis* and *T. popilliavora* are also parasitoids of oriental beetles (*Anomala orientalis*). These parasitic wasps burrow into the soil and search for grubs. When a host is found, the wasp paralyzes it momentarily and attaches an egg in a location that is species specific.

Several studies have shown that the field parasitism rate of *T. vernalis* on *P. japonica* is greater than the rate on *A. orientalis* (Reding and Klein 2007; Legrand 2009). No empirical studies have examined the *T. popilliavora* field parasitism rates on *P. japonica* and on *A. orientalis*. Moreover, the host acceptance of Tiphiid wasps is rarely addressed in the literature. Host acceptance is the process whereby the host is detected and utilized by the parasitoid and can be influenced by several host-related factors including shape, size, movement, and sound, although chemicals play an important role (Harvey and Thompson 1995, Vinson 1976). Both third-instar *P. japonica* and *A. orientalis* grubs are almost equal in shape and size (Vittum et al., 1999). This suggests that the host acceptance might not be attributed to the size or the shape of grubs. In a previous study, Rogers and Potter (2002) reported that *P. japonica* grubs show defensive behaviors with response to parasitism by *T. vernalis* such as rubbing their abdomen against the wasp's abdomen, biting at the attacking wasp, and burrowing away with initial contact with the wasps' antennae. The defensive behaviors of *P. japonica* and *A. orientalis* grubs in response to parasitoid attack may vary and could affect the success of *Tiphia* wasps. Examining the sequence, frequency, and duration of defensive behaviors of *P. japonica* and *A. orientalis* grubs upon attack by Tiphiid wasps could provide the basis for understanding how defensive behaviors of a particular host species affect *Tiphia* wasps. Therefore, the objective of this study was to determine whether the sequence, duration, and frequency of defensive behaviors *P. japonica* and *A. orientalis* vary when they are attacked by *T.vernalis* and *T. popilliavora*.

MATERIALS & METHODS

An observation chamber was used to simulate below-ground conditions and view the behaviors of the grubs before being stung by the wasp while in the soil. Two panes of glass (bottom, 27 × 30 cm; top, 20 × 20 cm), positioned horizontally, were separated by an outline of modeling clay. The gap between the glass panes (~ 0.75 cm) was filled with autoclaved, moist sifted soil. A 10-cm long piece of flexible plastic tubing was inserted through a break in the modeling clay at one end of the observation chamber to allow for introduction of wasps. A color video camera (Panasonic WV–CP504) was used to record the grub defensive behaviors upon attack by the wasp. The camera was positioned 0.3 m above the observation chamber and the recordings were made under low-light conditions with only a red bulb (40 W) as a light source. For each trial recorded, a host-grub and a wasp were introduced to the soil-filled observation chamber. Later the recordings were played back for scoring and analysis. Sequence, frequency, and duration of defensive behaviors of *P. japonica* and *A. orientalis* upon attack by Tiphiid wasps were scored and analyzed using the 'Noldus Observer' behavior recording software. Ten separate trials were recorded for each host and parasitoid species combination.

The sequences of defensive behaviors of *P. japonica* and *A. orientalis* attacked by Tiphiid wasps were developed based on lag sequential analysis using the Observer® XT (version 10.5) software. Lag-sequential analysis begins by designating one behavior as the 'criterion' behavior. Then a set of probability profiles was constructed for each of the other behaviors. Each profile graphs the conditional probabilities for the particular behavior immediately following the criterion behavior (lag 1). Peaks of the probabilities indicates sequential positions following the criterion at which a given behavior is more likely to occur, whereas low values indicate positions at which it is less likely to occur (Lehner 1996). Further visualization profiles were developed based on the relative time taken to perform each behavior by *P. japonica* and *A. orientalis* when attacked by *Tiphia* wasps using the Observer® XT (version 10.5) software. Duration and frequency of each defensive behavior performed by *P. japonica* and *A. orientalis* upon attack by *T. vernalis* and *T. popilliavora* were compared using Mann- Whitney U test (Wilcoxon rank sum test), using SAS 9.3.

RESULTS & DISCUSSION

Defensive behaviors of *P. japonica* and *A. orientalis*

The defensive behaviors performed by *P. japonica* and *A. orientalis* with response to initial contact by the wasp and up to the point when the grub is being stung by the wasp were broadly divided into three categories. These defensive behaviors include: vigorous movements, rubbing their abdomen or head against the wasp's abdomen, and biting at the attacking wasp.

Vigorous movements. With the initial contact with the wasps' antennae both *P. japonica* and *A. orientalis* grubs were observed to twist and turn with quick writhing movements. As soon as the wasp advanced onto the grub, the grub crawled rapidly and burrowed away from the wasp. These vigorous movements may help the grub to free itself from an attacking wasp and to move away from the second attack by the same wasp (Harvey and Thompson 1995, Rogers and Potter 2004). Of the three defensive behaviors, both grub species spent longer time on vigorous movements and these movements lasted up to ~ 6 min (Figure 4).

Biting. Both *P. japonica* and *A. orientalis* larvae were observed to lift their head toward the wasp and open their mandibles. Each biting event was very brief and lasted less than a second. Biting at the attacking wasp is considered as an aggressive behavior which drives off or disables the attacking parasitoid (Gross 1993). It has been shown that due to this defensive biting response some wasps lose parts of their antenna and such injury could impair the ability of wasps to locate and parasitize subsequent hosts (Rogers and Potter 2002, Rogers and Potter 2004).

Rubbing the abdomen or head against the wasp's abdomen. Grubs were observed to rub their head or abdomen against the wasp's abdomen as soon as the wasp inserted the stinger in the area of thoracic ganglia usually between first and second segments of the grub's thorax.

Sequence of defensive behaviors

The sequence of defensive behaviors of *P. japonica* and *A. orientalis* when attacked by *T. vernalis* and *T. popilliavora*, including the conditional probabilities of behavioral transitions, is shown in Figure 1. The sequence of grub defensive behaviors did not show a difference between *P. japonica* and *A. orientalis* when they are attacked by *T. vernalis* and *T. popilliavora*. When the wasp's antennae made initial contact with a grub, the grub often responded by twisting and turning with quick writhing movements and attempting to burrow away. Then as soon as the wasp advanced onto the region of the grub's thorax both *P. japonica* and *A. orientalis* larvae were observed lifting their heads toward the wasp and biting using their mandibles. When the wasp wraps her abdomen around the ventral-side of the grub's body and inserts the stinger in the area of thoracic ganglia, grubs tend to rub their head or abdomen against the wasp's abdomen to displace the stinger. Grubs were observed to perform either vigorous movements or to rub their head or abdomen against wasps' abdomen immediately before the temporary paralysis caused by the wasp's venom. Several studies have shown that after contact, many hosts defend themselves by biting, writhing, trashing, regurgitating fluids aimed at the parasitoid, crawling, burrowing and by head or abdominal flicking and rearing (reviewed in Gross, 1993, Godfray 1994, Harvey and Thompson 1995).

Frequency and duration of defensive behaviors

Frequency and duration of defensive behaviors when attacked by *T. vernalis*

Vigorous movements were performed more often by *A. orientalis* than *P. japonica*. (Figure 3, df = 1, χ^2 = 4.6801, P = 0.0305). Of the three defensive behaviors, *A. orientalis* grubs spent significantly more time on vigorous movements than *P. japonica* (Figure 2 and 4, df = 1, χ^2 = 3.8629, P = 0.0494). Vigorous movements are evasive behaviors that allow a potential host to free itself from an attacking parasitoid or to remove itself from the immediate area (Gross 1993). The active host resistance gained thorough vigorous movements by *A. orientalis* may prevent successful oviposition by *T. vernalis* and could make the grubs less susceptible to parasitoid attack. However, the total time spent on defensive behaviors by *A. orientalis* and *P. japonica* did not show a significant difference (df = 1, χ^2 = 2.7657, P = 0.0963). There was no difference in the number of biting acts (df = 1, χ^2 = 0.5342, P = 0.4649), and number of times grubs rubbed their head or abdomen against wasp's abdomen (df = 1, χ^2 = 0.1532, P = 0.6955).

Frequency and duration of defensive behaviors when attacked by *T. popilliavora*

There was no difference in the number of vigorous movements (Figure 5, df = 1, χ^2 = 0.0953, P = 0.7575), number of biting events (df = 1, χ^2 = 0.2935, P = 0.5880), or number of rubbing acts (df = 1, χ^2 = 0.0792, P = 0.7784) between the grub species. There was also no significant difference between the two grub species in their total duration of vigorous movements and rubbing acts (Figure 6, df = 1, χ^2 = 0.0914, P = 0.7624, df = 1, χ^2 = 0.3663, P = 0.5450) when they were attacked by *T. popilliavora*. Unlike *T. vernalis*, *T. popilliavora* attacks early third-instar and late-second instar grubs of *P. japonica* and *A. orientalis* during late summer (Vittum et al., 1999). The young larvae parasitized by *T. popilliavora* are relatively smaller compared to the fully-grown overwintered third instar larvae attacked by *T.vernalis*. Harvey and Thompson (1995) showed that host behavior with response to antennal stimulation could vary with species and instar. Moreover, it has been shown that ovipositional success of parasitoids decreases with host size where larger hosts tend to perform relatively violent defensive behaviors and gain aggressive resistance to parasitoid attack compared to the smaller size, early instars of the same species (Allen 1990, Gerling et al., 1990, Harvey and Thompson 1995).

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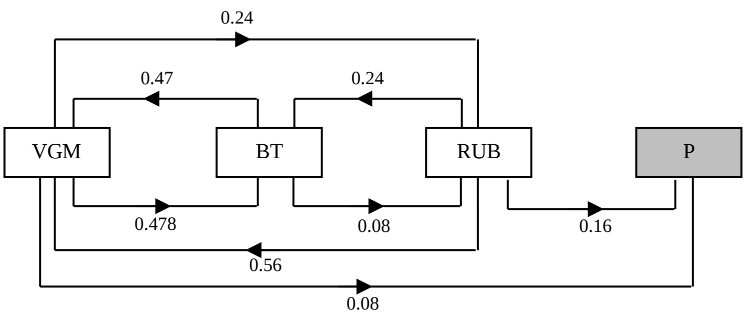
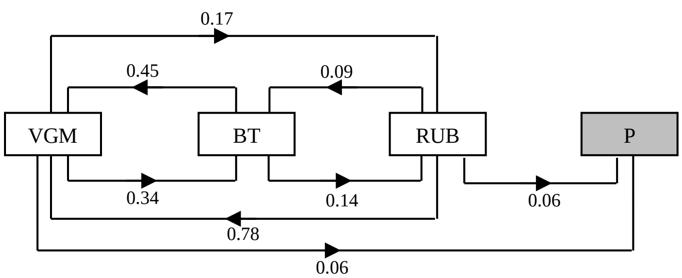
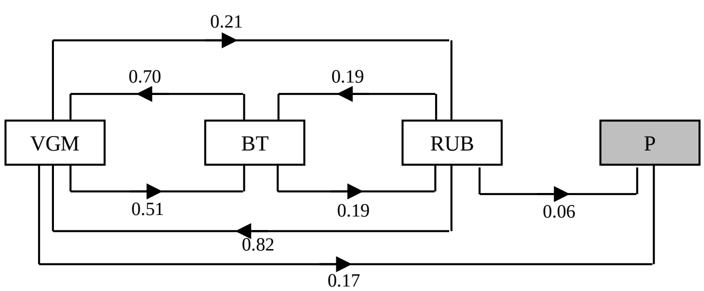


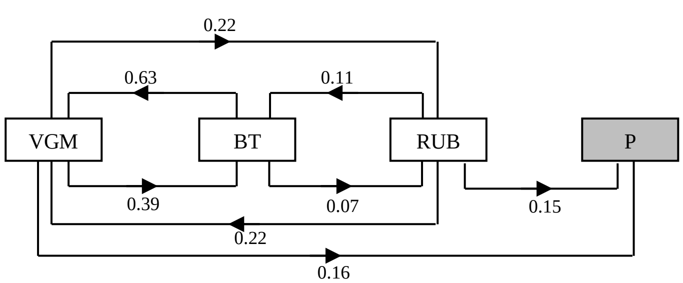
P. japonica attacked by *T. vernalis*



A. orientalis attacked by *T. vernalis*

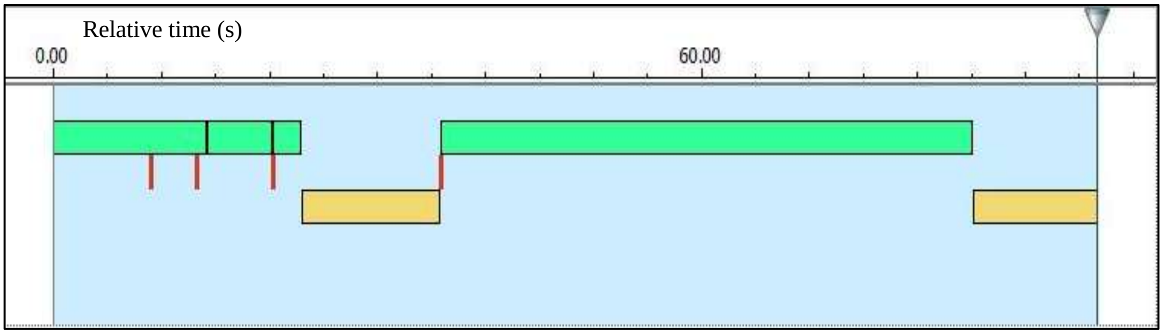


P. japonica attacked by *T. popilliavora*

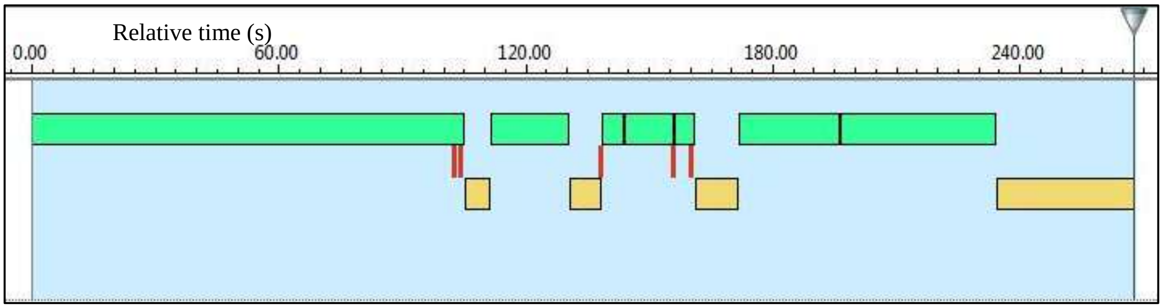


A. orientalis attacked by *T. popilliavora*

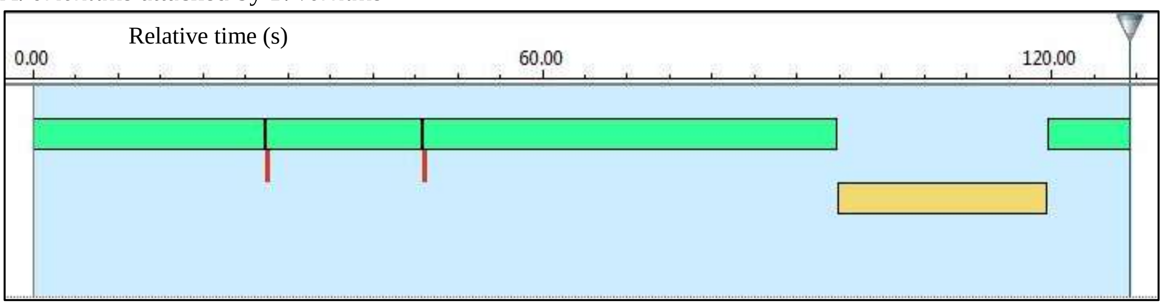
Figure 1. Flow charts of defensive behaviours of *P. japonica* and *A. orientalis* attacked by *T. vernalis* (upper two charts) and by *T. popilliavora* (lower two charts). Numbers associated with arrows are the conditional probabilities of an indicated transition. VGM, vigorous movements; BT, biting; RUB, rubbing head or abdomen against wasps' abdomen; P, Paralyzed.



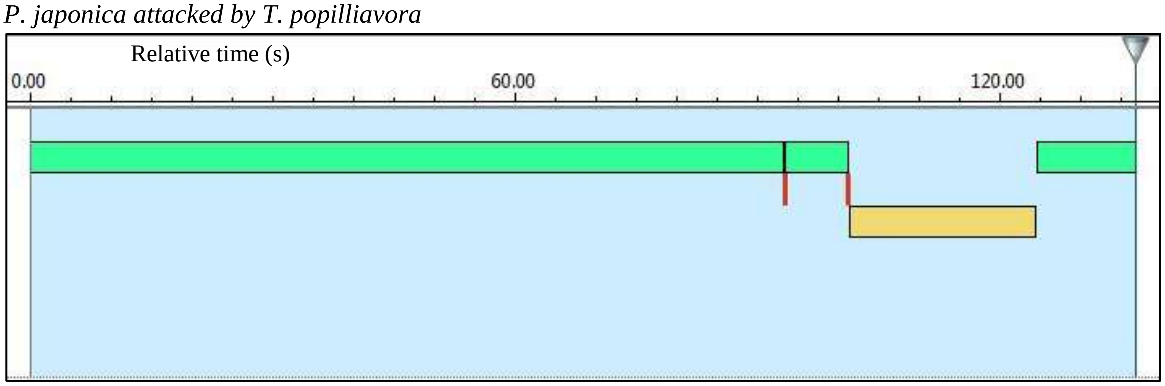
P. japonica attacked by *T. vernalis*



A. orientalis attacked by *T. vernalis*



P. japonica attacked by T. popilliavora



A. orientalis attacked by *T. popilliavora*

Figure 2. Typical visualization profiles which show the relative time that *A. orientalis* and *P. japonica* performed each defensive behavior before being stung by *T. vernalis* (upper two profiles) and by *T. popilliavora* (lower two profiles)

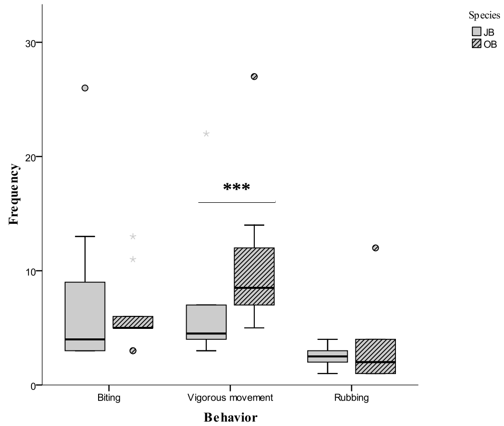


Figure 3. Frequency of behaviors performed by *P. japonica* and *A. orientalis* before being stung by *T. vernalis*. JB, *P. japonica*; OB, *A. orientalis*. (Mann- Whitney U test *** *P < 0.05*, illustrating medians, 25th and, 75th percentiles).

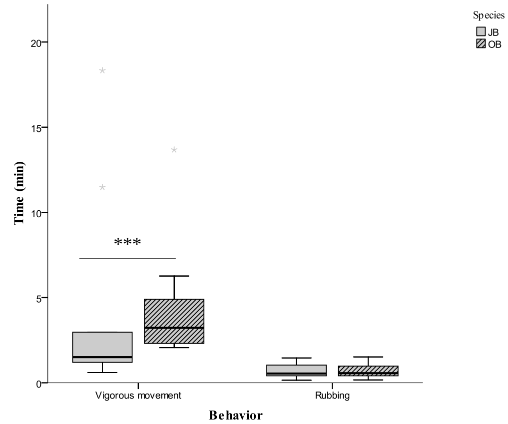


Figure 4. Total time that *A. orientalis* and *P. japonica* performed each defensive behavior before being stung by *T. vernalis*. JB, *P. japonica*; OB, *A. orientalis*. (Mann- Whitney U test *** *P* < 0.05, illustrating medians, 25th and, 75th percentiles).

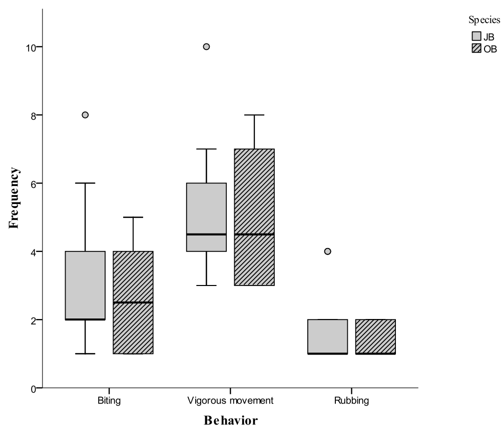


Figure 5. Frequency of behaviors performed by *P. japonica* and *A. orientalis* before being stung by *T. popilliavora*. JB, *P. japonica*; OB, *A. orientalis*. (illustrating medians, 25th and, 75th percentiles).

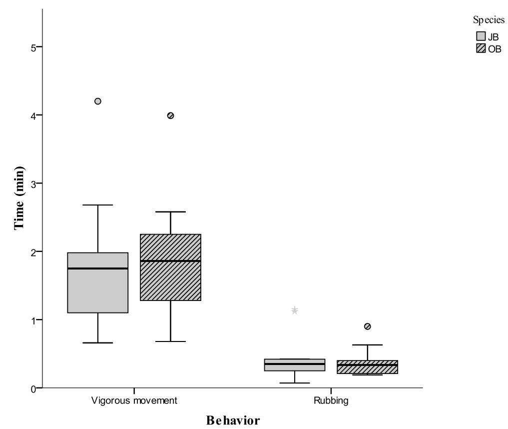


Figure 6. Total time that *A. orientalis* and *P. japonica* performed each defensive behavior before being stung by *T. vernalis*. JB, *P. japonica*; OB, *A. orientalis*. (illustrating medians, 25th and, 75th percentiles).

SURVEY OF TIPHIA PARASITOIDS OF THE JAPANESE AND ORIENTAL BEETLES IN MASSACHUSETTS AND NEW HAMPSHIRE

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INTRODUCTION

During 1920's and early 1930's USDA entomologists imported *Tiphia vernalis* Rohwer from Korea and *Tiphia popilliavora* Rohwer. (Hymenoptera: Tiphiidae) from Japan for Japanese beetle control. Several wasp releases were made throughout the northeastern United States. The primary target of these releases was the Japanese beetle. However, *T. vernalis* and *T. popilliavora* are parasitoids of the oriental beetle as well. These parasitoids feed on the larvae with *T. vernalis* attacking the 3rd instars during spring and *T. popilliavora* attacking 2nd or 3rd instars during late summer. Releases of *T. vernalis* were made between 1926 and 1949 in five of Massachusetts's fourteen counties and in three of New Hampshire's ten counties between 1936 and 1945. On the other hand, *T. popilliavora* was not released in Massachusetts or in New Hampshire by the USDA (King et al. 1951). *T. popilliavora* was released in other locations such as Connecticut between 1921-1940 (King et al. 1951). Surveys had confirmed the occurrence of *T. vernalis* and *T. popilliavora* in Connecticut (Ramoutar and Legrand 2007, Legrand 2009). However, since 1950 the status of *T. vernalis* in Massachusetts and in New Hampshire had not been monitored. In addition, the status of *T. popilliavora* remained to be investigated as very little information exists on this species' distribution after the initial releases in other states. Thus, the objective of this study was to determine the distribution and timing of occurrence of *T. vernalis* and *T. popilliavora* in Massachusetts and New Hampshire.

MATERIALS & METHODS

Tiphia vernalis Survey

In May and June of 2012 surveys were done by sampling turfgrass areas in public parks and recreational areas in Massachusetts counties where *T. vernalis* were originally released. Three New Hampshire counties were also visited. Wasps were attracted by spraying a 10% sugar solution on the grass or surrounding vegetation. Survey observations at each site were done every 30 min for 1 hour. Wasps were collected for identification according to Allen (1966) and Han and Kim (2009). Locations in Ware, Spencer, and Athol, MA were also visited weekly from mid-May to the end of June in order to determine the timing of *T. vernalis* adult wasp presence.

Tiphia popilliavora Survey

In August and September of 2012 surveys were carried out to determine the presence of *T. popilliavora* in Massachusetts and New Hampshire counties. Two to three public parks or recreational areas were visited per county starting on August 20th. At each location, wild carrot *Daucus carota* flowers were inspected for the presence of *Tiphia* wasps. A 10% sugar solution was sprayed on shrubs and tree branches adjacent to turfgrass areas when wild carrot plants were not present. Survey observations at each site were done every 30 min. for 1 hour. Wasps were collected for identification according to Allen (1966) and Han and Kim (2009). In addition, wasps were presented with Japanese or oriental beetle larvae for oviposition in order to gain more information on their identity. The specific egg location for this wasp is in the ventral crease between the 5th and 6th abdominal segments (Clausen et al. 1927).

RESULTS & DISCUSSION

Tiphia vernalis Survey

T. vernalis were found in all of the Massachusetts counties visited (Table 1). In 1950, the USDA had monitored the wasp presence in three of the five Massachusetts counties where *T. vernalis* had been originally released. At that time, wasps were not recovered from these locations (Table 1). *T. vernalis* adults were observed weekly in Ware, Spencer and Athol, MA. Wasps were observed starting in May 14 and the last adults observed in Ware and Athol were recorded on June 19th and June 26th, respectively.

In 2012, wasps were collected from Rockingham and Hillsborough counties in New Hampshire. Wasps were not collected from Cheshire county but only one location was visited in this county. Nevertheless, wasps were found in the neighboring Hillsborough county, NH to the east and Worcester county, MA in the south (Table 1).

Tiphia popilliavora Survey

T. popilliavora wasps were found in three of the seven Massachusetts counties visited (Table 2). The timing for the survey could have influenced the results since the survey dates in mid-September could have been late to detect wasp activity in some Massachusetts locations in 2012. However, it is significant to note that the species is found in northernmost

Massachusetts locations such as Athol in Worcester county and Methuen in Essex county.

The results from the New Hampshire survey indicate that *T.popilliavora* is present in all of the counties visited along the northern border with Massachusetts (Table 2). The 2012 survey documents the natural spread of this wasp to northern locations where it had not been released by the USDA and the results are an initial step to assist those persons wanting to conserve natural enemies of white grubs such as these *Tiphia* wasps.

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Table 1. Number of *Tiphia vernalis* colonies (100 females/colony) released by USDA and wasp presence as determined in 2012 surveys.

State	County	Colonies Released 1926 - 1949	Colonies Recovered in 1950	2012 Survey Results
Massachusetts	Worcester	2	0	Present
	Middlesex	1	0	Present
	Hampden	7	0	Present
	Hampshire	5	Not scouted	Present
	Franklin	1	Not scouted	Present
New Hampshire	Rockingham	0	Not scouted	Present
	Hillsborough	0	Not scouted	Present
	Cheshire	1	1	Not found

Table 2. Presence of *Tiphia popilliavora* per state and county as determined in 2012 surveys. Wasp colonies were not released by the USDA in 1921-1950.

State	County	2012 Survey Results
Massachusetts	Worcester	Present
	Hampden	Not found
	Hampshire	Present
	Franklin	Not found
	Essex	Present
	Bristol	Not found
	Norfolk	Not found
New Hampshire	Rockingham	Present
	Hillsborough	Present
	Cheshire	Present

DETERMINING THE IMPORTANCE OF LEAF COMPOST TOPDRESSING WHEN MANAGING ATHLETIC FIELDS ORGANICALLY

MAY 2012– DECEMBER 2012

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University of Connecticut

INTRODUCTION

Effective July 1, 2010, the state of Connecticut banned the usage of all lawn care pesticides on athletic fields at public and private schools grades pre-K through 8. Currently topdressing compost is being recommended by many as part of a pesticide free management program. However, the research-based information regarding compost topdressing on athletic fields is limited. Topdressing athletic fields with spent mushroom substrate (SPS) has been evaluated showing many positive impacts such as an increase in percent ground cover after wear, decreased bulk density, increased water retention, and decrease surface hardness (McNitt et al. 2004). However, composts can vary greatly and no research based information exists regarding topdressing leaf composts on athletic fields. Additionally, research on compost topdressing applications to soils ranging in organic matter content is very limited. Therefore, the potential benefit or detriment to increasing the organic matter level in a soil that is already considered suitable (4-6%) is not well understood. The specific objectives of this study are to: 1) Determine the effects of leaf compost and sand topdressing incorporated with core cultivation on soil physical properties when applied to low and high organic matter soils, and 2) Evaluate the effects of leaf compost topdressing and sand topdressing incorporated with core cultivation on the traffic tolerance of Kentucky bluegrass.

METHODS AND MATERIALS

The study is arranged in a Latin rectangle with three treatments and six replications 1) Leaf compost topdressing applied at ¼" in the spring and fall, 2) Sand topdressing applied at ¼" in the spring and fall (Table 1), and 3) No topdressing applied (Figure 1). Topdressing treatments were applied in the spring and fall of 2012. Plots were split by core cultivation at the end of the 2010 growing season. This means each topdressing treatment (sand, leaf compost and the untreated control) was split into two sub-plots. Half of each plot was core cultivated in two directions and the other half received no core cultivation. Cultivation was applied using a Ryan GreensAire II equipped with 5/8" hollow core tines. The first topdressing treatments were applied on May 31, 2012. All treatments were fertilized equally. Lime was applied on May 29, 2012 at a rate of 25 lbs per 1000 ft^2 to both plot areas to increase soil pH. Plots were mowed at 2" twice per week.

Traffic Simulation was conducted using a Cady Traffic Simulator, a modified walk-behind core cultivation unit. Traffic was applied three times per week for 11 weeks beginning on September 3, 2012 and ending in mid-November for a total of 26 traffic events. Data collected in this study included ratings of turf quality. This was done by visual rating using a scale of 1 to 9, where 1 = brown/dead turf; 6 = minimum acceptable quality; and 9 = optimum quality. Digital image analysis was utilized in assessing turf color and cover. Controlled light conditions were provided through the use of a light box. Images were scanned using Sigma Scan Software using the following threshold values; hue=55-125 and saturation=10-100. The Dark Green Color Index (DGCI) was calculated based on hue, saturation and brightness values. Color and quality data was collected on a biweekly basis. Surface hardness was measured using a Clegg impact hammer. Data was collected once a month from May 2012 to August 2012. Soil moisture readings were measured using a portable Field Scout TDR 300 probe (12 cm). Data was collected once a month from May 2012 to November 2012. Weed data was obtained for both crabgrass and broadleaf weeds. Due to increased populations of crabgrass during the 2012 growing season, crabgrass was rated on percent cover basis. Broad leaf weeds were assessed visually by counting each individual weed plant. Broad leaf counts and crabgrass percentage was done visually beginning on June 14, 2012 and was completed monthly through November. Undisturbed soil samples were extracted to assess soil bulk density and percent organic matter. Percent soil organic matter was assessed in spring 2012 before 2012 treatments were applied.

Figure 1. a) Sand topdressing being applied to the low organic soil plot area. b) Compost topdressing being applied to the high organic soil plot area. c) Low organic soil plot area after the treatments were applied. d) Incorporation of treatments using a Ryan GreensAire II Aerator.

Table 1: Particle size analyses of sand types. USGA recommendations for putting green.										
	Soil Separate %				% Retained					
Treatment	**Sand**	**Silt**	**Clay**	**No. 10 Gravel 2 mm**	**No. 18 VCS 1 mm**	**No. 35 CS 0.5 mm**	**No. 60 MS 0.25 mm**	**No. 100 FS 0.15 mm**	**No. 140 VFS 0.10 mm**	**No. 270 VFS 0.05 mm**
Coarse Sand (AA Will Mat. 2mm)	99.5	0.0	0.4	0.1	11.0	31.5	42.0	13.0	1.6	0.4
USGA Rec. for Putting Green Const		**$\leq$ 5%**	**$\leq$ 3%**	**$\leq$ 3% Gravel $\leq$ 10% Combined**		**$\geq$ 60%**		**$\leq$ 20%**	**$\leq$ 5%**	

RESULTS TO DATE

The compost treatments produced significantly darker green turf compared to the sand treatments during the spring on both soils. During the summer and fall, there was an overall treatment effect with compost treatments showing significantly darker green turf than the sand topdressed and untreated plots (Figure 2).

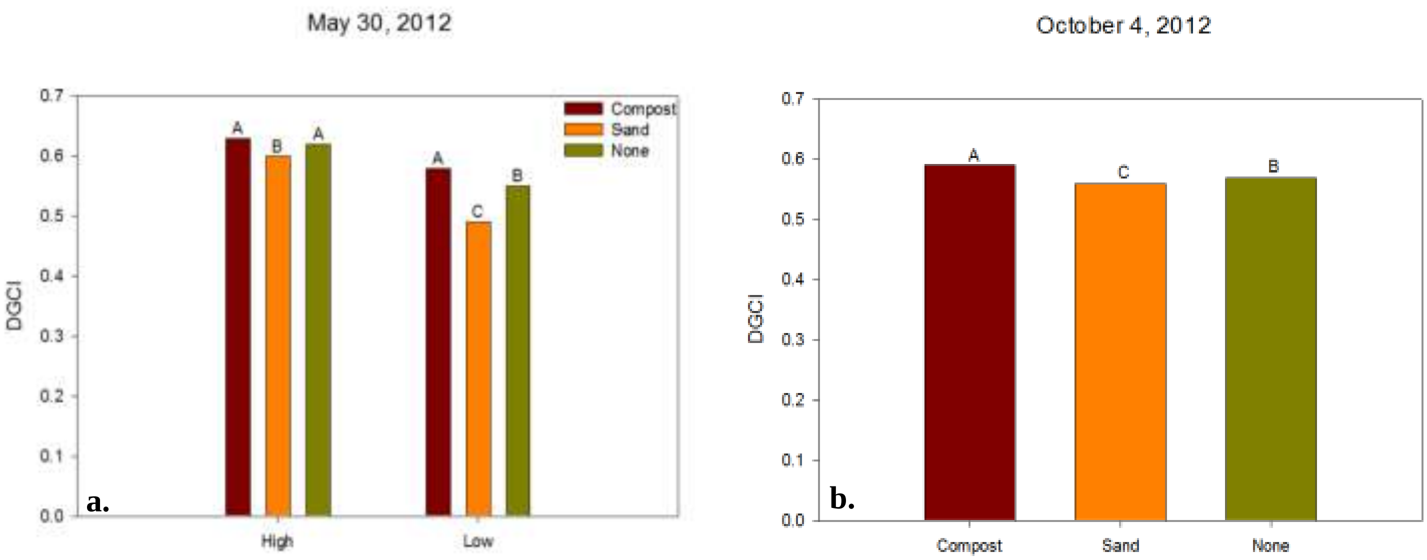

Figure 2. **a.)** The effect of leaf compost and sand topdressing treatments on turfgrass color when applied to two soils, 2012. **b.)** Overall topdressing effect of compost and sand topdressing applied during the 2012 growing season. Turfgrass color was quantified using digital image analysis.

The compost treatments produced significantly greater percent cover than the sand and the untreated control throughout the 2012 growing season on the high organic matter soil only. (Figure 3).

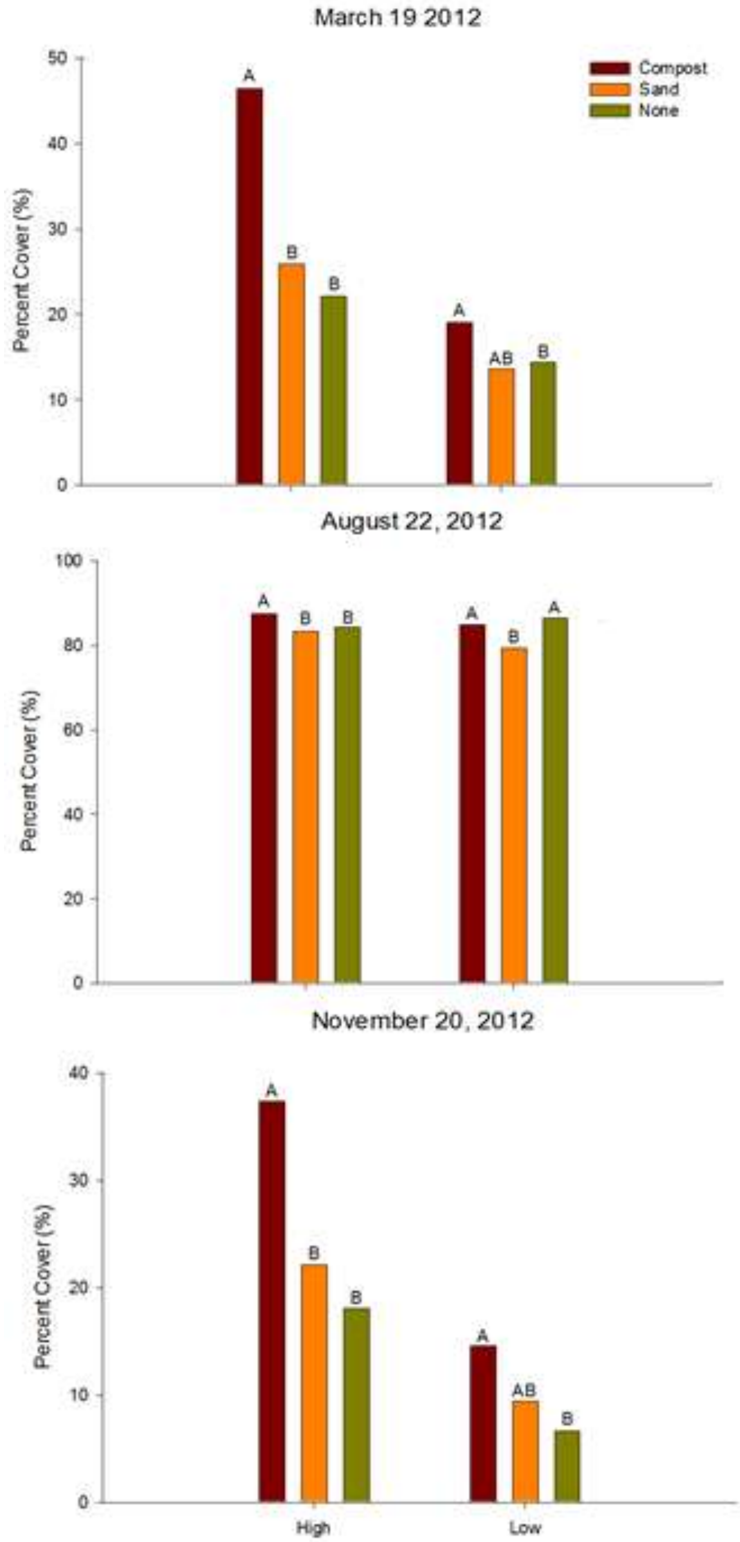

Figure 3. The effect of leaf compost and sand topdressing treatments on percent cover when applied to two soils, 2012.

Differences in broadleaf weed populations were observed as a soil main effect in June and July only. The high organic matter soil showed significantly higher broadleaf weed counts when compared to the low organic matter soil (Figure 4). There was also a treatment by cultivation interaction that showed inconsistent results.

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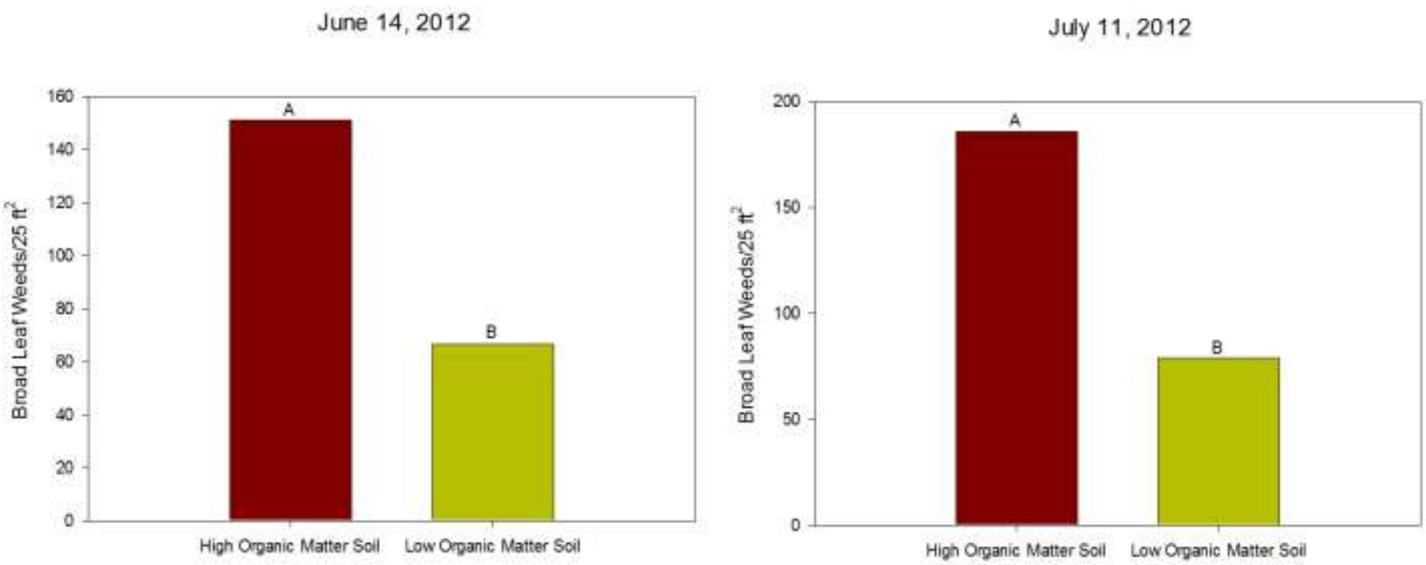

Figure 4. The high organic matter soil had significantly higher broad leaf weed populations in June and July of the 2012 growing season.

Compost topdressing applications showed significantly lower crabgrass populations when compared to the control in each soil during June and July only. During August, the composted treatments showed a decrease in crabgrass populations when compared to the control in the high organic matter soil only (Figure 5).

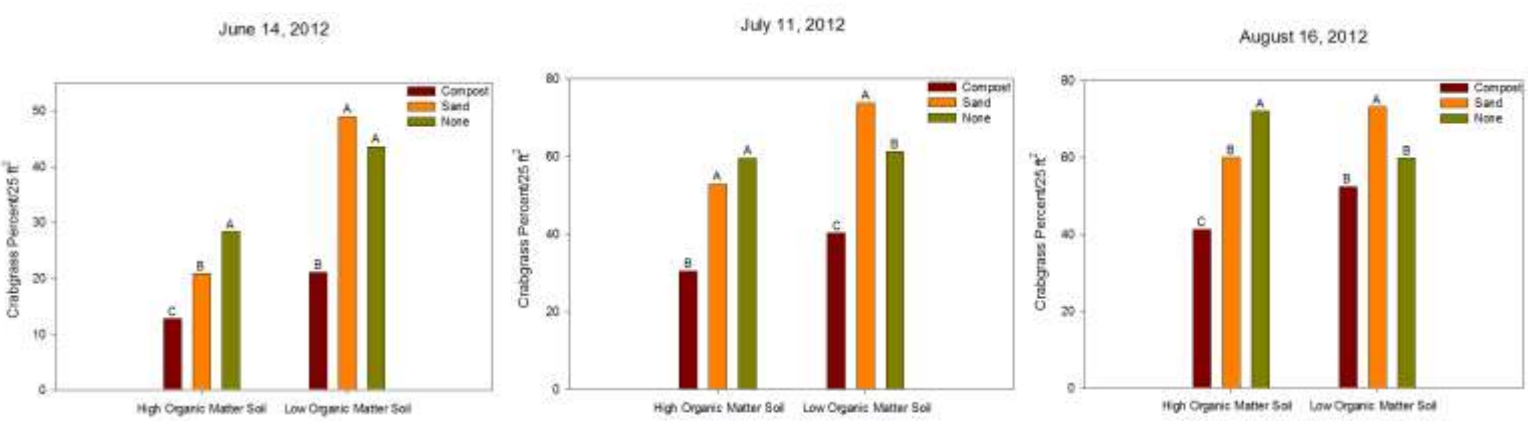

Figure 5. The effect of leaf compost and sand topdressing treatments on crabgrass when applied to two different soil types, 2012.

Applying leaf compost produced significant differences in volumetric soil moisture in the top 2" of the profile when compared to the sand or untreated control during the 2012 growing season regardless of soil type (Figure 6)

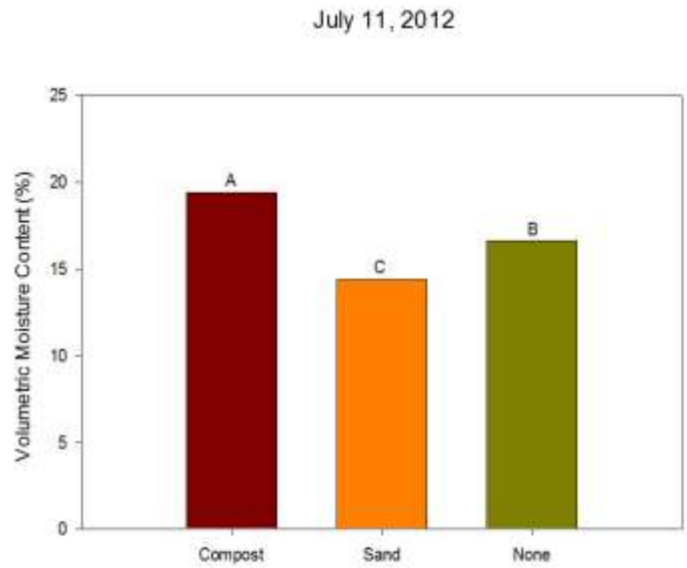

Figure 6. The effect of leaf compost and sand topdressing treatments on volumetric soil moisture, 2012.

The application of compost topdressing showed significantly higher organic matter content in the high organic matter soil only when compared to the sand topdressed plots and untreated control during the 2012 growing season (Figure 7

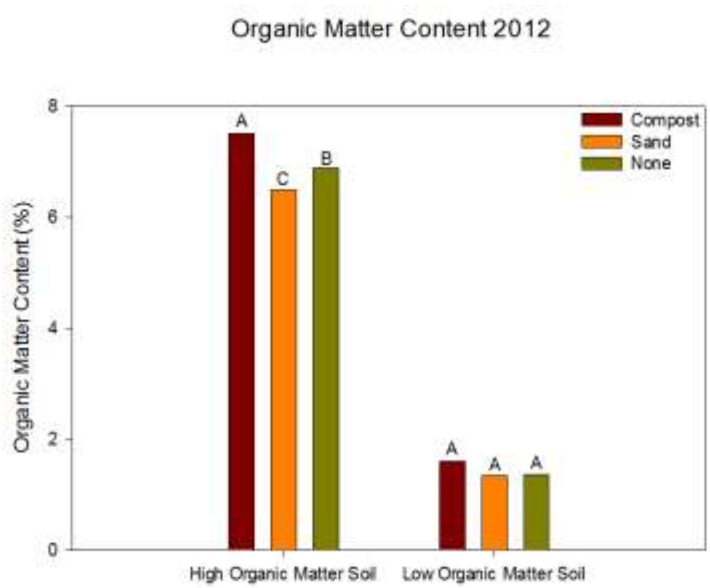

Figure 7. The effect of leaf compost and sand topdressing treatments on organic matter content, 2012.

SUMMARY TO DATE

The composted treatments showed significantly greater turf color compared to the sand and untreated control treatments regardless of soil type.

Leaf compost applications resulted in greater cover retention during the entire 2012 growing season on the high organic matter soil.

The high organic matter soil had increased broad leaf weed populations during June and July of the 2012 growing season regardless of topdressing treatments.

Compost topdressing applications showed decreased crabgrass populations when compared to the untreated control regardless of soil type in June and July only.

Leaf compost applications resulted in greater moisture retention regardless of soil type during the 2012 growing season.

Leaf compost applications resulted in higher organic matter content when compared to the sand topdressed and untreated control plots in the high organic matter soil only during the 2012 growing season.

LITERATURE CITED

McNitt, A. S., D. M. Petrunak, and W. X. Uddin. 2004. Evaluation of spent mushroom substrate as a topdressing to established turf. *Annu. Res. Rep. [Penn State]*. p. [102-110].

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ILLINOIS SOIL N TEST (ISNT) AND PERMANGANATE-OXIDIZABLE SOIL CARBON (POXC) CONCENTRATIONS AS PREDICTORS OF LAWN TURF RESPONSE
2012

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INTRODUCTION

The Illinois Soil N Test (ISNT) and the permanganate-oxidizable soil carbon (POXC) test may be able to predict the responsiveness of turf sites to N fertilization. The ISNT and POXC are thought to detect the amount of potentially labile N and C in soils, which is correlated to N mineralization and supplying capacity of a soil. In studies with corn, the ISNT has been relatively effective in predicting site responsiveness to N fertilization, especially when organic matter is taken into account, and POXC has correlated well with soil microbial activity. If applicable to turf, these tests may help guide N fertilization of turf sites so that optimum amounts of N are applied that maximize quality and reduce the threat of N leaching and runoff losses due to excess. These tests may be especially beneficial in guiding N fertilization rates of turf areas that receive organic fertilizers, composts, and amendments.

MATERIALS & METHODS

In September 2007, Kentucky bluegrass (*Poa pratensis*) and turf-type tall fescue (*Festuca arundinacea*; *Lolium arundinaceum*) were established in separate field plot experiments on a fine sandy-loam soil that received varying rates of the organic fertilizer compost Suståne. The experiments were set out as randomized complete block designs with three replicates. Suståne (5-2-4, fine grade, all natural) was applied to 1×1 m plots at 23 rates ranging from 0 to 400 kg available N ha^{-1}, and incorporated to a depth of 15 cm on September 3, 2007.Turf was managed as a lawn in subsequent years. Plots were mowed to a 7.5-cm height as needed, and did not receive irrigation. In the late fall of 2008, 2009, and 2010, plots were solid-tined aerified and compost was applied again to the same plots using the same rates, and brushed into the aerification holes.

In the spring of 2012, soil samples were collected from each plot to a depth of 10 cm below the thatch layer, and analyzed for concentrations of ISNT-N (Khan et al., 2001) and POXC (0.02M $KMnO_4$; Weil et al., 2003). During the 2012 growing season, plots were mowed to a height of 7.5 cm twice a week, or as needed depending on growth. No supplemental irrigation was applied. At approximately two-week intervals after soil sampling, and continuing until November, turf canopy reflectance was measured using a Spectrum TCM 500 NDVI reflectance meter (Spectrum Technologies, Inc., Aurora, IL). Nine measurements were taken per plot and averaged for each date. All measurements were taken on dry days between 1100hr and 1400hr. Clippings yield measurements were taken once a month from May through October each year, except for 2012 when five months were collected for Kentucky bluegrass and four months were collected for tall fescue due to weather-related reduced growth during the spring and early summer. Clipping samples were collected from a random $0.1m^2$ area in each plot with hand shears during the same day after NDVI measurements or one day later, then dried at 65°C for at least 48 h, weighed, ground to pass a 0.5mm sieve, and analyzed for concentrations of total N. Monthly clippings dry yield was summed across the growing season for each plot. The total mass of N obtained in the clippings from each harvest was summed across the growing season for each plot, then divided by the sum of clippings dry mass to obtain a yield-weighted total N concentration. Clippings uptake of N was calculated based on clippings total N concentration multiplied by the clippings dry matter yield, then summed across the growing season for each plot.

Linear regression models were applied for mean NDVI, clippings yield-weighted total N concentration, sum of the clippings yield, and sum of the clippings total N uptake as a function of the spring ISNT-N and POXC concentrations.

RESULTS

As an indicator of turfgrass color, NDVI readings were associated with ISNT-N and soil POXC concentrations for both species in a positive linear relationship (Fig. 1 A, B, C, D). The growth response of Kentucky bluegrass and tall fescue lawns, as measured by clippings yield, was positively related in a linear trend to ISNT-N and soil POXC concentrations (Fig. 1 E, F, G, H). The tissue concentration of total N in the clippings of Kentucky bluegrass and tall fescue managed as lawns was positively related to spring soil concentrations of ISNT-N and POXC in a linear response (Fig. 1 I, J, K, L). The seasonal total uptake of N in the clippings responded in a linear fashion as a function of spring ISNT-N and soil POXC concentrations (Fig. 1 M, N, O, P). The linear response was significant ($p<0.001$) in both species for all models.

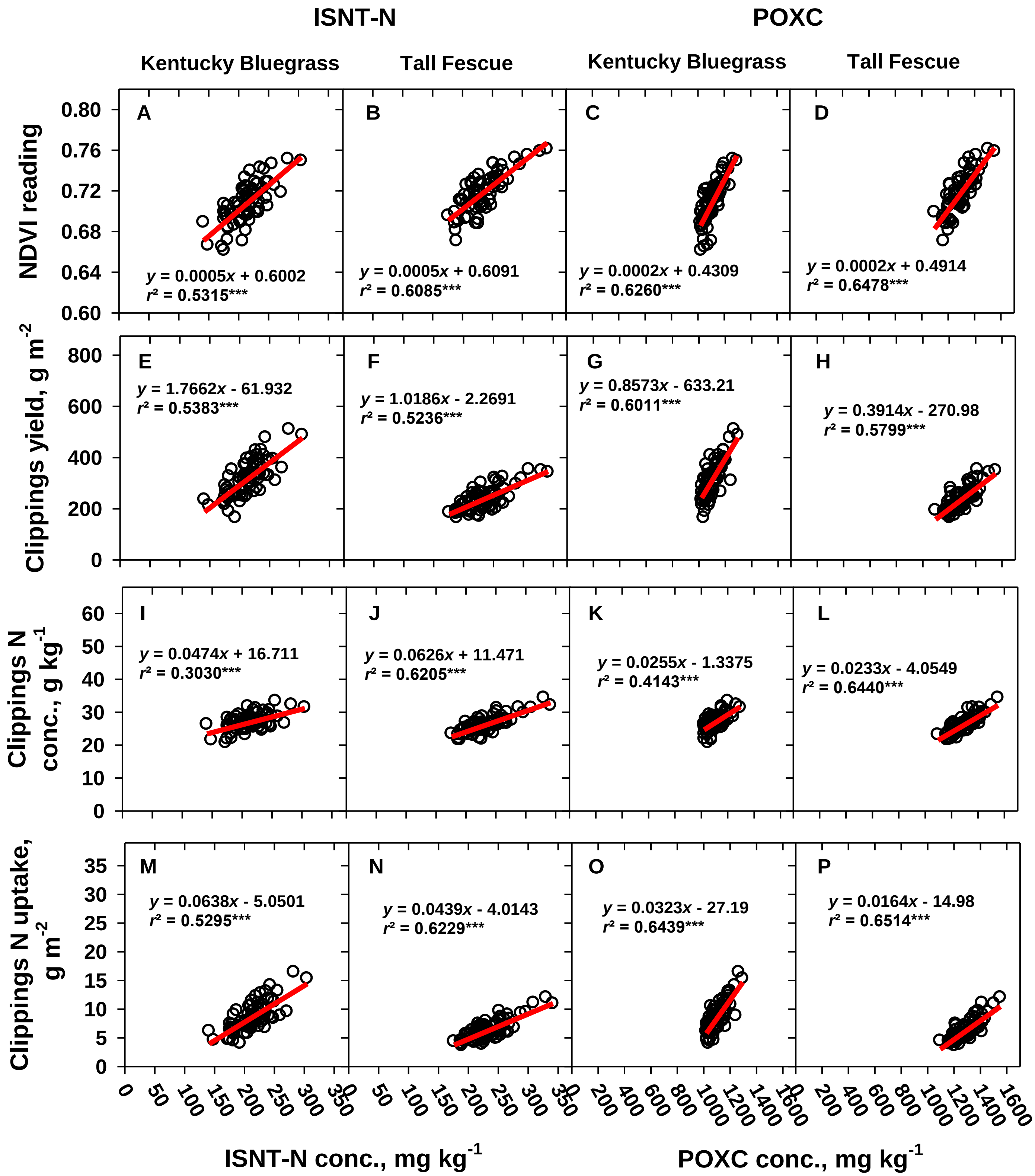

Fig. 1. Response of NDVI (panels A,B,C,D), clippings yield (panels E,F,G,H), total N concentration in the clippings (panels I.J.K.L), and total N uptake in the clippings (panels M,N,O,P) as a function of ISNT-N and POXC concentrations in 2012. Significance of coefficient of determination (r^2) for the linear response: * (p<0.001).**

Fig. 2. Kentucky bluegrass response to varying rates of compost.

Fig. 3. Tall fescue response to varying rates of compost.

DISCUSSION

The fifth year's results of this study show positive, and relatively strong relationships for Kentucky bluegrass and tall fescue quality and growth responses in response to ISNT-N and POXC concentrations. These responses of Kentucky bluegrass and tall fescue lawns were estimated with reasonable confidence from a single spring soil sample measured for concentrations of ISNT-N (Khan et al., 2001) and POXC (0.02M $KMnO_4$; Weil et al., 2003). Guiding N fertilization based on ISNT-N and/or soil POXC concentrations should help to decrease excess N loading rates, resulting in reduced maintenance costs and lower chances of water quality impairment. Adoption and implementation of these tests to turfgrass systems should also result in better objective guidance for N fertilization than the current practices of historical, subjective practices of N management. Monitoring of the plots will continue through 2013.

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Weil, R.R., K.R. Islam, M.A. Stine, J.B. Gruver, and S.E. Samson-Liebig. 2003. Estimating active carbon for soil quality assessment: A simplified method for laboratory and field use. Am. J. Altern. Agric. 18:3–17. doi:10.1079/ AJAA2003003

A detailed protocol for the updated POXC method of Weil et al. (2003) can be found at:
http://lter.kbs.msu.edu/protocols/133
(verified 18 September, 2013).

VERDURE SAP NITRATE-N CONCENTRATIONS AS A PREDICTOR OF TURF COLOR RESPONSE FALL 2012

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INTRODUCTION

Annual grasses tend to store N as nitrate in the bases of stems and shoots. Measurement of this nitrate pool can be used as an indicator of soil N availability for these grasses. For example, the end-of-season cornstalk nitrate test has been shown to correlate well with corn yield. This test gives corn producers a diagnostic assessment of their N management for the past growing season after corn has been harvested. Nitrate concentrations in the cornstalks at harvest are compared with an established critical value. If the values are far below the critical value, then the corn plant received insufficient N; if they are far above the critical value, then excess N was supplied. Concentrations nearer the critical value suggest that optimum N was available to the plant. A review of the past year's N management can then be useful in planning the following year's N management strategies.

Perennial turfgrasses also store N as nitrate, but storage of nitrate is typically minimal during the active growing season because of frequent mowing. This leads to the rapid assimilation of nitrate into leaf proteins as new leaf blades are formed. In northern climates, however, autumn marks the period when new leaf blade formation in perennial turfgrasses declines as the onset of winter dormancy begins. It is during this time that it is believed that N storage as nitrate increases in the verdure (all aboveground portions of the turf plant remaining after clippings removed by mowing), since the amount of N assimilated into leaf proteins is reduced because overall leaf formation declines. The storage of nitrate may mark the stage of the fall N assimilation period when chlorophyll levels in the plant are maximized. At this point, any further uptake of nitrate goes primarily into storage. A measure of this nitrate pool could be useful in the fall N fertilizer management of turfgrasses.

Typical measurements of plant tissues for nitrate-N concentrations are conducted on a dry weight basis. This entails the drying and grinding of samples prior to extraction and analysis. The availability of field-use nitrate meters has provided an alternative to drying and grinding of samples, which is a time-consuming process and delays results. In other horticulturally important crops such as potatoes, cotton, and numerous vegetables, sap is squeezed from fresh plant parts and analyzed directly for nitrate. This then serves as a guide for N fertilization based on previous calibration studies with those crops. The objective of this study was to determine if any relationship exists between fall sap nitrate-N concentrations in the verdure and fall turf quality as measured by color in a cool-season lawn grass mixture.

MATERIALS & METHODS

This study was conducted in the autumn of 2012 on a four-year old turfgrass stand consisting of a mixture of 35% Kentucky bluegrass (*Poa pratensis*), 30% perennial ryegrass (*Lolium perenne*), and 35% creeping red fescue (*Festuca rubra*). The experiment was set out as two randomized complete block designs with three replicates. Plot size was 5 × 5 feet. Treatments in each experiment were 13 N application rates (0, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.5, 3.0, 3.5, and 4.0 lbs N/1000ft^2) applied as urea on September 12 for the first experiment and on October 14 for the second experiment. For the September-fertilized plots, turf color was measured with a Spectrum TCM500 NDVI Turf Color Meter (Spectrum Technologies, Inc., Plainfield, IL) on October 8, 15, 21, and 27 before plots were mowed to a height of 2¼ inches using a rotary hand mower with a bagger to collect the clippings (Fig. 1). For the October-fertilized plots, turf color was measured with the NDVI meter on November 4, 11, 17, and 26. After mowing, verdure samples were removed from a small section (approximately 4 × 4-inch square) of each plot down to the soil surface using hand shears (Fig. 2). Fresh verdure samples were placed in a Spectrum hydraulic plant sap press and squeezed to expel the sap. The sap was placed into the sample well of a Cardy Nitrate Meter (Horiba B-343 Twin Nitrate Meter, Spectrum Technologies, Inc., Plainfield, IL; Fig. 9), and measurements were made for concentrations of nitrate-N. Measurements for all dates were taken between 1030 and 1600 hr. The sensor membrane in the sap nitrate meter was cleaned after each use with a mild dish-washing detergent to prevent the buildup of residue from the sap from interfering with the meter performance.

NDVI values for each sampling date were converted to a relative scale by dividing each value by the plateau value for each respective sampling date. Relative NDVI values were pooled across the sampling dates and correlated with fall verdure sap nitrate-N concentrations. Linear response-plateau (LRP) and quadratic response-plateau (QRP) models were applied to the data to determine a critical level for sap nitrate-N concentrations relative to turf color as indicated by NDVI. The critical fall sap nitrate-N value marks the concentration where no further change in NDVI response is observed with increasing concentration of verdure sap nitrate-N. The response value at this point and beyond the critical value is referred to as the plateau, which indicates the maximum response that will be observed in the relationship.

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Fig. 1. Removing clippings after NDVI meter readings and prior to verdure sap nitrate measurements.

Fig. 2. Collection of verdure samples down to the ground surface after clippings are removed.

Fig. 3. Fall color response of September fertilized plots on September 26, 2012.

Fig. 4. Fall color response of October fertilized plots on November 17, 2012.

Fig. 5. Cardy nitrate sap meter. Left-side of meter shows collection well, where sap is placed on membrane for direct nitrate analysis. Digital reading is shown in the display on the right.

RESULTS & DISCUSSION

2012 Fall Turf Color

Fall turf color response is presented in Figs. 3 and 4, and was highly correlated to fall verdure sap nitrate-N concentrations on Oct. 8, 15, 21, and 27 and Nov. 17 and 26. The relationship between fall verdure nitrate-N concentrations and fall NDVI readings for these dates are shown in Fig. 6.

When this study was conducted in previous years, higher critical levels were observed at the later sampling dates. This suggested that the turf plants were storing more nitrate in the verdure as top growth slowed with dormancy induced by the onset of colder weather. This effect was not as pronounced this year, possibly due to an unseasonably early snow-cover in early November.

LRP Model QRP Model

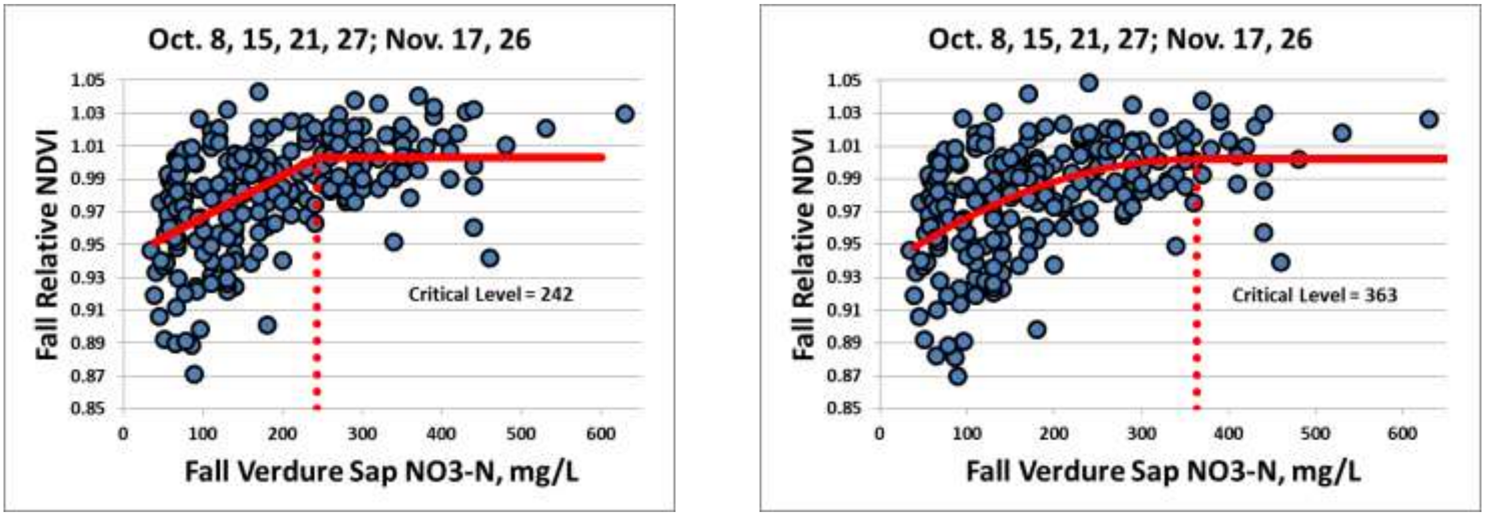

Figure 6. Linear Response and Plateau (LRP) and Quadratic Response and Plateau (QRP) modeling of fall turf color, as indicated by relative NDVI, in response to fall verdure sap nitrate-N concentrations, 2012.

These results suggest that sap nitrate concentrations from the verdure of fresh-cut turf can be used to predict turf color response in the fall. This further suggests that a sap nitrate test may have promise as an objective test to guide fall N fertilization of lawn and/or other types of turf.

However, a continuing issue we encountered with the meter concerned calibration drift. When testing a large number of samples, we suggest a regular checking of the standards and re-calibration if necessary. For research purposes, going from known lower nitrate concentrations to higher nitrate concentrations (i.e., lower to higher N rate treatments) resulted in better nitrate meter performance. However, in practice it may not be known which samples have higher nitrate-N concentrations. Additionally, we found that saturating the membrane (with the low nitrate standard solution) for a few hours prior to use increased the stability of meter readings. Because of the low moisture concentration in the verdure, especially for turf fertilized at low N rates, it was necessary to use a hydraulic press to expel the sap from the verdure tissue. A common kitchen garlic press was not able to exert sufficient pressure to produce consistent volumes of sap across samples.

The ability to conduct a nitrate analysis in the field, without the need for drying, grinding, and extracting plant tissue samples, significantly reduces the time needed for the return of results and actions based on those results. This could dramatically change the way in which turf N recommendations are made for fall-fertilized turf.

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COOPERATIVE TURFGRASS BREEDERS FIELD EVALUATION OF FINE FESCUE CULTIVARS, 2011-2012

Victoria Wallace and Steven Rackliffe
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University of Connecticut

INTRODUCTION

The 'Cooperative Turfgrass Breeders' Test (CTBT) is a variety evaluation trial program initiated by turfgrass breeders of commercial seed companies to support additional data on experimental cultivars considered for commercial production. Six plant breeding groups contribute to the CTBT program: DLF International Seeds, Peak Genetics, The Pickseed Group, Pure Seed Testing, NexGen Turf Research, and Rutgers' University.

The 2011 Fine Fescue Cooperator Trial has 10 locations throughout the United States. The University of Connecticut is one of the chosen locations (figure 1). Site cooperators collect data on turf quality, color and density. Turfgrass injury as related to insect, disease, drought, wear, and shade is also noted. Cultivars are evaluated for two years from the date of establishment.

MATERIALS AND METHODS

Ninety-nine cultivars of fine fescues were established on September 15, 2011 in Storrs Connecticut. A complete randomized block design with 3 replicates of each cultivar was utilized for this study. Plot size is 3' X 5'. Cultivars, species, and sponsors are listed in Table 1.

Establishment & Management Practices

All Cultivars received the same management protocol during establishment and throughout the study. Plots were planted on September 15, 2011 and were fertilized at the time of seeding at the rate of 1 pound of nitrogen per 1,000 ft^2. Once seeding was completed, the plots were protected with a turf cover until germination was evident. Plots were treated in April 2012 with a pre-emergent crabgrass control (prodiamine)/fertilizer combination product. Broadleaf weed control was applied May 2012. Plots were maintained at a mowing height of 2 ¾" height of cut and are mowed approximately 2 times per week. Irrigation was applied on an as needed basis. Plots were fertilized at the rate of 1 pound of nitrogen per 1,000 ft^2 on August 5, 2012.

Establishment ratings

Establishment ratings were made on October 6, 2011. Establishment ratings were based on a scale of 1-9. Ratings were based on percent germination and seedling vigor. A rating of 1 had the lowest percent germination/vigor and 9 the highest.

Quality ratings

Turfgrass quality ratings were taken on a monthly basis for overall turf quality (color / leaf texture / density) during the 2012 growing season. Overall turfgrass quality was determined using a visual rating system of 1-9. A score of 1 illustrates the poorest quality turf and 9 the highest quality.

RESULTS & DISCUSSION

Establishment ratings and mean overall turfgrass quality results are provided in Table 2. During 2012 the following observations were also noted: When comparing the fescue species in this study, the hard fescues required the greatest amount of time to establish and "fill in". However, at the end of the first year (at maturity) the hard fescues consistently rated higher in overall turfgrass quality when compared to the chewings fescue and creeping red fescue cultivars. In general, the hard fescues persisted season-long without loss of color, even during periods of drought and without supplemental irrigation. Red thread affected the ratings of numerous cultivars of chewings, strong and slender red fescues during the month of June 2012.

Figure 1 - Commercial Turfgrass Breeders Fine Fescue Test University of Connecticut

Table 1- Sponsors and Cultivars

SPONSOR	CULTIVAR	SPONSOR	CULTIVAR
Hard Fescues (Sheep)		***Strong Creeping Red Fescue***	
NexGen	AHF203	Peak Genetics	PPG-FRR106
Peak Genetics	Blue Ray	DLF	IS-FRR65
Peak Genetics	Beacon	Peak Genetics	PPG-FRR105
PSG	3J2927	Peak Genetics	PPG-FRR102
NexGen	AHF181	NexGen	Lustrous
PSG	SR 3150	PSG	5J51-15
DLF	IS-FL47	NexGen	ASC332
PSG	AZB (Sheep)	NexGen	ASC295
PSG	Azay Blue (sheep)	PSG	5RJ1L
DLF	IS-FL48	NexGen	ASC313
PSG	3TH3	PSG	ORC 126
NexGen	AHF204	NexGen	ASC321
DLF	IS-FL50	DLF	IS-FRR68C
PST	Big Horn GT (Sheep)	DLF	IS-FRR62
PSG	Spartan II	NexGen	ASC320
PST	4BIL	PSG	5RJ1E
PSG	S2SE	NexGEN	ASC323
PST	4HES	DLF	Cindy Lou
NexGen	AHF177	DLF	IS-FRR61
NexGen	AHF188	NexGen	ASC319
Rutgers	Firefly	Peak Genetics	PPG-FRR103
DLF	Eureka II	NexGen	ASC333
DLF	IS-FL46	PSG	OS2
PST	Soil Guard	PST	4GRY
PST	4NY	Peak Genetics	PPG-FRR104
Chewings Fescue		PST	4CRD-8
NexGen	ACF277	PST	4RED
PST	Enchantment	PST	4CR10-08
NexGen	ACF278	PST	4CRD-U
Peak Genetics	Radar	PST	4CRD-P
Peak Genetics	PPG-FRC103	PST	Shademaster III
DLF	Wrigley 2	PSG	SO
NexGen	ACF 261	PSG	SDT
PSG	FC 09-2	PSG	Gamet
PST	4CHY	PSG	SHST
PSG	50C3	PSG	SDHT
DLF	IS-FRC36	PSG	SG
DLF	IS-FRC37	PSG	SHSM
NexGen	ACF256	PSG	Boreal
NexGen	ACF283	***Slender Creeping Red Fescue***	
Peak Genetics	Koket	NexGen	ASR184
DLF	Longfellow II	PST	4SEA
PST	R4TC	NexGen	ASR176
DLF	Longfellow lll	NexGen	ASR181
PST	4CHT	NexGen	ASR172
Rutgers	Intrigue ll	Peak Genetics	Navigator II
PST	PST-4C30D	PSG	PSG 5RM
PST	4SHR-CH	PST	Seabreeze GT
PSG	PSG SPRS	PSG	Oracle
NexGen	Culumbra ll	PSG	07-1FF
NexGen	Survivor (ACF 266)		

Table 2- Establishment and Turfgrass Quality Ratings

CULTIVAR *Hard Fescues (Sheep)*	Establishment Rating Oct. 2011	Mean Quality Rating 2012	CULTIVAR *Strong Creeping Red F.*	Establishment Rating Oct. 2011	Mean Quality Rating 2012
AHF203	1.00	6.25	PPG-FRR106	3.67	5.63
Blue Ray	1.33	6.17	IS-FRR65	3.00	5.29
Beacon	1.33	6.17	PPG-FRR105	3.33	5.29
3J2927	1.33	6.13	PPG-FRR102	3.33	5.25
AHF181	2.00	6.04	Lustrous	3.00	5.25
SR 3150	1.00	6.00	5J51-15	3.00	5.13
IS-FL47	1.00	6.00	ASC332	2.67	5.04
AZB (Sheep)	1.33	6.00	ASC295	4.00	5.00
Azay Blue (sheep)	1.00	6.00	5RJ1L	2.67	4.96
IS-FL48	1.67	5.92	ASC313	2.33	4.96
3TH3	1.00	5.79	ORC 126	3.67	4.92
AHF204	1.67	5.71	ASC321	2.00	4.92
IS-FL50	1.00	5.71	IS-FRR68C	2.00	4.92
Big Horn GT (Sheep)	1.00	5.54	IS-FRR62	3.00	4.88
Spartan II	1.00	5.54	ASC320	2.33	4.88
4BIL	1.00	5.50	5RJ1E	2.67	4.84
S2SE	1.67	5.50	ASC323	2.33	4.80
4HES	1.00	5.46	Cindy Lou	3.00	4.79
AHF177	1.33	5.46	IS-FRR61	1.33	4.79
AHF188	1.33	5.46	ASC319	2.00	4.79
Firefly	1.00	5.34	PPG-FRR103	3.67	4.79
Eureka II	1.00	5.34	ASC333	3.00	4.71
IS-FL46	1.00	5.29	OS2	1.33	4.67
Soil Guard	1.00	5.13	4GRY	2.67	4.63
4NY	1.00	4.96	PPG-FRR104	3.33	4.59
Chewings Fescue			4CRD-8	2.67	4.54
ACF277	3.33	5.42	4RED	2.33	4.46
Enchantment	3.33	5.42	4CR10-08	3.00	4.46
ACF278	2.33	5.38	4CRD-U	3.00	4.42
Radar	4.00	5.34	4CRD-P	3.00	4.42
PPG-FRC103	3.00	5.25	Shademaster III	3.00	4.34
Wrigley 2	3.00	5.21	SO	4.33	4.34
ACF 261	2.67	5.21	SDT	3.33	4.21
FC 09-2	3.00	5.17	Gamet	1.33	4.13
4CHY	3.33	5.13	SHST	3.33	4.04
50C3	3.00	5.13	SDHT	3.33	4.00
IS-FRC36	2.67	5.09	SG	2.67	3.96
IS-FRC37	3.00	5.04	SHSM	3.00	3.88
ACF256	2.67	5.04	Boreal	3.00	3.63
ACF283	3.00	5.04	***Slender Creeping Red Fescue***		
Koket	4.33	5.00	ASR184	3.00	5.29
Longfellow II	2.33	5.00	4SEA	3.00	5.21
R4TC	3.67	4.96	ASR176	3.33	5.21
Longfellow lll	1.33	4.92	ASR181	3.00	4.96
4CHT	3.33	4.92	ASR172	3.33	4.88
Intrigue ll	2.00	4.83	Navigator II	4.00	4.75
PST-4C30D	3.00	4.71	PSG 5RM	2.00	4.46
4SHR-CH	2.67	4.71	Seabreeze GT	1.33	4.34
PSG SPRS	3.00	4.50	Oracle	2.67	3.88
Culumbra ll	3.00	4.50	07-1FF	2.00	3.29
Survivor (ACF 266)	2.67	4.46	***LSD (0.05)***	***0.78***	***0.51***

LSD (0.05) for establishment = 0.78; for Turf Quality = 0.51

FIELD EVALUATION OF PERENNIAL RYEGRASS SHORT-GROWTH MUTANTS INDUCED BY ETHYL METHANESULFONATE, GAMMA-RAY IRRADIATION AND FAST NEUTRONS, 2012

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INTRODUCTION

Perennial ryegrass (PRG; *Lolium perenne* L.) also known as English ryegrass is an important cool-season grass grown as a forage crop in pastures and as turfgrass in lawns, athletic fields and golf courses (Pearson et al., 2011). PRG is commonly used in residential and commercial lawns and maintained at optimum mowing height of 5-9 cm (Turgeon, 2005). Short-growth PRG mutants can reduce mowing frequency and may also be useful in fairways and tees where low mowing heights (i.e. $\leq$ 2.54 cm) are desirable. Water requirement of cool-season perennial ryegrass is also quite high (Liu and Jiang, 2010). Therefore there is an increasing demand for short-growth turf with reduced mowing, irrigation and fertilizer requirements, due to increased energy costs and limited water resources (Ma et al., 2008; Zurek and Tomaszewski, 2009).

Short-growth PRG cultivars can be developed through hybridization, transgenic and mutation breeding techniques. Hybridization breeding is based on the existing natural variation due to spontaneous mutations, while mutation breeding allows for creating variations not existent in the natural population (Ahloowalia and Maluszynski, 2001). Short-growth PRG has been developed by using RNA interference (RNAi) and genetic transformation techniques (Ma et al., 2008). It was reported that the mutant plants exhibited 50% reduction in growth compared to the wild-type plants after 90 days of growth in the greenhouse (Ma et al., 2008). Nonetheless, it is difficult to commercialize a transgenic cultivar due to regulatory issues and public mistrust of transgenic plants (Zapiola et al., 2008). Hence, mutation breeding methodologies provide an excellent tool to develop economically important turfgrass mutants. These techniques involve the usage of gamma-rays, X-rays, fast neutrons, ethyl methanesulfonate (EMS) and sodium azide to induce variations. Induced mutations have been utilized to improve major crops such as wheat, rice, barley, cotton, peanuts and beans (Ahloowalia and Maluszynski, 2001). This method has resulted in the development and release of more than 1800 cultivars in 50 countries (Maluszynski et al., 1995). Turfgrasses and forage grasses with changes in several morphological traits have also been generated using radiation-induced mutations (Krishna et al., 1984). According to the published reports, 10 turfgrass cultivars developed through irradiation mutagenesis were released for commercial use (FAO/IAEA database 2006). Dwarfism is the most frequent mutant character observed among the irradiated plants (Lu et al., 2009). Short-growth mutants were developed in bermudagrass (Lu et al., 2009); St. Augustinegrass (Busey, 1980; Li et al., 2010) and centipedegrass (Dickens et al., 1981) through gamma irradiation and the mutants displayed significant growth retardation and improved drought resistance (Busey, 1980; Lu et al., 2009).

The main objectives of this study were to develop short-growth mutants of PRG from ‘Fiesta 4’ seeds, using EMS, gamma-ray radiation and fast neutrons, and further characterize them under field conditions.

MATERIALS & METHODS

Seed material. ‘Fiesta 4’ PRG seeds were purchased, from the Chas. C. Hart Seed Co. Wethersfield, CT.

Gamma-ray irradiation screen. Seeds were soaked in tap water for 24 h and then the wet seeds were irradiated with gamma-rays from a Cobalt-60 source, with dosages of 0, 2.5, 5.0, 7.5, 10.0, 15.0 and 20.0 kilorads (kr) at the University of Massachusetts, gamma cave facility, Lowell, MA. Each treatment had 3 replicates with 1200 seeds per replicate. After the seeds were irradiated, they were germinated on moist paper towels (spread in growth trays) in an incubator at a temperature of 23 ± 2 °C under 35-45 $\mu mol \cdot m^{-2} \cdot s^{-1}$ light provided by white fluorescent tube lamps over a 16h photoperiod. To determine the optimum dose for LD_{50} (survival rate of 50%), germination observations were taken on the 21st day of the experiment. Germination percentages were reported as an average over three replicates.

EMS concentration screen. The EMS mutagenesis protocol developed by Kim et al., (2006) for *Arabidopsis* was followed with some modifications. Approximately 1200 ‘Fiesta 4’ seeds per replicate were soaked in 100 mM phosphate buffer (pH 7.5) for 24 h at room temperature. Then the supernatant buffer was discarded and 200 ml of freshly prepared 100 mM phosphate buffer solution containing EMS at 0, 0.2, 0.4, 0.6, 0.8 or 1.0 M, was added to each replicate and incubated on a shaker for 16 h. Each treatment had 3 replicates. After EMS treatment, seeds were washed two times in 200 ml of 3% sodium thiosulfate buffer for 20 min at room temperature with gentle shaking, followed by three washes in 200 ml of distilled water. The mutagen treated seeds were air-dried for 12 h, and then were germinated on moist paper towels (spread in growth trays) in an incubator. Culture conditions were same as those used for gamma-ray irradiation screen. To determine the optimum concentration for LD_{50} (survival rate of 50%), observations were recorded on the 21st day of culture. Data on germination were reported as a mean of three replicates for each treatment.

After the preliminary study, 10 kg of ‘Fiesta 4’ seeds were irradiated with 9.0 kr dose of gamma rays, while another 10 kg of seeds were treated with 0.8 M EMS based on the aforementioned procedures. Also, 5 kg of seeds were irradiated with 1.0 kr dose of fast neutrons (Van Harten, 1998), at the University of Massachusetts irradiation facility, Lowell, MA.

The mutagen treated M1 seeds (1^{st} mutant generation seeds) were air-dried for 12 h and stored at 4 °C until further use.

Field planting and harvesting of M2 (2^{nd} mutant generation) seeds. Mutagen treated seeds were hand-broadcasted at a rate of 1.5 kg per 100 m^2 to grow the M1 plants (the seedlings and adult plants developed from M1 seeds) for M2 seed production (the seeds which develop on M1 plants) at the University of Connecticut, Plant Science Research and Education Facility. At the end of fruit ripening phase, the M2 generation seeds were harvested, air-dried at room temperature and stored at 4 °C until further use.

Identification of short-growth mutants based on growth rate or their responses to GA. Wild-type 'Fiesta 4', EMS M2, gamma M2 and fast neutron M2 populations were soaked in 289 µM gibberellic acid (GA_3) solution for 2h. After soaking, the supernatant solution was removed and the seeds were cold-treated for 14 days at 4 °C. GA_3 concentration was selected based on a preliminary study conducted to obtain uniform germination of 'Fiesta 4' seeds. The cold treated seeds were then germinated on moist paper towels in growth trays, maintained in an incubator at a temperature of 25 ± 2 °C with 16 h of light. After 3 weeks of growth, seedlings were transferred to plug trays containing promix potting soil (Premier Horticulture Inc; PA). Seedlings were allowed to grow for 3 months in a greenhouse at a temperature of 20-25 °C under natural light. Plants were fertilized every 14 days with a 0.12% solution of 20-20-20, and irrigated as per requirement. After 3 months, short-growth mutants were selected based on growth rate or their responses to GA (can germinate only when GA is present).

Morphological characterization of mutant plant lines. A number of mutant lines exhibiting short-growth characteristics were selected from M2 generation. When sufficient plant materials were obtained through vegetative propagation, a field trial was conducted for 6 lines. Wild-type 'Fiesta 4' (WT) was used as a control. Transplanting of 3-inch plugs (with 8-10 tillers) was done in September, 2011. The field test employed randomized design with three replicates. The spacing between two plants in a row and between 2 rows was 30 cm. All the plants were watered as per requirement until they were established in the field. Measurements were taken in June 2012 (at maturity stage), on ten randomly picked tillers from each replicate for leaf blade length, leaf blade width and internode length. Top three leaves and internodes on the ten tillers were measured and mean values were calculated for each replicate. Canopy height and root length were measured for three replicates. Data were reported as a mean of 3 replicates for each plant line.

Statistical analysis. Analysis of variance was performed on the data collected from the field-grown plants, using IBM SPSS software (Version 19.0; IBM Corporation, Somers, NY). When sufficient differences ($P = 0.05$) were observed, the least significant difference (LSD, Steel et al., 1996) test was performed to detect differences between treatments.

RESULTS & DISCUSSION

Gamma-ray dose and EMS concentration effects on seed germination. Untreated 'Fiesta 4' seeds germinated by the 3^{rd} day; whereas germination in gamma irradiated seeds was delayed 1 and 2 days by gamma rates ≤ 7.5 and ≥ 10.0 kr, respectively. Germination data was collected on the 21^{st} day of the experiment. Germination decreased as gamma-ray dosage increased (Table 1). Germination of 7.5 kr and 10.0 kr gamma irradiated seeds was reduced by 39.96% and 58.68%, respectively, compared to the untreated seeds (Table 1). Published reports indicate that in mutation breeding experiments, a mutagen dose which causes 50% reduction in seed germination percentage compared to the untreated seeds is thought to be an adequate dose for producing a maximum number of desirable mutations (Li et al., 2010; Van Harten, 1998). Therefore, a 9.0 kr dose was selected to treat 'Fiesta 4' seeds with gamma-rays for subsequent irradiation experiments to screen for short-growth mutants. EMS also delayed the germination of seeds by 2 days. There were no significant differences among the seeds treated with 0, 0.2 and 0.4 M EMS (Table 2). However, at higher concentrations (i.e. 0.6 M and 0.8 M), seed germination was reduced by 13.79% and 53.67% compared to the control (Table 2). At the highest concentration (1.0 M) only 0.17% of seeds germinated after 21 days (Table 2). Based on these data, 'Fiesta 4' seeds in subsequent experiments were treated with 0.8 M EMS to generate short-growth mutants.

Morphological characteristics of the mutants. The data from field study shows that the FN-4, FN-5 and Gamma-17 mutants had significantly lower canopy heights (87%, 72% and 35% reduction respectively, compared to WT), significantly shorter leaf blades (63%, 56% and 45%, respectively, shorter than WT) and significantly shorter internodes (80%, 74% and 51%, respectively, shorter when compared with WT) (Table 3; Fig. 1 and 2). All the three mutants had significantly narrower leaves (50%, 9% and 19%, respectively, when compared with WT). FN-5 and Gamma-17 had significantly longer roots (11% and 9% longer than WT) (Table 3). Similarly, the EMS mutants GAD-1, GAD-2 and EMS-4 displayed desirable turf characteristics compared to the wild-type. They had significantly lower canopy heights (27%, 31% and 26% reduction respectively, than WT), significantly shorter leaf blades (39%, 49% and 23%, respectively, shorter when compared with WT) (Table 4; Fig. 3 and 4). Their leaf blade widths were reduced by 15%, 19% and 15%, respectively (Table 4). However, only GAD-1 had significantly shorter internodes (45% shorter) when compared with WT. GAD-2 mutant had 7% longer roots than WT; while GAD-1 and EMS-4 mutants had similar root lengths as the WT (Fig. 3 and 4). Published reports indicate that the compact turfgrass lines improve turf quality, require low maintenance under greenhouse and field conditions (Hanna et al., 1997; Hanna and Elsner, 1999; Reynolds et al., 2009). Because of their short-growth characteristics, all the six mutants included in this study will need mowing less frequently and their requirements for water and fertilizers should also be reduced. Further evaluation is in progress to characterize the performance of these plants under drought, low fertilizer and other conditions.

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Table 1: Effect of gamma-ray dose on the germination of 'Fiesta 4' perennial ryegrass seeds.

Gamma-ray dose[z] (kr)	Germination rate[y] (% ± SE)
0	92.39 ± 2.02 a[x]
2.5	78.93 ± 0.71 b
5.0	70.03 ± 1.52 c
7.5	55.47 ± 1.61 d
10.0	38.17 ± 1.03 e
15.0	24.37 ± 1.45 f
20.0	19.10 ± 0.15 g

kr = kilorad; SE = standard error.
[z]Each dosage treatment had three replicates with 1200 seeds per replicate.
[y]Germination data were recorded on the 21st day of experiment. Germination rates were calculated by dividing the number of seeds germinated by the number of seeds treated.
[x]Values followed by the same letter were not significantly different from each other according to the LSD (P=0.05).

Table 2: Effect of EMS concentration on the germination of 'Fiesta 4' perennial ryegrass seeds.

Concentration of EMS (M)[z]	Germination rate[y] (% ± SE)
0	92.60 ± 1.33 a[x]
0.2	90.37 ± 0.58 a
0.4	89.17 ± 0.44 a
0.6	79.83 ± 0.75 b
0.8	42.90 ± 0.52 c
1.0	0.17 ± 0 d

EMS = ethyl methanesulfonate; SE = standard error.
[z]Each EMS treatment had three replicates with 1200 seeds per replicate.
[y]Germination data were recorded on the 21st day of experiment. Germination rates were calculated by dividing the number of seeds germinated by the number of seeds treated.
[x]Values followed by the same letter were not significantly different from each other according to the LSD (P=0.05).

Table 3: Morphological characteristics of gamma-ray and fast neutron induced short-growth mutants in comparison to the wild-type 'Fiesta 4' perennial ryegrass.

Genotype	CH[z] (cm ± SE)	RL[z] (cm ± SE)	LL[z] (cm ± SE)	LW[z] (cm ± SE)	IL[z] (cm ± SE)
Wild-type	68.33 ± 0.33 a[y]	33.00 ± 0.57 b[y]	13.07 ± 0.15 a[y]	0.32 ± 0 a[y]	7.71 ± 1.13 a[y]
FN-4	9.00 ± 0.57 d	22.67 ± 0.33 c	4.74 ± 0.35 d	0.16 ± 0 d	1.56 ± 0.28 b
FN-5	19.33 ± 0.33 c	36.67 ± 1.33 a	5.80 ± 0.21 c	0.29 ± 0 b	1.98 ± 0.40 b
Gamma-17	44.33 ± 1.85 b	36.00 ± 0.58 a	7.16 ± 0.27 b	0.26 ± 0 c	3.79 ± 0.79 b

SE = standard error; CH = canopy height; RL = root length; LL = leaf blade length; LW = leaf blade width; IL = internode length.
[z]Each value represents the mean of three replicates. Measurements were taken in June 2012 (at maturity stage), on ten randomly picked tillers from each replicate for leaf blade length, leaf blade width and internode length.
[y]Values followed by the same letter were not significantly different from each other according to the LSD (P=0.05).

Table 4: Morphological characteristics of ethyl methanesulfonate induced short-growth mutants in comparison to the wild-type ‘Fiesta 4’ perennial ryegrass.

Genotype	CH^z (cm ± SE)	RL^z (cm ± SE)	LL^z (cm ± SE)	LW^z (cm ± SE)	IL^z (cm ± SE)
Wild-type	68.33 ± 0.33 a^y	33.00 ± 0.57 b^y	13.07 ± 0.15 a^y	0.32 ± 0 a^y	7.71 ± 1.13 a^y
GAD-1	50.00 ± 0 b	31.33 ± 0.33 b	7.93 ± 0.50 c	0.27 ± 0 b	4.24 ± 1.06 b
GAD-2	47.00 ± 0.57 c	35.33 ± 1.33 a	6.61 ± 0.34 d	0.26 ± 0 b	4.64 ± 0.75 ab
EMS-4	50.33 ± 1.45 b	32.00 ± 0.58 b	10.00 ± 0.36 b	0.27 ± 0 b	5.05 ± 0.57 ab

SE = standard error; CH = canopy height; RL = root length; LL = leaf blade length; LW = leaf blade width; IL = internode length.

^{z}Each value represents the mean of three replicates. Measurements were taken in June 2012 (at maturity stage), on ten randomly picked tillers from each replicate for leaf blade length, leaf blade width and internode length.

^{y}Values followed by the same letter were not significantly different from each other according to the LSD (P=0.05).

Fig. 1: Comparison of canopy height and root length of field-grown wild-type ‘Fiesta 4’ perennial ryegrass (left) and Gamma-17 mutant (right).

Fig. 2: Comparison of canopy height and rootlength of field-grown wild-type ‘Fiesta 4’ perennial ryegrass (left) and FN-5 mutant (right).

Fig. 3: Comparison of canopy height and root length of field-grown wild-type ‘Fiesta 4’ perennial ryegrass (left) and EMS-4 mutant (right).

Fig. 4: Comparison of canopy height and root length of field-grown wild-type ‘Fiesta 4’ perennial ryegrass (left) and GAD-2 mutant (right).

CULTIVATION AND MANGANESE FERTILITY EFFECTS ON SUMMER PATCH SEVERITY IN COMPACTED AND NON-COMPACTED TURFGRASS

Inguagiato, J.C., and J.J. Henderson. 2012. Cultivation and manganese fertility effects on summer patch severity in compacted and non-compacted turfgrass. *In* 2012 Agronomy Abstracts. ASA-CSSA-SSSA, Madison, WI.

Summer patch, caused by *Magnaporthe poae*, is a common disease of annual bluegrass and Kentucky bluegrass turf areas. The disease is most often problematic in areas with poor drainage. Supplemental manganese fertility has been purported to reduce summer patch severity, although the effect of this practice on disease is unknown. A two year field study was initiated on a Kentucky bluegrass (*Poa pratensis*) turf maintained at 3.8 cm in June 2011 to determine the effects of soil compaction, cultivation and manganese fertilization on the incidence and severity of summer patch. The study was established as a split plot design arranged in a 2 x 3 x 2 factorial with four blocks. The main plot factor was compaction, the subplot factors were cultivation and manganese fertilization. Compaction treatments received 64 or 32 passes with a 1361 kg sheepsfoot roller in 2011 and 2012, respectively to create soil bulk density differences throughout the study. Cultivation treatments were conducted using a Toro ProCore aerifier with 1.9 cm tines spaced on 2.54 cm centers on 29 June. Manganese was applied as a manganese sulfate ($MnSO_4$) solution containing 293 kg ha^{-1} on 3 August. Compacted plots consistently had lower soil water content (5.7 – 7.0%) and higher soil temps compared to non-compacted turf. Hollow and solid tine aerification reduced soil water content. Hollow tine aerification increased soil temperatures compared to other cultivation treatments. Summer patch initiated in late-August 2011 and late-July 2012, although disease development was not uniform, and no differences were observed at that time. Results from this study will improve recommendations for cultivation and fertilization to reduce the incidence and severity of anthracnose on turfgrass surfaces.

DETERMINING THE IMPORTANCE OF LEAF COMPOST TOPDRESSING WHEN MANAGING ATHLETIC FIELDS ORGANICALLY

Tencza, B.J., and J. J. Henderson. 2012. Determining the importance of leaf compost topdressing when managing athletic fields organically. *In* 2012 Agronomy Abstracts. ASA-CSSA-SSSA, Madison, WI.

Effective July 1, 2010, the state of Connecticut banned the usage of all lawn care pesticides on athletic fields at public and private schools grades pre-K through 8. Currently, the research-based information regarding compost topdressing on athletic fields is limited. Additionally, research on compost topdressing applications to soils ranging in organic matter content is very limited. The specific objectives of this research was to determine the effects of leaf compost and sand topdressing incorporated with core cultivation on soil physical properties when applied to low and high organic matter soils, and evaluate the effects of leaf compost topdressing and sand topdressing incorporated with core cultivation on the traffic tolerance of Kentucky bluegrass (*Poa pratensis* L.), '25% Award, 25% America, 25% Alpine, and 25% Northstar'. The study is arranged in a Latin rectangle with three treatments and six replications 1) Leaf compost topdressing applied at 6.3mm in the spring and fall, 2) Sand topdressing applied at 6.3mm in the spring and fall, and 3) No topdressing applied. Plots were split by core cultivation. Traffic simulation was conducted using a Cady Traffic Simulator during the fall to simulate a fall sports season. Leaf compost treatments consistently increased turfgrass color, percent cover, volumetric soil moisture and had lower surface hardness values on the low organic matter soil. Leaf compost treatments increased percent cover, volumetric soil moisture, and organic matter, while decreasing surface hardness values on the high organic matter soil.

DO TIPHIID WASPS USE HERBIVORE-INDUCED PLANT VOLATILES FOR FINDING WHITE GRUBS?

Obeysekara, P., and A. Legrand. 2012. Do tiphiid wasps use herbivore-induced plant volatiles for finding white grubs? Entomological Society of America, Eastern Branch 83rd Annual Meeting, Hartford, CT. March 24th, 2012.

Japanese beetle (*Popillia japonica*) and Oriental beetle (*Anomala orientalis*) are considered as invasive species and have been reported as key pests of urban landscapes in the Northeast. Tiphia vernalis Rohwer and Tiphia popilliavora Rohwer were introduced as biocontrol agents against these beetles. These parasitic wasps burrow into the soil and search for grubs. When a host is found, the wasp paralyzes it momentarily and attaches an egg in a location that is specific for that species. It is unknown if these wasps can detect patches of concealed hosts from a distance above ground and what role, if any, herbivore-induced plant volatiles play in their host location. The work reported here increases our understanding of Tiphia wasp host location in turfgrass systems. This study evaluated the responses of female T. vernalis and T. popilliavora to grub-infested and healthy plants in Y-tube olfactometer bioassays. Also the effect of root-herbivory on the composition of turfgrass volatile profiles was investigated by collecting volatiles from healthy and grub-infested grasses. Tiphia wasps were highly attracted to volatiles emitted by grub-infested tall fescue (TF) and Kentucky bluegrass (KBG) over healthy grasses. In contrast, wasps did not exhibit a significant preference for grub-infested perennial ryegrass (PR) as compared to the control plants. Monoterpene levels emitted by grub-infested KBG and TF were greater than that of control plants. Low levels of monoterpenes were observed for both test and control PR plants.

SAND TOPDRESSING RATE AND INTERVAL EFFECTS ON ANTHRACNOSE SEVERITY OF AN ANNUAL BLUEGRASS PUTTING GREEN

Inguagiato, J.C., J.A. Murphy, and B.B. Clarke. 2012. Sand topdressing rate and interval effects on anthracnose severity of an annual bluegrass putting green. Crop Sci. 52:1406-1415.

Sand topdressing has been reputed to increase anthracnose caused by *Colletotrichum cereale* Manns sensu lato Crouch, Clarke, and Hillman on annual bluegrass (ABG) [*Poa annua* L. forma *reptans* (Hausskn.) T. Koyama] putting greens. Field trials were conducted to determine the effects of (i) frequent (7 d) and low-rate (0.3 L m^{-2}) sand topdressing and brushing, (ii) infrequent (21 and 42 d) and increased-rate (1.2 L m^{-2}) sand topdressing, and (iii) sand topdressing application intervals (7, 14, and 28 d) and rates (0.3 and 0.6 L m^{-2}) on anthracnose severity of ABG turf mowed at 3.2 mm. Topdressing every 7 d at 0.3 L m^{-2} initially enhanced disease (8%) during the first year of the trial; however, continued topdressing reduced anthracnose severity 17 to 47% later in 2006 and 3 to 26% in 2007 compared to nontopdressed turf. Topdressing every 21 and 42 d at 1.2 L m^{-2} reduced disease 4 to 28% over the 2-yr study; however, sand applied every 21 d reduced disease 5 to 13% more than the 42-d interval in 2007. Topdressing rate (0, 0.3, and 0.6 L m^{-2}) and interval (7, 14, and 28 d) interacted to affect anthracnose severity in both years. Disease declined in a curvilinear manner as rate increased at the 7- and 14-d intervals each year. Increased rates applied every 28 d reduced disease linearly in 2006 and curvilinearly at rates exceeding 0.3 L m^{-2} in 2007. Topdressing every 7 or 14 d at 0.3 or 0.6 L m^{-2}, respectively, provided the most rapid and effective anthracnose reduction and best turf quality.

ORGANIC MANAGEMENT PRACTICES ON ATHLETIC FIELDS: PART 1. THE EFFECTS ON COLOR, QUALITY, COVER, AND WEED POPULATIONS

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Many organic products have been used effectively in turfgrass management programs, but their exclusive use in athletic field maintenance and effect on playing surface quality has not been extensively researched. The objectives were to determine the effects of management regimes and overseeding during simulated traffic on (i) turfgrass color and quality, (ii) percent cover, and (iii) weed populations. The experimental design was a 2 × 6 factorial, with two overseeding levels (overseeded and not overseeded) of a perennial ryegrass (*Lolium perenne* L.) blend during traffic and six management regimes: (i) conventional, (ii) organic manure (OMan), (iii) organic protein (OPro), (iv) organic manure plus compost tea (OMan+CT), (v) organic protein plus compost tea (OPro+CT), and (vi) none or the control. This research was conducted over 2 yr on a mature stand of 'Langara' Kentucky bluegrass (*Poa pratensis* L.) on a Paxton sandy loam soil. Fall traffic was simulated with a Cady Traffic Simulator. The conventional treatment consistently produced higher quality turfgrass, lower weed counts, and better mid- to late-fall color. Weed populations were significantly less with the conventional regime. Overseeding increased cover at the end of the traffic periods by 32% in the first year and by 103% in the second year. Overseeding was also beneficial to turfgrass color and quality and in reducing weeds. The conventional treatment also retained significantly higher turfgrass cover than the organic regimes under trafficked conditions late into the fall in 2008. However, no difference in late fall cover between the conventional and organic management regimes was observed in late fall 2009. Compost tea applications showed no enhancement of turfgrass color, quality, or cover over the entire duration of the study.