University of Connecticut

College of Agriculture, Health and Natural Resources

2017 Annual Turfgrass Research Report

Quantifying foliar dislodgeable pesticide residues

UCONN | COLLEGE OF AGRICULTURE, HEALTH AND NATURAL RESOURCES

PLANT SCIENCE AND LANDSCAPE ARCHITECTURE

Cover photo: Using a California Roller system to quantify dislodgeable pesticide residues collected from turfgrass foliage to characterize differences in persistence among pesticide formulations. (Photo credits: Sean Flynn, Senior Designer/Photographer University Communications, UCONN)

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PLANT SCIENCE AND LANDSCAPE ARCHITECTURE

2017 Annual Turfgrass Research Report Summary

University of Connecticut
College of Agriculture, Health 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 turf pathology, athletic field and golf turf maintenance, fertility and nutrient management, and cultivar evaluation and improvement. Additionally, abstracts and citations of scientific publications and presentations published in calendar year 2017 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.

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2017 Financial Support

The University of Connecticut Turfgrass Science Program appreciates the support of the turfgrass industry, state and federal agencies, private foundations, and university units and departments. Without your contributions, we would be unable to conduct many of the research projects included in this report. We extend our thanks to all of the individuals and companies who supported turfgrass research and education at the University of Connecticut.

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The University of Connecticut Turfgrass Science Program

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The University of Connecticut Turfgrass Science Program

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PREVENTIVE ANTHRACNOSE CONTROL WITH VARIOUS FUNGICIDES ON AN ANNUAL BLUEGRASS PUTTING GREEN TURF, 2017

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INTRODUCTION

Anthracnose (caused by *Colletotrichum cereale*) is a devastating disease of annual bluegrass putting green turf. An integrated disease control program including cultural management and fungicides is required to minimize turf loss due to this disease. Rotational fungicide programs utilizing different chemical modes of action and multi-site fungicides have been found to be most effective in providing season-long anthracnose control. Identifying new fungicides with unique modes of action effective against anthracnose is important to continued control of this disease and resistance management. The objective of this study was to examine the efficacy of experimental and commonly used fungicides for anthracnose control on an annual bluegrass putting green turf.

MATERIALS & METHODS

A field study was conducted on an annual bluegrass (*Poa annua*) turf grown on a Paxton fine sandy loam at the Plant Science Research and Education Facility in Storrs, CT. Turf was mowed five days wk^{-1} at a bench setting of 0.125-inches. Minimal nitrogen was applied to the study area to encourage anthracnose development. A total of 1.35 lb N $1000\text{-}ft^{-2}$ was applied as water soluble sources from April through August. Overhead irrigation and hand-watering was applied as needed to prevent drought stress. A rotation of Xzemplar (0.26 fl.oz.), Curalan (1.0 oz.), and Emerald (0.18 oz.) was applied every 14-d between 11 May and 15 August to prevent dollar spot development; ProStar (1.5 oz.) was applied preventively for brown patch on 22 July. Scimitar (0.237 fl.oz.) was applied on 3 May and Ference (0.275 oz.) was applied on 28 May for control of annual bluegrass weevil. Wetting agents Duplex (0.46 fl.oz.) and Dispatch (0.55 fl.oz.) were applied on 17 June and 10 July. Protect (6.0 oz) was applied on 19 July for control of algae.

Treatments consisted of tank mixes and rotational programs of commercially available and developmental fungicides. Initial applications were made on 24 May prior to disease developing in the trial area. Subsequent applications were made every 14-d through 3 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 2 gal $1000\text{-}ft^{-2}$ at 40 psi. 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 30 June through 11 August. Turf quality was visually assessed on a 1 to 9 scale; where 9 represented the best possible 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 of injury. Normalized difference vegetative index (NDVI) was calculated as the mean of 10 subsamples taken randomly throughout the plot area (NDVI 500, Spectrum Technologies). All 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 symptoms first appeared on 30 June and increased from 7% to 19% plot area blighted in untreated control plots as of 25 July (Table 1). Anthracnose symptoms increased further during early August, with UTC plots reaching 47% plot area blighted as of 11 August.

Many of the treatments provided complete control of anthracnose for the duration of the trial including Syngenta Programs 1, 2, 3, and 4, UC17-1 + Daconil Action, Signature Xtra + Daconil Action, Tekken, the PBI Program, the BASF Program, and UC17-1 + Daconil Action + Primo Maxx.

Plots treated with Torque were free of anthracnose on all but one rating date (13 July). Velista + Heritage Action controlled disease until 11 Aug, when plots averaged 11% plot area blighted, although it should be noted that the *C. cereale* at the study site has shown reistance to strobilurin fungicides in the past.

UC17-3 treated plots did not differ from untreated control plots in terms of anthracnose incidence on all but the last rating date, although were still over 30% blighted as of 11 August.

Turf Quality, Phytotoxicity, and NDVI

Turf quality was primarily influenced by disease incidence. Generally, treatments which provided good anthracnose control throughout the trial had the greatest turf quality including: Syngenta Program 2, Syngenta Program 3, UC17-1 + Daconil Action, Signature Xtra + Daconil Action, and UC17-1 + Daconil Action + Primo Maxx (Table 2).

Velista + Heritage Action had unacceptable turf quality on several dates due to anthracnose. Tekken, a premix of isofetamid and tebuconazole, as well as Torque had unacceptable turf quality for the duration of the trial due to phytotoxic growth regulation likely resulting from the repeated use of a DMI fungicide (Table 3) and a subsequent increase in algae. This is further evidenced by the 20 June NDVI reading (Table 4), in which these two treatments had the lowest NDVI of all treatments.

Table 1. Effect of various fungicides on preventative anthracnose control in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft[2]	Application Dates[z]	Anthracnose Incidence 30 Jun	13 Jul	25 Jul	11 Aug
			---------------- % plot area blighted	----------------		
Syngenta Program 1			0.0 b[y]	0.0 b	0.0 b	0.0 d
+UC17-1	6.0 fl.oz.	ACEGIK				
+Primo Maxx	0.125 fl.oz.	ACEGIK				
-Daconil Action	3.5 fl.oz.	AEI				
-Velista	0.5 oz.	CGK				
Syngenta Program 2			0.0 b	0.0 b	0.0 b	0.0 d
+UC17-1	6.0 fl.oz.	ACEGIK				
+Primo Maxx	0.125 fl.oz.	ACEGIK				
-Daconil Action	3.5 fl.oz.	AEI				
-Velista	0.5 oz.	CGK				
-Medallion SC	1.0 fl.oz.	CGK				
Syngenta Program 3			0.0 b	0.0 b	0.0 b	0.0 d
+UC17-1	6.0 fl.oz.	ACEGIK				
+Primo Maxx	0.125 fl.oz.	ACEGIK				
+Daconil Action	3.5 fl.oz.	ACEGIK				
-Medallion SC	1.0 fl.oz.	AEI				
-UC17-5	0.5 fl.oz.	CGK				
Syngenta Program 4			0.0 b	0.0 b	0.0 b	0.0 d
+UC17-1	6.0 fl.oz.	ACEGIK				
+Primo Maxx	0.125 fl.oz.	ACEGIK				
+Daconil Action	3.5 fl.oz.	ACEGIK				
-Velista	0.5 oz.	AG				
-Briskway	0.5 fl.oz.	CI				
-Medallion SC	1.0 fl.oz.	EK				
Velista	0.5 oz.	ACEGIK	0.0 b	0.0 b	0.0 b	17.5 c
+Heritage Action	0.2 oz.	ACEGIK				
UC17-3	0.34 fl.oz.	ACEGIK	4.5 a	11.5 a	20.0 a	32.5 b
UC17-1	6.0 fl.oz.	ACEGIK	0.0 b	0.0	0.0 b	0.0 d
+Daconil Action	3.5 fl.oz.	ACEGIK				
Signature Xtra	4.0 oz.	ACEGIK	0.0 b	0.0 b	0.0 b	0.0 d
+Daconil Action	3.5 fl.oz.	ACEGIK				
Tekken	3.0 fl.oz.	ACEGIK	0.0 b	0.0 b	0.0 b	0.0 d
PBI Gordon Program			0.0 b	0.0 b	0.0 b	0.0 d
-Daconil Ultrex	3.25 oz	A				
-Autilus	6.0 fl.oz.	C				
-Harrell's Par	0.18 fl.oz.	C				
-Tekken	3.0 fl.oz.	EI				
-Medallion SC	0.9 fl.oz.	G				
-Affirm	0.9 oz.	K				
BASF Program			0.0 b	0.0 b	0.0 b	0.0 d
+Primo Maxx	0.125 fl.oz.	ACEGIK				
-Autilus	6.0 fl.oz.	A				
-Signature Xtra	4.0 oz.	AI				
-Lexicon Intrinsic	0.34 fl.oz.	CGK				
-Daconil Action	3.0 fl.oz.	CGK				
-Mirage	1.5 fl.oz.	E				
-Velista	0.5 oz.	I				
Torque	0.6 fl.oz.	ACEGIK	0.0 b	2.3 b	0.0 b	0.0 d
UC17-1	6.0 fl.oz	ACEGIK	0.0 b	0.0 b	0.0 b	0.0 d
+Daconil Action	3.5 fl.oz.	ACEGIK				
+Primo Maxx	0.125 fl.oz.	ACEGIK				
Untreated			7.3 a	13.8 a	19.3 a	47.5 a
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001	0.0001
Days after treatment		14-d	9	7	6	8

[z] A=24 May, C=9 June, E=21 June, G=6 July, I=19 July, K=3 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 2 gal 1000-ft^{-2} at 40 psi.

[y] 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 2. Effect of various fungicides on turf quality in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft^2	Application Dates[z]	Turf Quality 2 Jun	9 Jun	15 Jun	23 Jun	30 Jun	13 Aug
			------------------------- 1-9; 6=min acceptable					---------------------------
Syngenta Program 1			6.3 b[y]	7.3 ab	7.8 b	8.0 b	8.0 b	6.5 bc
+UC17-1	6.0 fl.oz.	ACEGIK						
+Primo Maxx	0.125 fl.oz.	ACEGIK						
-Daconil Action	3.5 fl.oz.	AEI						
-Velista	0.5 oz.	CGK						
Syngenta Program 2			7.3 a	6.5 cd	8.0 ab	8.5 ab	8.2 ab	7.3 ab
+UC17-1	6.0 fl.oz.	ACEGIK						
+Primo Maxx	0.125 fl.oz.	ACEGIK						
-Daconil Action	3.5 fl.oz.	AEI						
-Velista	0.5 oz.	CGK						
-Medallion SC	1.0 fl.oz.	CGK						
Syngenta Program 3			7.0 a	6.8 bc	7.5 bc	8.5 ab	9.0 a	7.8 a
+UC17-1	6.0 fl.oz.	ACEGIK						
+Primo Maxx	0.125 fl.oz.	ACEGIK						
+Daconil Action	3.5 fl.oz.	ACEGIK						
-Medallion SC	1.0 fl.oz.	AEI						
-UC17-5	0.5 fl.oz.	CGK						
Syngenta Program 4			7.0 a	6.3 cde	6.8 d	8.0 b	8.0 b	7.5 ab
+UC17-1	6.0 fl.oz.	ACEGIK						
+Primo Maxx	0.125 fl.oz.	ACEGIK						
+Daconil Action	3.5 fl.oz.	ACEGIK						
-Velista	0.5 oz.	AG						
-Briskway	0.5 fl.oz.	CI						
-Medallion SC	1.0 fl.oz.	EK						
Velista	0.5 oz.	ACEGIK	5.5 cde	5.8 efg	6.0 ef	5.8 de	6.2 c	5.8 cd
+Heritage Action	0.2 oz.	ACEGIK						
UC17-3	0.34 fl.oz.	ACEGIK	5.8 bcd	6.0 def	6.5 de	5.3 ef	5.7 cd	4.0 ef
UC17-1	6.0 fl.oz.	ACEGIK	7.0 a	7.5 a	8.0 ab	8.8 a	7.9 b	7.0 ab
+Daconil Action	3.5 fl.oz.	ACEGIK						
Signature Xtra	4.0 oz.	ACEGIK	7.5 a	7.5 a	8.5 a	8.5 ab	7.5 b	6.5 bc
+Daconil Action	3.5 fl.oz.	ACEGIK						
Tekken	3.0 fl.oz.	ACEGIK	5.3 de	5.0 h	5.3 g	4.0 h	4.0 f	4.5 ef
PBI Gordon Program			6.0 bc	6.3 cde	7.0 cd	6.0 d	5.0 e	5.0 de
-Daconil Ultrex	3.25 oz	A						
-Autilus	6.0 fl.oz.	C						
-Harrell's Par	0.18 fl.oz.	C						
-Tekken	3.0 fl.oz.	EI						
-Medallion SC	0.9 fl.oz.	G						
-Affirm	0.9 oz.	K						
BASF Program			7.0 a	6.8 bc	7.0 cd	6.8 c	6.2 c	5.8 cd
+Primo Maxx	0.125 fl.oz.	ACEGIK						
-Autilus	6.0 fl.oz.	A						
-Signature Xtra	4.0 oz.	AI						
-Lexicon Intrinsic	0.34 fl.oz.	CGK						
-Daconil Action	3.0 fl.oz.	CGK						
-Mirage	1.5 fl.oz.	E						
-Velista	0.5 oz.	I						
Torque	0.6 fl.oz.	ACEGIK	5.3 de	5.3 gh	5.8 fg	4.5 gh	4.7 e	4.8 def
UC17-1	6.0 fl.oz	ACEGIK	7.0 a	7.3 ab	8.0 ab	8.5 ab	9.0 a	7.3 ab
+Daconil Action	3.5 fl.oz.	ACEGIK						
+Primo Maxx	0.125 fl.oz.	ACEGIK						
Untreated			5.0 e	5.5 fgh	6.0 ef	5.0 fg	5.2 de	3.8 f
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		14-d	9	1	6	2	9	10

[z] A=24 May, C=9 June, E=21 June, G=6 July, I=19 July, K=3 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 2 gal 1000-ft^{-2} at 40 psi.

[y] 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. Effect of various fungicides on phytotoxicity in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft²	Application Dates[z]	Phytotoxicity 2 Jun	9 Jun	15 Jun	23 Jun
			---------------- 0-5: 2=max acceptable---------------			
Syngenta Program 1			0.0	0.0	0.0 b[y]	0.0 c
+UC17-1	6.0 fl.oz.	ACEGIK				
+Primo Maxx	0.125 fl.oz.	ACEGIK				
-Daconil Action	3.5 fl.oz.	AEI				
-Velista	0.5 oz.	CGK				
Syngenta Program 2			0.0	0.0	0.0 b	0.0 c
+UC17-1	6.0 fl.oz.	ACEGIK				
+Primo Maxx	0.125 fl.oz.	ACEGIK				
-Daconil Action	3.5 fl.oz.	AEI				
-Velista	0.5 oz.	CGK				
-Medallion SC	1.0 fl.oz.	CGK				
Syngenta Program 3			0.0	0.0	0.0 b	0.0 c
+UC17-1	6.0 fl.oz.	ACEGIK				
+Primo Maxx	0.125 fl.oz.	ACEGIK				
+Daconil Action	3.5 fl.oz.	ACEGIK				
-Medallion SC	1.0 fl.oz.	AEI				
-UC17-5	0.5 fl.oz.	CGK				
Syngenta Program 4			0.0	0.0	0.0 b	0.0 c
+UC17-1	6.0 fl.oz.	ACEGIK				
+Primo Maxx	0.125 fl.oz.	ACEGIK				
+Daconil Action	3.5 fl.oz.	ACEGIK				
-Velista	0.5 oz.	AG				
-Briskway	0.5 fl.oz.	CI				
-Medallion SC	1.0 fl.oz.	EK				
Velista	0.5 oz.	ACEGIK	0.0	0.0	0.0 b	0.3 c
+Heritage Action	0.2 oz.	ACEGIK				
UC17-3	0.34 fl.oz.	ACEGIK	0.0	0.0	0.0 b	0.3 c
UC17-1	6.0 fl.oz.	ACEGIK	0.0	0.0	0.0 b	0.0 c
+Daconil Action	3.5 fl.oz.	ACEGIK				
Signature Xtra	4.0 oz.	ACEGIK	0.0	0.0	0.0 b	0.0 c
+Daconil Action	3.5 fl.oz.	ACEGIK				
Tekken	3.0 fl.oz.	ACEGIK	0.0	0.0	2.5 a	4.0 a
PBI Gordon Program			0.0	0.0	0.0 b	0.5 c
-Daconil Ultrex	3.25 oz	A				
-Autilus	6.0 fl.oz.	C				
-Harrell's Par	0.18 fl.oz.	C				
-Tekken	3.0 fl.oz.	EI				
-Medallion SC	0.9 fl.oz.	G				
-Affirm	0.9 oz.	K				
BASF Program			0.0	0.0	0.5 b	0.0 c
+Primo Maxx	0.125 fl.oz.	ACEGIK				
-Autilus	6.0 fl.oz.	A				
-Signature Xtra	4.0 oz.	AI				
-Lexicon Intrinsic	0.34 fl.oz.	CGK				
-Daconil Action	3.0 fl.oz.	CGK				
-Mirage	1.5 fl.oz.	E				
-Velista	0.5 oz.	I				
Torque	0.6 fl.oz.	ACEGIK	0.0	0.0	0.5 b	2.5 b
UC17-1	6.0 fl.oz	ACEGIK	0.0	0.0	0.0 b	0.0 c
+Daconil Action	3.5 fl.oz.	ACEGIK				
+Primo Maxx	0.125 fl.oz.	ACEGIK				
Untreated			0.0	0.0	0.3 b	0.0 c
ANOVA: Treatment (P > F)			1.0000	1.0000	0.0001	0.0001
Days after treatment		14-d	16	2	8	2

[z] A=24 May, C=9 June, E=21 June, G=6 July, I=19 July, K=3 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 2 gal 1000-ft^{-2} at 40 psi.

[y] 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 4. Effect of various fungicides on NDVI in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft^2	Application Dates[z]	NDVI 2 Jun	NDVI 20 Jun	NDVI 11 Aug
			-------------- Vegetative Index	--------------	
Syngenta Program 1			0.715 ab[y]	0.721 de	0.708
+UC17-1	6.0 fl.oz.	ACEGIK			
+Primo Maxx	0.125 fl.oz.	ACEGIK			
-Daconil Action	3.5 fl.oz.	AEI			
-Velista	0.5 oz.	CGK			
Syngenta Program 2			0.703 b-f	0.736 ab	0.703
+UC17-1	6.0 fl.oz.	ACEGIK			
+Primo Maxx	0.125 fl.oz.	ACEGIK			
-Daconil Action	3.5 fl.oz.	AEI			
-Velista	0.5 oz.	CGK			
-Medallion SC	1.0 fl.oz.	CGK			
Syngenta Program 3			0.700 def	0.725 bcd	0.704
+UC17-1	6.0 fl.oz.	ACEGIK			
+Primo Maxx	0.125 fl.oz.	ACEGIK			
+Daconil Action	3.5 fl.oz.	ACEGIK			
-Medallion SC	1.0 fl.oz.	AEI			
-UC17-5	0.5 fl.oz.	CGK			
Syngenta Program 4			0.700 c-f	0.730 a-d	0.704
+UC17-1	6.0 fl.oz.	ACEGIK			
+Primo Maxx	0.125 fl.oz.	ACEGIK			
+Daconil Action	3.5 fl.oz.	ACEGIK			
-Velista	0.5 oz.	AG			
-Briskway	0.5 fl.oz.	CI			
-Medallion SC	1.0 fl.oz.	EK			
Velista	0.5 oz.	ACEGIK	0.712 abc	0.735 abc	0.715
+Heritage Action	0.2 oz.	ACEGIK			
UC17-3	0.34 fl.oz.	ACEGIK	0.708 a-d	0.733 a-d	0.701
UC17-1	6.0 fl.oz.	ACEGIK	0.713 ab	0.729 a-d	0.706
+Daconil Action	3.5 fl.oz.	ACEGIK			
Signature Xtra	4.0 oz.	ACEGIK	0.716 a	0.722 de	0.707
+Daconil Action	3.5 fl.oz.	ACEGIK			
Tekken	3.0 fl.oz.	ACEGIK	0.696 ef	0.701 f	0.704
PBI Gordon Program			0.701 c-f	0.727 bcd	0.712
-Daconil Ultrex	3.25 oz	A			
-Autilus	6.0 fl.oz.	C			
-Harrell's Par	0.18 fl.oz.	C			
-Tekken	3.0 fl.oz.	EI			
-Medallion SC	0.9 fl.oz.	G			
-Affirm	0.9 oz.	K			
BASF Program			0.716 a	0.740 a	0.703
+Primo Maxx	0.125 fl.oz.	ACEGIK			
-Autilus	6.0 fl.oz.	A			
-Signature Xtra	4.0 oz.	AI			
-Lexicon Intrinsic	0.34 fl.oz.	CGK			
-Daconil Action	3.0 fl.oz.	CGK			
-Mirage	1.5 fl.oz.	E			
-Velista	0.5 oz.	I			
Torque	0.6 fl.oz.	ACEGIK	0.694 f	0.711 ef	0.708
UC17-1	6.0 fl.oz	ACEGIK	0.708 a-e	0.722 de	0.704
+Daconil Action	3.5 fl.oz.	ACEGIK			
+Primo Maxx	0.125 fl.oz.	ACEGIK			
Untreated			0.701 c-f	0.723 cde	0.694
ANOVA: Treatment (P > F)			0.0017	0.0001	0.6999
Days after treatment		14-d	16	13	8

[z] A=24 May, C=9 June, E=21 June, G=6 July, I=19 July, K=3 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 2 gal 1000-ft^{-2} at 40 psi.

[y] 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 ANTHRACNOSE CONTROL WITH AUTILUS AND OREON/PREMION ON AN ANNUAL BLUEGRASS PUTTING GREEN TURF, 2017

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INTRODUCTION

Anthracnose (caused by *Colletotrichum cereale*) is a devastating disease of annual bluegrass putting green turf. An integrated disease control program including cultural management and fungicides is required to minimize turf loss due to this disease. Rotational fungicide programs utilizing different chemical modes of action and multi-site fungicides have been found to be most effective in providing season-long anthracnose control. Identifying new fungicides with unique modes of action effective against anthracnose is important to continued control of this disease and resistance management. The objective of this study was to examine the efficacy of experimental and commonly used fungicides for anthracnose control on an annual bluegrass putting green turf.

MATERIALS & METHODS

A field study was conducted on an annual bluegrass (*Poa annua*) turf grown on a Paxton fine sandy loam at the Plant Science Research and Education Facility in Storrs, CT. Turf was mowed five days wk^{-1} at a bench setting of 0.125-inches. Minimal nitrogen was applied to the study area to encourage anthracnose development. A total of 1.35 lb N $1000\text{-}ft^{-2}$ was applied as water-soluble sources from April through August. Overhead irrigation and handwatering was applied as needed to prevent drought stress. A rotation of Xzemplar (0.26 fl.oz.), Curalan (1.0 oz.), and Emerald (0.18 oz.) was applied every 14-d between 11 May and 15 August to prevent dollar spot development; ProStar (1.5 oz.) was applied preventively for brown patch on 22 July. Scimitar (0.237 fl.oz.) was applied on 3 May and Ference (0.275 oz.) was applied on 28 May for control of annual bluegrass weevil. Wetting agents Duplex (0.46 fl.oz.) and Dispatch (0.55 fl.oz.) were applied on 17 June and 10 July. Protect (6.0 oz) was applied on 19 July for control of algae.

Treatments consisted of fungicides applied individually or as tank mixes at reduced rates. Initial applications were made on 24 May prior to disease developing in the trial area. Subsequent applications were made every 14-d through 3 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 2 gal $1000\text{-}ft^{-2}$ at 40 psi. 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 30 June through 11 August. Turf quality was visually assessed on a 1 to 9 scale; where 9 represented the best possible 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 of injury. Algae was assessed on a 0 to 5 scale, where 0 was equal to no algae and 2 represented the maximum acceptable level. All 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 was slow to develop during June, with 11% plot area blighted on untreated control plots by 30 June. Symptoms increased through July and August, reaching 56% plot area blighted as of 11 August (Table 1).

Most treatments significantly reduced anthracnose compared to untreated control throughout the trial, and few differences were observed among these fungicides. Anthracnose severity among the top performing fungicides was less than or equal to 3% plot area blighted, which was considered a good level of disease control in this trial. Treatments which consistently provided good anthracnose control in this trial included treatments containing: Oreon (*syn.,* Premion) at all rates, Autilus, UC17-8, Mirage, and Rotational Program 1, which was a program containing Oreon applied in rotation with various other classes of fungicides with efficacy on anthracnose.

Several fungicides were applied alone and in combination with Oreon (tebuconazole + PCNB), and Harrell's Par, a green pigment. At the peak of the epidemic on 11 August, plots treated only with Velista, Medallion SC, or Daconil Weather Stik reduced disease compared to untreated, but still contained an unacceptable level of anthracnose (>10% plot area blighted). Plots treated with Insignia alone were not statistically different from untreated control plots on this date. However, tank-mixes of Oreon with each of these fungicides resulted in good anthracnose control throughout the duration of the trial.

Turf Quality, Phytotoxicity, and Algae Severity

Turf quality was influenced throughout the trial by treatment effects on anthracnose severity, algae, and phytotoxiicty. Treatments which consistently resulted in the greatest turf quality include Autilus + Harrell's Par, Velista + Oreon + Harrell's Par, Signature Xtra + Oreon, Daconil Weather Stik + Oreon+ Harrell's Par, and Rotational Program 1 (Table 2).

Phytotoxicity in the form of excessive growth regulation was apparent in UC17-8 treated plots on 23 June (Table 3). The response was rate dependent with the greatest phytotoxicity observerved in turf treated 1.6 fl.oz. with less severe sympotms observed at the two lower rates. Additionally, turf treated with Mirage and Primo MAXX appeared to have similar, albeit less severe symptoms.

Algae developed uniformly throughout the study area following a particularly wet June and July. An unacceptable amount of algae was observed in all treatments, except Daconil WeatherStik treated turf, and the rotational program. Algae was most severe in plots treated with products which retard turf growth. During the peak of the algae growth on 25 July, plots treated with UC17-8 (1.0 and 1.6 fl.oz. rates), Mirage, Primo MAXX, and Oreon (8.0 fl.oz. rate) + Harrell's Par all had the greatest algae incidence.

Table 1. Effect of various fungicides on preventative anthracnose control in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft^2	Int[y]	Anthracnose Severity 30 Jun	25 Jul	11 Aug
			----------- % plot area blighted------------		
Oreon	2.0 fl.oz.	14-d	0.3 b[x]	0.5 d	1.0 d
+ Harrell's Par	0.37 fl.oz.				
Oreon	4.0 fl.oz.	14-d	0.0 c	0.0 d	3.2 d
+ Harrell's Par	0.37 fl.oz.				
Oreon	6.0 fl.oz.	14-d	0.0 c	0.3 d	0.0 d
+ Harrell's Par	0.37 fl.oz.				
Oreon	8.0 fl.oz.	14-d	0.0 c	0.0 d	0.0 d
+Harrell's Par	0.37 fl.oz.				
Autilus	6.0 fl.oz.	14-d	0.0 c	0.0 d	0.7 d
+ Harrell's Par	0.37 fl.oz.				
Velista	0.3 oz.	14-d	0.0 c	6.3 cd	16.2 b
Velista	0.3 oz.	14-d	0.0 c	1.3 d	3.8 cd
+ Oreon	2.0 fl.oz.				
+ Harrell's Par	0.37 oz.				
Velista	0.3 oz.	14-d	0.0 c	0.0 d	0.0 d
+ Oreon	4.0 fl.oz.				
+ Harrell's Par	0.37 oz.				
Velista	0.5 oz.	14-d	0.0 c	0.0 d	17.8 b
Insignia SC	0.5 fl.oz.	14-d	0.3 bc	21.8 b	41.8 a
Insignia SC	0.5 fl.oz.	14-d	0.0 c	0.0 d	0.0 d
+Oreon	2.0 fl.oz.				
+Harrell's Par	0.37 fl.oz.				
Insignia SC	0.5 fl.oz.	14-d	0.0 c	1.0 d	2.7 d
+Oreon	4.0 fl.oz.				
+Harrell's Par	0.37 fl.oz.				
Medallion SC	1.5 fl.oz.	14-d	0.1 bc	6.0 cd	19.0 b
Medallion SC	1.5 fl.oz.	14-d	0.0 c	0.3 d	3.2 d
+Oreon	2.0 fl.oz.				
+Harrell's Par	0.37 fl.oz.				
Medallion SC	1.5 fl.oz.	14-d	0.0 c	0.0 d	0.0 d
+Oreon	4.0 fl.oz.				
+Harrell's Par	0.37 fl.oz.				
Signature XTRA	4.0 oz.	14-d	0.0 c	2.3 d	4.6 cd
Signature XTRA	4.0 oz.	14-d	0.0 c	0.0 d	0.7 d
+Oreon	2.0 fl.oz.				
Signature XTRA	4.0 oz.	14-d	0.0 c	0.0 d	0.0 d
+Oreon	4.0 fl.oz.				
Daconil Weatherstik	3.6 fl.oz.	14-d	0.0 c	11.5 c	13.7 bc
Daconil Weatherstik	3.6 fl.oz.	14-d	0.0 c	6.0 cd	1.3 d
+Oreon	2.0 fl.oz.				
+Harrell's Par	0.37 fl.oz.				
Daconil Weatherstik	3.6 fl.oz.	14-d	0.0 c	0.0 d	0.0 d
+Oreon	4.0 fl.oz.				
+Harrell's Par	0.37 fl.oz.				
Rotational Program 1	pgm[z]	14-d	0.0 c	0.0 d	0.0 d
UC17-8	0.8 fl.oz.	14-d	0.0 c	0.0 d	0.0 d
UC17-8	1.0 fl.oz.	14-d	0.0 c	0.0 d	0.0 d
UC17-8	1.6 fl.oz.	14-d	0.0 c	0.0 d	0.0 d
Mirage	1.0 fl.oz.	14-d	0.0 c	0.0 d	0.0 d
Oreon	6.0 fl.oz.	14-d	0.0 c	0.3 d	1.3 d
+Primo MAXX	0.125 fl.oz.				
+Harrell's Par	0.37 fl.oz.				
Untreated		14-d	14.8 a	46.3 a	56.9 a
ANOVA: Treatment ($P > F$)			0.0001	0.0001	0.0001
Days after treatment		14-d	8	5	8

[x]Rotational Program 1 consisted of the following treatments: 24 May: Oreon (8.0 fl.oz.) + Harrell's Par (0.37 fl.oz); 7 June: Signature Xtra (4.0 oz) + Daconil Weatherstik (3.6 fl.oz.); 22 June: Velista (0.3 oz.) + Affirm (4.0 oz); 5 July: Medallion (1.5 fl.oz.) + Oreon (4.0 fl.oz.) + Harrell's Par (0.37 fl.oz.); 20 July: Signature Xtra (4.0 oz.) + Daconil Weatherstik (3.6 fl.oz.); 3 August: Velista (0.3 oz.) + Affirm (4.0 oz.)

[y]Initial applications were made on 24 May prior to disease developing in the trial area. Subsequent applications were made every 14-d through 3 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 2 gal 1000-ft^{-2} at 40 psi.

[x y]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. Effect of various fungicides on turf quality in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft^2	Int[y]	Turf Quality 2 Jun	9 Jun	15 Jun	23 Jun	30 Jun	14 Aug
			-------------------------1-9, 6=min acceptable	-----	-----	-----	-----	-----
Oreon	2.0 fl.oz.	14-d	7.0 bcd[x]	7.0 bcd	7.3 a-d	6.5 b-e	6.8 a-d	6.3 abc
+ Harrell's Par	0.37 fl.oz.							
Oreon	4.0 fl.oz.	14-d	7.0 bcd	6.8 cde	7.5 abc	6.3 cde	6.8 a-d	6.3 abc
+ Harrell's Par	0.37 fl.oz.							
Oreon	6.0 fl.oz.	14-d	7.0 bcd	7.0 bcd	7.3 a-d	6.3 cde	6.3 c-f	5.3 c-f
+ Harrell's Par	0.37 fl.oz.							
Oreon	8.0 fl.oz.	14-d	7.0 bcd	7.0 bcd	7.3 a-d	5.8 def	5.5 f-i	4.3 ef
+Harrell's Par	0.37 fl.oz.							
Autilus	6.0 fl.oz.	14-d	7.8 a	7.8 a	7.5 abc	7.0 abc	7.5 a	6.0 abc
+ Harrell's Par	0.37 fl.oz.							
Velista	0.3 oz.	14-d	6.0 fgh	6.0 fgh	6.8 c-f	5.5 efg	5.8 e-h	5.8 bcd
Velista	0.3 oz.	14-d	7.5 ab	7.0 bcd	8.0 a	7.5 ab	6.8 a-d	6.8 ab
+ Oreon	2.0 fl.oz.							
+ Harrell's Par	0.37 oz.							
Velista	0.3 oz.	14-d	7.0 bcd	7.3 abc	7.8 ab	7.3 abc	6.8 a-d	5.8 bcd
+ Oreon	4.0 fl.oz.							
+ Harrell's Par	0.37 oz.							
Velista	0.5 oz.	14-d	5.5 hi	6.0 fgh	6.3 efg	5.8 def	6.3 c-f	5.8 bcd
Insignia SC	0.5 fl.oz.	14-d	5.8 gh	5.8 gh	6.8 c-f	5.0 fgh	6.0 d-g	4.3 ef
Insignia SC	0.5 fl.oz.	14-d	7.0 bcd	6.5 def	7.3 a-d	6.3 cde	7.0 abc	5.5 b-e
+Oreon	2.0 fl.oz.							
+Harrell's Par	0.37 fl.oz.							
Insignia SC	0.5 fl.oz.	14-d	6.8 cde	6.8 cde	7.5 abc	5.8 def	6.0 d-g	5.8 bcd
+Oreon	4.0 fl.oz.							
+Harrell's Par	0.37 fl.oz.							
Medallion SC	1.5 fl.oz.	14-d	5.8 gh	6.0 fgh	6.5 d-g	6.3 cde	6.0 d-g	6.0 abc
Medallion SC	1.5 fl.oz.	14-d	7.8 a	7.3 abc	7.5 abc	7.3 abc	6.5 b-e	5.5 b-e
+Oreon	2.0 fl.oz.							
+Harrell's Par	0.37 fl.oz.							
Medallion SC	1.5 fl.oz.	14-d	7.0 bcd	6.8 cde	7.0 b-e	6.5 b-e	6.3 c-f	6.8 ab
+Oreon	4.0 fl.oz.							
+Harrell's Par	0.37 fl.oz.							
Signature XTRA	4.0 oz.	14-d	7.0 bcd	7.0 bcd	7.5 abc	7.5 ab	7.3 ab	5.8 bcd
Signature XTRA	4.0 oz.	14-d	7.8 a	7.3 abc	8.0 a	8.0 a	6.8 a-d	7.3 a
+Oreon	2.0 fl.oz.							
Signature XTRA	4.0 oz.	14-d	6.8 cde	7.0 bcd	8.0 a	7.5 ab	6.8 a-d	6.8 ab
+Oreon	4.0 fl.oz.							
Daconil Weatherstik	3.6 fl.oz.	14-d	6.3 efg	6.0 fgh	6.5 d-g	6.8 bcd	6.3 c-f	6.3 abc
Daconil Weatherstik	3.6 fl.oz.	14-d	7.0 bcd	7.3 abc	7.8 ab	8.0 a	7.5 a	7.3 a
+Oreon	2.0 fl.oz.							
+Harrell's Par	0.37 fl.oz.							
Daconil Weatherstik	3.6 fl.oz.	14-d	7.0 bcd	7.3 abc	7.8 ab	7.5 ab	7.0 abc	6.0 abc
+Oreon	4.0 fl.oz.							
+Harrell's Par	0.37 fl.oz.							
Rotational Program 1	pgm[z]	14-d	7.3 abc	7.5 ab	7.5 abc	7.0 abc	7.0 abc	7.3 a
UC17-8	0.8 fl.oz.	14-d	5.8 gh	5.8 gh	6.5 d-g	5.5 efg	5.3 ghi	5.8 bcd
UC17-8	1.0 fl.oz.	14-d	5.8 gh	5.8 gh	6.0 fg	4.5 gh	4.8 ij	4.5 def
UC17-8	1.6 fl.oz.	14-d	5.0 i	5.5 hi	5.8 g	4.3 h	4.3 j	4.0 fg
Mirage	1.0 fl.oz.	14-d	5.8 gh	6.3 efg	6.3 efg	5.5 efg	5.3 ghi	5.3 c-f
Oreon	6.0 fl.oz.	14-d	6.5 def	6.8 cde	6.8 c-f	5.5 efg	5.3 ghi	5.3 c-f
+Primo MAXX	0.125 fl.oz.							
+Harrell's Par	0.37 fl.oz.							
Untreated		14-d	5.5 hi	5.0 i	6.0 fg	5.0 fgh	5.0 hij	2.8 g
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		14-d	16	2	8	1	8	11

[x]Rotational Program 1 consisted of the following treatments: 24 May: Oreon (8.0 fl.oz.) + Harrell's Par (0.37 fl.oz); 7 June: Signature Xtra (4.0 oz) + Daconil Weatherstik (3.6 fl.oz.); 22 June: Velista (0.3 oz.) + Affirm (4.0 oz); 5 July: Medallion (1.5 fl.oz.) + Oreon (4.0 fl.oz.) + Harrell's Par (0.37 fl.oz.); 20 July: Signature Xtra (4.0 oz.) + Daconil Weatherstik (3.6 fl.oz.); 3 August: Velista (0.3 oz.) + Affirm (4.0 oz.)

[y]Initial applications were made on 24 May prior to disease developing in the trial area. Subsequent applications were made every 14-d through 3 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 2 gal 1000-ft^{-2} at 40 psi.

[x y] 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 3. Effect of various fungicides on phytotoxicity in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft^2	Int[y]	Phytotoxicity 2 Jun	9 Jun	15 Jun	23 Jun
			-----------0-5;2=max acceptable-----------			
Oreon	2.0 fl.oz.	14-d	0.0	0.0	0.0	0.0 e[x]
+ Harrell's Par	0.37 fl.oz.					
Oreon	4.0 fl.oz.	14-d	0.0	0.0	0.0	0.0 e
+ Harrell's Par	0.37 fl.oz.					
Oreon	6.0 fl.oz.	14-d	0.0	0.0	0.0	0.0 e
+ Harrell's Par	0.37 fl.oz.					
Oreon	8.0 fl.oz.	14-d	0.0	0.0	0.0	0.1 cde
+Harrell's Par	0.37 fl.oz.					
Autilus	6.0 fl.oz.	14-d	0.0	0.0	0.0	0.0 e
+ Harrell's Par	0.37 fl.oz.					
Velista	0.3 oz.	14-d	0.0	0.0	0.0	0.0 e
Velista	0.3 oz.	14-d	0.0	0.0	0.0	0.0 e
+ Oreon	2.0 fl.oz.					
+ Harrell's Par	0.37 oz.					
Velista	0.3 oz.	14-d	0.0	0.0	0.0	0.0 e
+ Oreon	4.0 fl.oz.					
+ Harrell's Par	0.37 oz.					
Velista	0.5 oz.	14-d	0.0	0.0	0.0	0.1 de
Insignia SC	0.5 fl.oz.	14-d	0.0	0.0	0.0	0.7 bc
Insignia SC	0.5 fl.oz.	14-d	0.0	0.0	0.0	0.0 e
+Oreon	2.0 fl.oz.					
+Harrell's Par	0.37 fl.oz.					
Insignia SC	0.5 fl.oz.	14-d	0.0	0.0	0.0	0.0 e
+Oreon	4.0 fl.oz.					
+Harrell's Par	0.37 fl.oz.					
Medallion SC	1.5 fl.oz.	14-d	0.0	0.0	0.0	0.1 de
Medallion SC	1.5 fl.oz.	14-d	0.0	0.0	0.0	0.0 e
+Oreon	2.0 fl.oz.					
+Harrell's Par	0.37 fl.oz.					
Medallion SC	1.5 fl.oz.	14-d	0.0	0.0	0.0	0.0 e
+Oreon	4.0 fl.oz.					
+Harrell's Par	0.37 fl.oz.					
Signature XTRA	4.0 oz.	14-d	0.0	0.0	0.0	0.0 e
Signature XTRA	4.0 oz.	14-d	0.0	0.0	0.0	0.0 e
+Oreon	2.0 fl.oz.					
Signature XTRA	4.0 oz.	14-d	0.0	0.0	0.0	0.0 e
+Oreon	4.0 fl.oz.					
Daconil Weatherstik	3.6 fl.oz.	14-d	0.0	0.0	0.0	0.1 de
Daconil Weatherstik	3.6 fl.oz.	14-d	0.0	0.0	0.0	0.0 e
+Oreon	2.0 fl.oz.					
+Harrell's Par	0.37 fl.oz.					
Daconil Weatherstik	3.6 fl.oz.	14-d	0.0	0.0	0.0	0.0 e
+Oreon	4.0 fl.oz.					
+Harrell's Par	0.37 fl.oz.					
Rotational Program 1	pgm[z]	14-d	0.0	0.0	0.0	0.0 e
UC17-8	0.8 fl.oz.	14-d	0.0	0.0	0.0	1.3 ab
UC17-8	1.0 fl.oz.	14-d	0.0	0.0	0.0	1.3 ab
UC17-8	1.6 fl.oz.	14-d	0.0	0.0	0.0	2.7 a
Mirage	1.0 fl.oz.	14-d	0.0	0.0	0.0	0.7 bc
Oreon	6.0 fl.oz.	14-d	0.0	0.0	0.0	0.7 bc
+Primo MAXX	0.125 fl.oz.					
+Harrell's Par	0.37 fl.oz.					
Untreated		14-d	0.0	0.0	0.0	0.5 bcd
ANOVA: Treatment (P > F)			1.0000	1.0000	1.0000	0.0001
Days after treatment		14-d	16	2	8	1

[x]Rotational Program 1 consisted of the following treatments: 24 May: Oreon (8.0 fl.oz.) + Harrell's Par (0.37 fl.oz); 7 June: Signature Xtra (4.0 oz) + Daconil Weatherstik (3.6 fl.oz.); 22 June: Velista (0.3 oz.) + Affirm (4.0 oz); 5 July: Medallion (1.5 fl.oz.) + Oreon (4.0 fl.oz.) + Harrell's Par (0.37 fl.oz.); 20 July: Signature Xtra (4.0 oz.) + Daconil Weatherstik (3.6 fl.oz.); 3 August: Velista (0.3 oz.) + Affirm (4.0 oz.)

[y]Initial applications were made on 24 May prior to disease developing in the trial area. Subsequent applications were made every 14-d through 3 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 2 gal 1000-ft^{-2} at 40 psi.

[x y]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 4. Effect of various fungicides on algae severity in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft²	Int[y]	Algae Incidence 19 Jun	25 Jul
			--0-5;2=max acceptable--	
Oreon	2.0 fl.oz.	14-d	3.0 de[x]	3.3 e-h
+ Harrell's Par	0.37 fl.oz.			
Oreon	4.0 fl.oz.	14-d	3.5 b-e	3.8 c-f
+ Harrell's Par	0.37 fl.oz.			
Oreon	6.0 fl.oz.	14-d	3.0 de	4.0 b-e
+ Harrell's Par	0.37 fl.oz.			
Oreon	8.0 fl.oz.	14-d	3.0 de	4.5 abc
+Harrell's Par	0.37 fl.oz.			
Autilus	6.0 fl.oz.	14-d	2.0 fg	2.8 ghi
+ Harrell's Par	0.37 fl.oz.			
Velista	0.3 oz.	14-d	2.8 ef	2.3 ijk
Velista	0.3 oz.	14-d	3.0 de	2.5 hij
+ Oreon	2.0 fl.oz.			
+ Harrell's Par	0.37 oz.			
Velista	0.3 oz.	14-d	3.3 cde	3.3 e-h
+ Oreon	4.0 fl.oz.			
+ Harrell's Par	0.37 oz.			
Velista	0.5 oz.	14-d	2.8 ef	2.5 hij
Insignia SC	0.5 fl.oz.	14-d	3.8 a-d	3.0 f-i
Insignia SC	0.5 fl.oz.	14-d	3.8 a-d	3.8 c-f
+Oreon	2.0 fl.oz.			
+Harrell's Par	0.37 fl.oz.			
Insignia SC	0.5 fl.oz.	14-d	4.3 ab	3.8 c-f
+Oreon	4.0 fl.oz.			
+Harrell's Par	0.37 fl.oz.			
Medallion SC	1.5 fl.oz.	14-d	1.5 gh	2.3 ijk
Medallion SC	1.5 fl.oz.	14-d	3.0 de	2.8 ghi
+Oreon	2.0 fl.oz.			
+Harrell's Par	0.37 fl.oz.			
Medallion SC	1.5 fl.oz.	14-d	2.0 fg	3.3 e-h
+Oreon	4.0 fl.oz.			
+Harrell's Par	0.37 fl.oz.			
Signature XTRA	4.0 oz.	14-d	2.0 fg	2.3 ijk
Signature XTRA	4.0 oz.	14-d	2.8 ef	3.0 f-i
+Oreon	2.0 fl.oz.			
Signature XTRA	4.0 oz.	14-d	1.5 gh	2.8 ghi
+Oreon	4.0 fl.oz.			
Daconil Weatherstik	3.6 fl.oz.	14-d	1.0 h	1.0 l
Daconil Weatherstik	3.6 fl.oz.	14-d	1.5 gh	1.5 kl
+Oreon	2.0 fl.oz.			
+Harrell's Par	0.37 fl.oz.			
Daconil Weatherstik	3.6 fl.oz.	14-d	1.0 h	1.5 kl
+Oreon	4.0 fl.oz.			
+Harrell's Par	0.37 fl.oz.			
Rotational Program 1	pgm[z]	14-d	1.5 gh	1.8 jkl
UC17-8	0.8 fl.oz.	14-d	4.0 abc	3.0 f-i
UC17-8	1.0 fl.oz.	14-d	4.5 a	4.8 ab
UC17-8	1.6 fl.oz.	14-d	4.5 a	5.0 a
Mirage	1.0 fl.oz.	14-d	3.5 b-e	4.3 a-d
Oreon	6.0 fl.oz.	14-d	3.3 cde	4.5 abc
+Primo MAXX	0.125 fl.oz.			
+Harrell's Par	0.37 fl.oz.			
Untreated		14-d	3.3 cde	3.5 d-g
ANOVA: Treatment (P > F)			0.0001	0.0001
Days after treatment		14-d	12	5

[x]Rotational Program 1 consisted of the following treatments: 24 May: Oreon (8.0 fl.oz.) + Harrell's Par (0.37 fl.oz); 7 June: Signature Xtra (4.0 oz) + Daconil Weatherstik (3.6 fl.oz.); 22 June: Velista (0.3 oz.) + Affirm (4.0 oz); 5 July: Medallion (1.5 fl.oz.) + Oreon (4.0 fl.oz.) + Harrell's Par (0.37 fl.oz.); 20 July: Signature Xtra (4.0 oz.) + Daconil Weatherstik (3.6 fl.oz.); 3 August: Velista (0.3 oz.) + Affirm (4.0 oz.)

[y]Initial applications were made on 24 May prior to disease developing in the trial area. Subsequent applications were made every 14-d through 3 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 2 gal 1000-ft^{-2} at 40 psi.

[x y]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 SUMMER DISEASE CONTROL WITH ROTATIONAL FUNGICIDE PROGRAMS ON AN ANNUAL BLUEGRASS PUTTING GREEN TURF, 2017

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INTRODUCTION

Anthracnose (caused by *Colletotrichum cereale*) is a devastating disease of annual bluegrass putting green turf. An integrated disease control program including cultural management and fungicides is required to minimize turf loss due to this disease. Rotational fungicide programs utilizing different chemical modes of action and multi-site fungicides have been found to be most effective in providing season-long anthracnose control. Identifying new fungicides with unique modes of action effective against anthracnose is important to continued control of this disease and resistance management. The objective of this study was to examine the efficacy of fungicide programs for anthracnose control on an annual bluegrass putting green turf.

MATERIALS & METHODS

A field study was conducted on an annual bluegrass (*Poa annua*) turf grown on a Paxton fine sandy loam at the Plant Science Research and Education Facility in Storrs, CT. Turf was mowed five days wk^{-1} at a bench setting of 0.125-inches. Minimal nitrogen was applied to the study area to encourage anthracnose development. A total of 1.35 lb N 1000-ft^{-2} was applied as water soluble sources from April through August. Overhead irrigation and hand-watering was applied as needed to prevent drought stress. Scimitar (0.237 fl.oz.) was applied on 3 May and Ference (0.275 oz.) was applied on 28 May for control of annual bluegrass weevil. Wetting agents Duplex (0.46 fl.oz.) and Dispatch (0.55 fl.oz.) were applied on 17 June and 10 July. Protect (6.0 oz) was applied on 19 July for control of algae.

Treatments consisted three different rotational fungicide programs applied every 14 days. Each program contained Primo Maxx, a plant growth regulator, tank-mixed with a rotation of fungicides. Initial applications were made on 10 May prior to disease developing in the trial area. Subsequent applications were made every 14-d through 1 September. All treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2 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.

Anthracnose was determined visually as the percent area blighted by *C. cereale* from 30 June through 1 September. Turf quality was visually assessed on a 1 to 9 scale; where 9 represented the best possible 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 of injury. Dollar spot was assessed as a count of disease foci. Algae was assessed visually on a 0 to 5 scale where 0 indicated no algae and 2 was the maximum acceptable level. Normalized difference vegetative index (NDVI) was calculated as the mean of 10 subsamples taken randomly throughout the plot area (NDVI 500, Spectrum Technologies). All data were subjected to an analysis of variance and means were separated using Fisher's Protected Least Significant Difference Test.

RESULTS AND DISCUSSION

Anthracnose and Dollar Spot Severity

Anthracnose disease pressure was moderate for the duration of the trial. Symptoms first appeared on untreated control plots on 30 June, averaging 4.8% plot area blighted. The disease steadily increased in severity through the beginning of August, averaging 47% plot area blighted on 11 August before decreasing to 33% as of 1 September (Table 1). All treated plots provided excellent anthracnose control for the entirety of the trial. Minor anthracnose symptoms (i.e., 1.3% plot area blighted) were observed only on one observation date throughout this trial.

Dollar spot first appeared in untreated control plots on 15 June, with 3.1 dollar spot infection centers (DSIC) $plot^{-1}$ (Table 2). Disease increased slowly, with UTC plots averging 10 DSIC $plot^{-1}$ on 13 July and 26 DSIC $plot^{-1}$ on 11 August. As of 26 August, all treatments provided excellent (<5 DSIC $plot^{-1}$) control of dollar spot.

Turf Quality, Phytotoxicity, NDVI and Algae Severity

Due to effective disease control, turf quality was high in all treated plots for the duration of the trial (Tables 3a and 3b). Program 3 was consistently the highest performer in terms of quality (11 of 11 dates). Program 1 provided equivalent quality to Program 3 on 5 of 11 observation dates, mostly from 13 July onwards. Program 2 also provided quality equivalent to Program 3 on 5 of 11 dates, although optimal quality occurred intermittently throughout the trial.

Quality differences between these treatments were influenced by algae which developed during particularly wet periods in June and July. Algae was most severe on 13 July, and reached unacceptable levels in Program 2 (Table 4). Program 3 provided the best control of algae, likely due to Daconil Action (chlorothalonil) being applied with every application. Although programs 1 and 2 contain Daconil Ultrex in the rotation, it was not applied in the application preceeding the severe algae outbreak in June, and was applied only 4 days before the outbreak in July.

No phytoxicity (Table 5) was detected at any point during the trial from any of the treatments, and there were no differences in NDVI among treated plots (Table 6).

Table 1. Effect of various fungicides on preventative anthracnose control in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft²	Application Dates[z]	Anthracnose Severity					
			30 Jun	13 Jul	25 Jul	11 Aug	17 Aug	1 Sept
			% plot area blighted					
Rotational Program 1			0.0 b[y]	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ						
-Mirage	2.0 fl.oz.	A						
-Signature Xtra	4.0 oz.	CGIKMO						
-Daconil Ultrex	3.2 oz.	CGKO						
-Mirage	1.0 fl.oz.	E						
-Exteris Stressgard	4.0 fl.oz.	EIM						
-Interface	3.0 oz.	Q						
Rotational Program 2			0.0 b	0.0 b	0.0 b	1.3 b	0.0 b	0.0 b
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ						
-Mirage	2.0 fl.oz.	AI						
-Signature Xtra	4.0 oz.	EGIKMOQ						
-Exteris Stressgard	4.0 fl.oz.	CM						
-Daconil Ultrex	3.2 oz.	EKO						
-Interface	3.0 oz.	G						
-26 GT	4.0 fl.oz.	Q						
Rotational Program 3			0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ						
+Daconil Action	3.0 fl.oz.	ACEGIKMOQ						
+Appear II	6.0 fl.oz.	ACEGIKMOQ						
-Velista	0.5 oz.	AGM						
-Briskway	0.5 fl.oz.	CIO						
-Medallion SC	1.0 fl.oz.	EKQ						
Untreated			4.8 a	22.5 a	27.5 a	47.5 a	41.3 a	33.6 a
ANOVA: Treatment (P > F)			0.0052	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		14-d	8	7	5	7	13	14

[z]Application dates were as follows: A=10 May; C=24 May; E=9 June; G=22 June; I=6 July; K=21 July; M=4 August; O=17 August; Q=1 September. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2 gal 1000-ft^{-2} at 40 psi.

[y] 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. Effect of various fungicides on preventative dollar spot control in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft^2	Application Dates[z]	Dollar Spot Incidence 15 Jun	23 Jun	30 Jun	13 Jul	25 Jul	11 Aug
			# dollar spot foci 18ft^{-2}					
Rotational Program 1			1.0	0.8	0.7	1.1 b[y]	4.1 b	4.0 b
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ						
-Mirage	2.0 fl.oz.	A						
-Signature Xtra	4.0 oz.	CGIKMO						
-Daconil Ultrex	3.2 oz.	CGKO						
-Mirage	1.0 fl.oz.	E						
-Exteris Stressgard	4.0 fl.oz.	EIM						
-Interface	3.0 oz.	Q						
Rotational Program 2			1.0	1.7	0.4	1.5 b	2.7 b	3.5 b
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ						
-Mirage	2.0 fl.oz.	AI						
-Signature Xtra	4.0 oz.	EGIKMOQ						
-Exteris Stressgard	4.0 fl.oz.	CM						
-Daconil Ultrex	3.2 oz.	EKO						
-Interface	3.0 oz.	G						
-26 GT	4.0 fl.oz.	Q						
Rotational Program 3			0.2	1.0	0.4	1.3 b	2.5 b	3.8 b
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ						
+Daconil Action	3.0 fl.oz.	ACEGIKMOQ						
+Appear II	6.0 fl.oz.	ACEGIKMOQ						
-Velista	0.5 oz.	AGM						
-Briskway	0.5 fl.oz.	CIO						
-Medallion SC	1.0 fl.oz.	EKQ						
Untreated			3.1	3.2	5.8	10.8 a	14.2 a	26.2 a
ANOVA: Treatment (P > F)			0.1250	0.3269	0.0541	0.0108	0.0082	0.0025
Days after treatment		14-d	6	1	8	7	5	7

[z]Application dates were as follows: A=10 May; C=24 May; E=9 June; G=22 June; I=6 July; K=21 July; M=4 August; O=17 August; Q=1 September. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2 gal 1000-ft^{-2} at 40 psi.

[y] 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 3a. Effect of various fungicides on turf quality in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft²	Application Dates[z]	Turf Quality 19 May	2 Jun	9 Jun	15 Jun	23 Jun	30 Jun
			1-9;6=min acceptable					
Rotational Program 1			7.0 b[y]	8.0 b	7.8 b	7.0 b	7.0 b	7.5 b
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ						
-Mirage	2.0 fl.oz.	A						
-Signature Xtra	4.0 oz.	CGIKMO						
-Daconil Ultrex	3.2 oz.	CGKO						
-Mirage	1.0 fl.oz.	E						
-Exteris Stressgard	4.0 fl.oz.	EIM						
-Interface	3.0 oz.	Q						
Rotational Program 2			7.0 b	7.3 c	7.5 b	8.0 a	8.5 a	9.0 a
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ						
-Mirage	2.0 fl.oz.	AI						
-Signature Xtra	4.0 oz.	EGIKMOQ						
-Exteris Stressgard	4.0 fl.oz.	CM						
-Daconil Ultrex	3.2 oz.	EKO						
-Interface	3.0 oz.	G						
-26 GT	4.0 fl.oz.	Q						
Rotational Program 3			8.0 a	9.0 a	9.0 a	8.5 a	8.8 a	9.0 a
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ						
+Daconil Action	3.0 fl.oz.	ACEGIKMOQ						
+Appear II	6.0 fl.oz.	ACEGIKMOQ						
-Velista	0.5 oz.	AGM						
-Briskway	0.5 fl.oz.	CIO						
-Medallion SC	1.0 fl.oz.	EKQ						
Untreated			6.3 c	6.0 d	5.8 c	5.3 c	4.0 c	4.5 c
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		14-d	9	9	16	6	1	8

[z]Application dates were as follows: A=10 May; C=24 May; E=9 June; G=22 June; I=6 July; K=21 July; M=4 August; O=17 August; Q=1 September. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2 gal 1000-ft-2 at 40 psi.

[y] 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 3b. Effect of various fungicides on turf quality in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2016.

Treatment	Rate per 1000ft^2	Application Dates[z]	Turf Quality 13 Jul	25 Jul	11 Aug	17 Aug	1 Sept
			---------------------- 1-9;6=min acceptable				------------------------
Rotational Program 1							
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ	7.3 a[y]	6.8 ab	7.8 a	8.0 a	7.8 a
-Mirage	2.0 fl.oz.	A					
-Signature Xtra	4.0 oz.	CGIKMO					
-Daconil Ultrex	3.2 oz.	CGKO					
-Mirage	1.0 fl.oz.	E					
-Exteris Stressgard	4.0 fl.oz.	EIM					
-Interface	3.0 oz.	Q					
Rotational Program 2							
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ	5.5 b	6.0 b	6.3 b	7.3 a	7.0 a
-Mirage	2.0 fl.oz.						
-Signature Xtra	4.0 oz.	EGIKMOQ					
-Exteris Stressgard	4.0 fl.oz.	AI					
-Daconil Ultrex	3.2 oz.	EKO					
-Interface	3.0 oz.	G					
-26 GT	4.0 fl.oz.	Q					
Rotational Program 3							
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ	8.0 a	7.3 a	7.3 a	7.3 a	7.8 a
+Daconil Action	3.0 fl.oz.	ACEGIKMOQ					
+Appear II	6.0 fl.oz.	ACEGIKMOQ					
-Velista	0.5 oz.	AGM					
-Briskway	0.5 fl.oz.	CIO					
-Medallion SC	1.0 fl.oz.	EKQ					
Untreated			2.8 c	3.3 c	3.0 c	3.0 b	3.5 b
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001	0.0002	0.0002
Days after treatment		14-d	7	5	7	13	14

[z]Application dates were as follows: A=10 May; C=24 May; E=9 June; G=22 June; I=6 July; K=21 July; M=4 August; O=17 August; Q=1 September. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2 gal 1000-ft-2 at 40 psi.

[y] 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 4. Effect of various fungicides on algae severity in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft^2	Application Dates[z]	Algae Severity 19 Jun	13 Jul	25 Jul	11 Aug
			--------------------- 0-5;2=max acceptable			-----------------------
Rotational Program 1			2.0 a[y]	1.5 c	1.8 c	0.3 b
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ				
-Mirage	2.0 fl.oz.	A				
-Signature Xtra	4.0 oz.	CGIKMO				
-Daconil Ultrex	3.2 oz.	CGKO				
-Mirage	1.0 fl.oz.	E				
-Exteris Stressgard	4.0 fl.oz.	EIM				
-Interface	3.0 oz.	Q				
Rotational Program 2			0.8 b	2.8 b	2.5 b	0.8 ab
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ				
-Mirage	2.0 fl.oz.	AI				
-Signature Xtra	4.0 oz.	EGIKMOQ				
-Exteris Stressgard	4.0 fl.oz.	CM				
-Daconil Ultrex	3.2 oz.	EKO				
-Interface	3.0 oz.	G				
-26 GT	4.0 fl.oz.	Q				
Rotational Program 3			0.0 b	1.0 c	0.8 d	0.5 b
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ				
+Daconil Action	3.0 fl.oz.	ACEGIKMOQ				
+Appear II	6.0 fl.oz.	ACEGIKMOQ				
-Velista	0.5 oz.	AGM				
-Briskway	0.5 fl.oz.	CIO				
-Medallion SC	1.0 fl.oz.	EKQ				
Untreated			2.3 a	3.8 a	3.5 a	1.7 a
ANOVA: Treatment (P > F)			0.0002	0.0001	0.0001	0.0320
Days after treatment		14-d	10	7	5	7

[z]Application dates were as follows: A=10 May; C=24 May; E=9 June; G=22 June; I=6 July; K=21 July; M=4 August; O=17 August; Q=1 September. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2 gal 1000-ft-2 at 40 psi.

[y] 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)

UCONN TURFGRASS

Table 5. Effect of various fungicides on phytotoxicity in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2016.

Treatment	Rate per 1000ft^2	Application Dates	Phytotoxicity 2 Jun	9 Jun	15 Jun	23 Jun
			---------------------- 0-5;2=max acceptable			------------------------
Rotational Program 1			0.0	0.0	0.0	0.0
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ				
-Mirage	2.0 fl.oz.	A				
-Signature Xtra	4.0 oz.	CGIKMO				
-Daconil Ultrex	3.2 oz.	CGKO				
-Mirage	1.0 fl.oz.	E				
-Exteris Stressgard	4.0 fl.oz.	EIM				
-Interface	3.0 oz.	Q				
Rotational Program 2			0.0	0.0	0.0	0.0
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ				
-Mirage	2.0 fl.oz.	AI				
-Signature Xtra	4.0 oz.	EGIKMOQ				
-Exteris Stressgard	4.0 fl.oz.	CM				
-Daconil Ultrex	3.2 oz.	EKO				
-Interface	3.0 oz.	G				
-26 GT	4.0 fl.oz.	Q				
Rotational Program 3			0.0	0.0	0.0	0.0
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ				
+Daconil Action	3.0 fl.oz.	ACEGIKMOQ				
+Appear II	6.0 fl.oz.	ACEGIKMOQ				
-Velista	0.5 oz.	AGM				
-Briskway	0.5 fl.oz.	CIO				
-Medallion SC	1.0 fl.oz.	EKQ				
Untreated			0.0	0.0	0.0	0.0
ANOVA: Treatment (P > F)			1.0000	1.0000	1.0000	1.0000
Days after treatment		14-d	9	16	6	1

[z]Application dates were as follows: A=10 May; C=24 May; E=9 June; G=22 June; I=6 July; K=21 July; M=4 August; O=17 August; Q=1 September. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2 gal 1000-ft-2 at 40 psi.

[y] 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 6. Effect of various fungicides on NDVI in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft^2	Application Dates[z]	NDVI 2 Jun	13 Jul	11 Aug
			------------ Vegetation Index	------------	
Rotational Program 1			0.719 a[y]	0.741	0.690
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ			
-Mirage	2.0 fl.oz.	A			
-Signature Xtra	4.0 oz.	CGIKMO			
-Daconil Ultrex	3.2 oz.	CGKO			
-Mirage	1.0 fl.oz.	E			
-Exteris Stressgard	4.0 fl.oz.	EIM			
-Interface	3.0 oz.	Q			
Rotational Program 2			0.713 a	0.729	0.689
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ			
-Mirage	2.0 fl.oz.	AI			
-Signature Xtra	4.0 oz.	EGIKMOQ			
-Exteris Stressgard	4.0 fl.oz.	CM			
-Daconil Ultrex	3.2 oz.	EKO			
-Interface	3.0 oz.	G			
-26 GT	4.0 fl.oz.	Q			
Rotational Program 3			0.724 a	0.741	0.693
+Primo Maxx	0.125 fl.oz.	ACEGIKMOQ			
+Daconil Action	3.0 fl.oz.	ACEGIKMOQ			
+Appear II	6.0 fl.oz.	ACEGIKMOQ			
-Velista	0.5 oz.	AGM			
-Briskway	0.5 fl.oz.	CIO			
-Medallion SC	1.0 fl.oz.	EKQ			
Untreated			0.683 b	0.706	0.670
ANOVA: Treatment (P > F)			0.0049	0.1755	0.2595
Days after treatment		14-d	9	7	7

[z]Application dates were as follows: A=10 May; C=24 May; E=9 June; G=22 June; I=6 July; K=21 July; M=4 August; O=17 August; Q=1 September. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2 gal 1000-ft-2 at 40 psi.

[y] 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 ANTHRACNOSE CONTROL WITH VARIOUS FUNGICIDES TANK-MIXED WITH ZIO BIOFUNGICIDE ON AN ANNUAL BLUEGRASS PUTTING GREEN TURF, 2017

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INTRODUCTION

Anthracnose (caused by *Colletotrichum cereale*) is a devastating disease of annual bluegrass putting green turf. An integrated disease control program including cultural management and fungicides is required to minimize turf loss due to this disease. However, identifying effective biological controls could reduce the rate or number of fungicide applications. Zio is a new *Pseudomonas*-based biofungicide that is anticipated to be released soon. A study was developed to determine whether this new biofungicide can be effective in controlling anthracnose.

MATERIALS & METHODS

A field study was conducted on an annual bluegrass (*Poa annua*) turf grown on a Paxton fine sandy loam at the Plant Science Research and Education Facility in Storrs, CT. Turf was mowed five days wk^{-1} at a bench setting of 0.125-inches. Minimal nitrogen was applied to the study area to encourage anthracnose development. A total of 1.35 lb N $1000\text{-}ft^{-2}$ was applied as water soluble sources from April through August. Overhead irrigation and hand-watering was applied as needed to prevent drought stress. To reduce anthracnose incidence prior to initiation of treatments, Daconil Ultrex (3.2 oz.) was applied on 24 May and 7 June. A rotation of Xzemplar (0.26 fl.oz.), Curalan (1.0 oz.), and Emerald (0.18 oz.) was applied every 14-d between 11 May and 15 August to prevent dollar spot development; ProStar (1.5 oz.) was applied preventively for brown patch on 22 July. Scimitar (0.237 fl.oz.) was applied on 3 May and Ference (0.275 oz.) was applied on 28 May for control of annual bluegrass weevil. Wetting agents Duplex (0.46 fl.oz.) and Dispatch (0.55 fl.oz.) were applied on 17 June and 10 July. Protect (6.0 oz) was applied on 19 July for control of algae.

Treatments consisted of various fungicides applied individually or tank-mixed with Zio, a biological fungicide. All treatments (including untreated control plots) were applied with Intake, a non-ionic surfactant. Initial applications were made on 21 June, after disease had developed naturally in the trial area. Subsequent applications were made every 14-d through 4 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 2 gal $1000\text{-}ft^{-2}$ at 40 psi. 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 30 June through 11 August. Turf quality was visually assessed on a 1 to 9 scale; where 9 represented the best possible 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 of injury. All 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 was present throught the trial area prior to the initiation of treatments, with plots averaging up to 9% plot area blighted. Disease symptoms increased though July, reaching a peak of 32% plot area blighted as of 25 July on untreated control (Intake NIS only) plots, and remained at this level through 11 August (Table 1).

Only plots treated with QP Tebuconazole had acceptable levels of anthracnose control. There was no difference between plots that received QP Tebuconazole alone vs. plots that were tank-mixed with Zio at any point during the trial. Plots treated with QP Chorothalonil did reduce anthracnose relative to UTC plots, but disease never reached acceptable levels, and again there was no difference between the Zio and non-Zio treatments.

Zio applied alone did not reduce anthracnose relative to UTC, except on 25 July (although symptoms remained unacceptable). QP Strobe (azoxystrobin) applied alone also provided no reduction in disease, although it should be noted that the population of *Colletotrichum cereale* present in the trial area has a history of resistance to strobilurin fungicides. Despite the failure of either of these treatments to control anthracnose when applied individually, the combination of Zio + QP Strobe as a tank-mix did reduce disease somewhat when compared to UTC plots on 25 July and 11 August.

All other treatments provided unacceptable levels of anthracnose control. This may be due in part to the fact that treatments were initiated after the onset of disease. Although numerous fungicides have been proven effective in controlling anthracnose preventatively, the disease can be difficult to control after symptoms have appeared.

Turf Quality and Phytotoxicity

No phytotoxicity was observed during the trial (Table 3), so Turf Quality was primarily influenced by anthracnose incidence. Quality was generally poor as disease was already present in the trial area when treatments were initiated. On 14 August, the only rating date which had significant quality differences between treatments, Plots treated with QP Tebuconazole or QP Chlorothalonil had greater quality compared to other treastments, although TQ ratintgs were still unacceptable due to excessive growth regulation in QP Tebuconazole or anthracnose in QP Chlorothalonil.

Table 1. Effect of various fungicides tank-mixed with Zio on preventative anthracnose control in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment Rate per 1000ft²	Int[z]	Anthracnose Incidence			
		30 Jun	13 Jul	25 Jul	11 Aug
		------------------ % plot area blighted -----------------			
Zio.....1.3 oz. +Intake NIS..... 0.25%v/v	14-d	5.5	26.8 a[y]	21.3 bcd	28.8 ab
Zio.....1.3 oz. +QP Tebuconazole..... 0.6 fl.oz. +Intake NIS..... 0.25%v/v	14-d	0.5	1.0 e	0.0 e	3.0 d
Zio.....1.3 oz. +QP Strobe .....0.2 oz. +Intake NIS..... 0.25%v/v	14-d	1.1	16.8 a-d	16.8 cd	18.0 bc
Zio.....1.3 oz. +QP Chlorothalonil 720...0.2 oz. +Intake NIS..... 0.25%v/v	14-d	3.6	8.3 cde	12.3 cd	11.3 cd
Zio.....1.3 oz. +UC17-16.....0.18 fl.oz. +Intake NIS..... 0.25%v/v	14-d	6.8	30.0 a	30.0 ab	23.8 ab
Zio.....1.3 oz. +UC17-15.....3.0 oz. +Intake NIS..... 0.25%v/v	14-d	7.8	25.0 a	32.5 a	30.0 a
QP Tebuconazole..... 0.6 fl.oz. +Intake NIS..... 0.25%v/v	14-d	1.6	3.3 de	0.0 e	4.3 d
QP Strobe.....0.2 oz. +Intake NIS..... 0.25%v/v	14-d	1.1	23.8 ab	30.0 ab	33.3 a
QP Chlorothalonil 720.....0.2 oz. +Intake NIS..... 0.25%v/v	14-d	2.0	9.8 b-e	11.8 d	11.3 cd
UC17-16.....0.18 fl.oz. +Intake NIS..... 0.25%v/v	14-d	9.2	20.8 abc	21.0 bcd	23.0 abc
UC17-15.....3.0 oz. +Intake NIS..... 0.25%v/v	14-d	4.9	22.0 abc	23.0 abc	30.8 a
Intake NIS..... 0.25%v/v	14-d	9.4	26.5 a	32.5 a	32.5 a
ANOVA: Treatment (P > F)		0.2958	0.0023	0.0001	0.0001
Days after treatment	14-d	9	7	4	10

[z]Initial applications were made on 21 June, after disease had naturally developed in the trial area. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2 gal 1000-ft^{-2} at 40 psi.

[y] 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. Effect of various fungicides tank-mixed with Zio on turf quality in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft^2	Int[z]	Turf Quality 23 Jun	30 Jun	14 Aug
			-------- 1-9;6=min acceptable--------		
Zio	1.3 oz.	14-d	6.8	5.8	4.0 cd[y]
+Intake NIS	0.25%v/v				
Zio	1.3 oz.	14-d	6.5	6.8	5.8 a
+QP Tebuconazole	0.6 fl.oz.				
+Intake NIS	0.25%v/v				
Zio	1.3 oz.	14-d	6.5	6.5	4.3 cd
+QP Strobe	0.2 oz.				
+Intake NIS	0.25%v/v				
Zio	1.3 oz.	14-d	5.8	6.5	4.5 bc
+QP Chlorothalonil 720	0.2 oz.				
+Intake NIS	0.25%v/v				
Zio	1.3 oz.	14-d	6.5	5.8	4.3 cd
+UC17-16	0.18 fl.oz.				
+Intake NIS	0.25%v/v				
Zio	1.3 oz.	14-d	6.3	5.8	3.8 cd
+UC17-15	3.0 oz.				
+Intake NIS	0.25%v/v				
QP Tebuconazole	0.6 fl.oz.	14-d	5.8	6.0	5.5 ab
+Intake NIS	0.25%v/v				
QP Strobe	0.2 oz.	14-d	6.8	6.8	3.8 cd
+Intake NIS	0.25%v/v				
QP Chlorothalonil 720	0.2 oz.	14-d	6.3	6.3	4.8 abc
+Intake NIS	0.25%v/v				
UC17-16	0.18 fl.oz.	14-d	6.5	5.8	4.0 cd
+Intake NIS	0.25%v/v				
UC17-15	3.0 oz.	14-d	6.8	6.0	3.3 d
+Intake NIS	0.25%v/v				
Intake NIS	0.25%v/v	14-d	6.0	5.8	4.3 cd
ANOVA: Treatment (P > F)			0.2230	0.3097	0.0048
Days after treatment		14-d	2	9	10

[z]Initial applications were made on 21 June, after disease had naturally developed in the trial area. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2 gal 1000-ft^{-2} at 40 psi.

[y] 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. Effect of various fungicides tank-mixed with Zio on phytotoxicity in an annual bluegrass putting turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft^2	Int[z]	Phytotoxicity 23 Jun	Phytotoxicity 30 Jun
			---- 0-5;2=max acceptable---	
Zio	1.3 oz.	14-d	0.0	0.0
+Intake NIS	0.25%v/v			
Zio	1.3 oz.	14-d	0.0	0.0
+QP Tebuconazole	0.6 fl.oz.			
+Intake NIS	0.25%v/v			
Zio	1.3 oz.	14-d	0.0	0.0
+QP Strobe	0.2 oz.			
+Intake NIS	0.25%v/v			
Zio	1.3 oz.	14-d	0.0	0.0
+QP Chlorothalonil 720	0.2 oz.			
+Intake NIS	0.25%v/v			
Zio	1.3 oz.	14-d	0.0	0.0
+UC17-16	0.18 fl.oz.			
+Intake NIS	0.25%v/v			
Zio	1.3 oz.	14-d	0.0	0.0
+UC17-15	3.0 oz.			
+Intake NIS	0.25%v/v			
QP Tebuconazole	0.6 fl.oz.	14-d	0.0	0.0
+Intake NIS	0.25%v/v			
QP Strobe	0.2 oz.	14-d	0.0	0.0
+Intake NIS	0.25%v/v			
QP Chlorothalonil 720	0.2 oz.	14-d	0.0	0.0
+Intake NIS	0.25%v/v			
UC17-16	0.18 fl.oz.	14-d	0.0	0.0
+Intake NIS	0.25%v/v			
UC17-15	3.0 oz.	14-d	0.0	0.0
+Intake NIS	0.25%v/v			
Intake NIS	0.25%v/v	14-d	0.0	0.0
ANOVA: Treatment (P > F)			1.0000	1.0000
Days after treatment		14-d	2	9

[z]Initial applications were made on 21 June, after disease had naturally developed in the trial area. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2 gal 1000-ft^{-2} at 40 psi.

PREVENTIVE COPPER SPOT AND BROWN PATCH CONTROL USING VARIOUS SDHI FUNGICIDES APPLIED WITH AND WITHOUT CHLOROTHALONIL ON A CREEPING BENTGRASS PUTTING GREEN TURF, 2017

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INTRODUCTION

Copper spot disease of cool-season turfgrasses caused by the *Gloeocercospora sorghi* fungal pathogen. On golf course putting greens it is characterized by small, copper-colored spots. The fungus produces abundant spores which may be tracked by turf equipment leaving linear patterns on the putting surface as the disease spreads. It is particularly active during periods of hot daytime temperatures (85°F), warm nighttime temperatures (65°F), and high humidity. Excessive nitrogen and low pH can also enhance disease growth. Copper spot can be controlled by a wide range of fungicides, and because it typically develops later in the summer than other diseases, control is often achieved as part of an already-in-place fungicide rotation program. The objective of this study was to evaluate the efficacy of various SDHI fungicides in controlling copper spot on a creeping bentgrass putting green turf.

MATERIALS & METHODS

A field study was conducted on a 'Penn A-4' 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 five days wk^{-1} at a bench setting of 0.125-inch. Nitrogen was applied at a total of 1.0 lb N $1000\text{-}ft^{-2}$ as water soluble sources from May through August. Tempo SC was applied on 22 June for control of white grubs. Meridian was applied on 26 June for control of ants. To help alleviate dry surface conditions, the wetting agent Primer Select was applied on 17 May, Duplex was applied on 17 June, and Dispatch was applied on 10 July. Overhead irrigation was applied as needed to prevent drought stress.

Treatments consisted of various SDHI fungicides, applied individually or tank-mixed with Daconil Ultrex. Initial applications were made prior to the onset of disease symptoms on 15 June. Subsequent applications were made on a 14-d interval through 24 August. Plots were inoculated with spores of *Gloeocercospora sorghi* at 100,000 spores ml^{-1} in 2 gal of water carrier $1000ft^{-2}$ on 14 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 2.0 gal $1000\text{-}ft^{-2}$ at 40 psi. Plots measured 3 x 6 ft and were arranged in a randomized complete block design with four replications.

Copper spot incidence was assessed as a count of individual disease foci within each plot. All data were subjected to an analysis of variance and means were separated using Fisher's protected least significant difference test. Copper spot incidence data were log transformed for ANOVA and mean separation tests, although means presented are de-transformed values.

RESULTS AND DISCUSSION

Copper Spot Incidence

The infestation of copper spot was limited prior to and following inoculation. Untreated plots peaked at 6 disease infection centers (DISC) $plot^{-1}$ on 22 August (Table 1). Dry and relatively cool weather conditions following this date resulted in a total cessation of the disease outbreak.

Although some copper spot was detected in treated plots on 22 August, including Velista, Xzemplar, Kabuto, and UC17-12, disease in these plots was not statistically different than in plots with no disease. No disease was detected on any of the plots treated with Daconil Ultrex or Exteris Stressgard.

Brown Patch

Brown patch developed on a limited basis during mid-August, allowing the opportunity to assess the treatments for brown patch efficacy. As of 22 August, brown patch severity averaged 7% plot area blighted in untreated control plots. On the same date, disease was completely absent in plots treated with Exteris (all rates and intervals), Exteris + Daconil (all rates and intervals), Velista, Velista + Daconil, Xzemplar, Xzemplar + Daconil, Kabuto + Daconil, UC17-12 + Daconil, and Daconil Ultrex applied alone. Kabuto (applied without Daconil Ultrex), averaged 5.5% plot area blighted, although this was not statistically different from the control and disease-free treatments. UC17-12 averaged 25.5% plot area blighted, indicating that this treatment is not suitable for brown patch control and may enhance disease incidence.

Table 1. Copper spot incidence influenced by various SDHI fungicides and chlorothalonil on a creeping bentgrass putting green turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment[z] Rate per 1000ft^2	Int	Copper Spot Incidence			Brown Patch	
		30 Jun	11 Aug	22 Aug	11 Aug	22 Aug
		------ # copper spot foci 18ft^{-2} -----			-------% of plot area blighted------	
Exteris Stressgard .... 3.0 fl.oz.	14-d	0.0	0.0	0.0 b[y]	0.0 b	0.0 b
Exteris Stressgard .... 3.0 fl.oz. +Daconil Ultrex ....3.2 oz.	14-d	0.0	0.0	0.0 b	0.0 b	0.0 b
Exteris Stressgard .... 4.0 fl.oz.	21-d	0.0	0.0	0.0 b	0.0 b	0.0 b
Exteris Stressgard .... 4.0 fl.oz. +Daconil Ultrex ....3.2 oz.	21-d	0.0	0.3	0.0 b	0.0 b	0.0 b
Velista..........................0.5 oz.	14-d	0.0	0.0	3.0 ab	0.8 b	0.0 b
Velista..........................0.5 oz. +Daconil Ultrex ....3.2 oz.	14-d	0.0	0.0	0.0 b	0.0 b	0.0 b
Xzemplar .... 0.16 fl.oz.	14-d	0.0	0.0	3.0 ab	0.5 b	0.0 b
Xzemplar .... 0.16 fl.oz. +Daconil Ultrex ....3.2 oz.	14-d	0.0	0.0	0.0 b	0.0 b	0.0 b
Kabuto .... 0.4 fl.oz.	14-d	0.0	0.8	2.3 ab	1.5 b	5.5 b
Kabuto .... 0.4 fl.oz. +Daconil Ultrex ....3.2 oz.	14-d	0.0	0.0	0.0 b	0.0 b	0.0 b
UC17-12 .... 0.0935 fl.oz.	14-d	0.0	0.0	3.8 ab	3.8 a	25.5 a
UC17-12 .... 0.0935 fl.oz. +Daconil Ultrex ....3.2 oz.	14-d	0.0	0.0	0.0 b	0.0 b	0.0 b
Daconil Ultrex ....3.2 oz.	14-d	0.0	0.0	0.0 b	0.0 b	0.0 b
Untreated		0.0	0.3	6.3 a	0.8 b	7.3 b
ANOVA: Treatment (P > F)		1.0000	0.5702	0.0427	0.0422	0.0001
Days after treatment	14-d	1	1	12	1	12
	21-d	15	14	5	14	5

[z]Treatments were initiated on 15 June prior to disease developing in the trial area. Subsequent applications were made at specified intervals through 24 August. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2.0 gal 1000-ft-2 at 40 psi.

[y]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 WITH VARIOUS FUNGICIDES ON A CREEPING BENTGRASS PUTTING GREEN TURF, 2017

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INTRODUCTION

Dollar spot is a common disease of cool-season turfgrasses caused by the fungal pathogen *Sclerotinia homoeocarpa*. On golf course fairways it is characterized by light, straw-colored spots that may coalesce into larger irregularly shaped areas. It is particularly active during periods of warm daytime temperatures (80°F), cool nighttime temperatures (60°F), and high humidity. It can be managed in part with cultural practices such as maintaining moderate nitrogen fertility and reducing leaf wetness period. However, the use of fungicides is often still necessary on high priority areas such as greens, tees and fairways. The objective of this study was to evaluate the efficacy of rotational fungicide programs as well as new and existing fungicides in controlling dollar spot on a creeping bentgrass putting green turf.

MATERIALS & METHODS

A field study was conducted on a 'Penn A-4' 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 five days wk^{-1} at a bench setting of 0.125-inches. Nitrogen was applied as water soluble sources totaling 1.45 lb N 1000-ft^{-2} from April through September. Tempo SC was applied on 19 May to control cutworms. Localized dry spot was managed with applications of wetting agents Primer Select on 19 May, Duplex on 17 June, and Dispatch on 10 July. Overhead irrigation was applied as needed to prevent drought stress.

Treatments consisted of new and exisiting fungicide formulations applied individually, as tank mixes, and/or in rotational program. Initial applications were made on 10 May, prior to disease developing in the trial area. Subsequent applications were made at specified intervals through 1 September. All treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2.0 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 incidence was assessed as a count of individual disease foci within each plot. 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. NDVI measurements were taken with a FieldScout TCM 500 NDVI meter (Spectrum Technologies, Aurora, IL). All data were subjected to an analysis of variance and means were separated using Fisher's protected least significant difference test. Dollar spot incidence data were square-root or log transformed for ANOVA and mean separation tests, although means presented are de-transformed values.

RESULTS AND DISCUSSION

Dollar Spot Incidence

Disease first appeared in untreated plots on 30 May (Table 1a). Dollar spot pressure slowly increased through the end of July, when untreated control plots averaged 34 disease foci per plot. The epidemic became much more severe during August into September, reaching over 130 foci on 22 August and over 180 foci on 11 September in untreated control plots (Table 1b).

PBI Gordon program 1 consisted of various fungicides that were tank-mixed or applied in rotation with Kabuto, a new SDHI fungicide (isofetamid), and Tekken, a new premix of isofetamid and tebuconazole. It provided excellent [<5 dollar spot infection centers (DSIC) plot^{-1}] dollar spot control through the end of July, and maintained good (< 10 DSIC plot^{-1}) control as the epidemic became more severe through August and September. PBI Gordon programs 2 and 3 were very similar to program 1, but included a additional fungicides to control summer diseases like brown patch and Pythium blight. They both provided good control of disease through July. Following the 3 August application of Affirm + Segway in both programs disease began to increase in severity, especially in program 2 where it reached unacceptable levels (>20 DSIC plot^{-1}) as of 11 August. It is possible that a fungicide with greater activity on dollar spot may have been needed at this point in the rotational program to maintain acceptable levels of control.

Tekken applied individually, or in alternation treatments and tank mixes with Primo Maxx provided excellent dollar spot control (<5 DSIC plot^{-1}) throughout the trial. Kabuto applied individually also provided excellent dollar spot control throughout most of the trial.

The Bayer program consisted of various fungicides containing Stressgard, including Exteris, Signature XTRA + Daconil Ultrex, and Interface. This program provided complete control of dollar spot through the end of June, and exhibited only minor levels of disease (< 3 DSIC plot^{-1}) thereafter. Exteris Stressgard, a premix containing fluopyram (SDHI) and trifloxystrobin (strobilurin) was applied alone at several rates and intervals. The 2.5 fl.oz. 1000 ft^{-2} rate provided excellent control for the duration of the study when applied every 14-d. The 4.0 fl.oz. 1000ft^{-2} applied at the same interval (14-d) provided complete control of dollar spot through the end of August. Conversely, the 4.0 fl.oz. rate applied every 21-d resulted in minor, albiet acceptable levels of disease by 22 August.

Pinpoint is a new strobilurin (Q_oI) fungicide which is unique among other fungicides in this chemical class due to its activity against the causal agent of dollar spot. When applied alone every 14-d at 0.28 fl.oz. $1000ft^{-2}$ it provided excellent dollar spot control, until August when disease pressure increased. Dollar spot control was improved during July-Sept when Pinpoint was tank-mixed with either Tourney or Rotator (fluazinam). Traction, a new premix containing both fluazinam and tebuconazole, also provided complete control of disease, and Secure provided excellent control for the duration of the study.

The BASF program consisted of various classes of fungicides tank-mixed with Primo Maxx on a 14-d basis. It provided excellent control throughout the tiral.

Oreon, a PCNB-based fungicide, provided good acceptable control for the duration of the study, except on 11 Sept.

Turf Quality and Phytotoxicity

Quality was primarily influenced by disease incidence. As several treatments were effective in controlling disease, quality was generally high (>7.5) during favorable weather conditions through June and July (Table 2). However, as disease pressure and summer stress increased in August, a few treatments stood out as having exceptionally high quality, including the Bayer Program, Exteris Stressgard (4.0 oz., 14-d), Traction, and the BASF program.

Several treatments exhibited moderate-to-severe phytotoxicity following application which reduced quality ratings (Table 2). Some phytotoxicity, albeit at acceptable levels, was temporarily observed on plots treated with Tekken or Kabuto alone during late May and early June (Table 3a). Phytotoxcicty was more severe on plots where Tekken was tank-mixed or alternated with Primo Maxx. For both of these treatments, phytoxicity reached unacceptable (>2) levels during late May through early June, and although symptoms became less severe during July and August (especially in the rotational treatment) it never fully disappeared.

Oreon, a tebuconazole + PCNB pre-mix fungicide, exhibited severe chlorosis following each treatment application. The phytoxicity would appear as soon as 1 day after treatment (DAT), and would remain at unacceptable levels for 7-10 DAT before beginning to fade. The yellowing did not appear to negatively impact the density of the turf canopy at the surface but did have a significant affect on visual apperance. Severe chlorosis with Oreon has not been observed on annual bluegrass putting greens when used to control anthracnose, so the effect it has on creeping bentgrass should be considered when applying this material to mixed poa/bent turf stands.

Table 1a. Effect of various fungicides on dollar spot incidence in a creeping bentgrass putting green at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment[z]	Rate per 1000ft^2	Int	Dollar Spot Incidence					
			22 May	30 May	9 Jun	15 Jun	23 Jun	30 Jun
			-------------------------------# dollar spot foci 18ft^{-2}	----------------------------------				
PBI Gordon Program 1	pgm[y]	14-d	0.0	0.3[t] bc[s]	1.7 b	0.2 c	2.1 bc	0.2 cd
PBI Gordon Program 2	pgm[x]	14-d	0.0	0.1 bc	0.2 cd	0.0 c	3.9 b	1.4 b
PBI Gordon Program 3	pgm[w]	14-d	0.0	0.0 c	0.4 bcd	0.0 c	1.4 bcd	1.2 bc
Kabuto	0.5 fl.oz.	14-d	0.0	0.1 bc	0.6 bcd	0.4 c	1.6 bcd	0.0 d
Tekken	3.0 fl.oz.	14-d	0.0	0.1 bc	0.0 d	0.7 c	0.6 cde	0.2 cd
Exteris Stressgard	2.5 fl.oz.	14-d	0.0	0.7 b	1.4 bc	0.0 c	1.4 bcd	0.0 d
Primo Maxx	0.125 fl.oz.	14-d	0.0	2.8 a	1.2 bcd	9.0 a	21.8 a	35.1 a
Primo Maxx	0.125 fl.oz.	14-d	0.0	0.1 bc	0.4 bcd	0.7 c	0.0 e	0.0 d
+Tekken	3.0 fl.oz.							
Tekken	3.0 fl.oz.	7-d	0.0	0.1 bc	0.2 cd	0.3 c	0.3 de	0.0 d
-Primo Maxx	0.125 fl.oz.							
Bayer Program	pgm[v]	14-d	0.0	0.0 c	0.0 d	0.0 c	0.0 e	0.0 d
Exteris Stressgard	4.0 fl.oz.	14-d	0.0	0.0 c	0.0 d	0.0 c	0.0 e	0.0 d
Exteris Stressgard	4.0 fl.oz.	21-d	0.0	0.3 bc	0.6 bcd	2.7 b	3.7 b	0.4 bcd
Traction (NUP-15014).......	1.5 fl.oz.	14-d	0.0	0.0 c	0.6 bcd	0.3 c	0.0 e	0.0 d
Pinpoint............................	0.28 fl.oz.	14-d	0.0	0.0 c	0.9 bcd	0.6 c	1.6 bcd	0.6 bcd
Pinpoint............................	0.28 fl.oz.	14-d	0.0	0.1 bc	0.0 d	0.0 c	0.6 cde	0.2 cd
+Tourney	0.28 oz.							
Pinpoint............................	0.28 fl.oz.	14-d	0.0	0.1 bc	0.6 bcd	0.6 c	0.3 de	0.0 d
+Rotator (NUP-15013)	0.5 fl.oz							
Pinpoint.............................	0.28 fl.oz	14-d	0.0	0.0 c	0.0 d	0.6 c	3.1 b	0.3 bcd
+Spectro 90..........................	3.5 oz.							
BASF Program.........................	pgm[u]	14-d	0.0	0.0 c	0.0 d	0.0 c	0.0 e	0.0 d
Oreon	6.0 fl.oz.	14-d	0.0	0.0 c	0.3 bcd	0.5 c	1.6 bcd	0.9 bcd
Secure	0.5 fl.oz	14-d	0.0	0.1 bc	0.0 d	0.2 c	0.7 cde	0.2 cd
Untreated			0.0	3.3 a	5.9 a	10.7 a	24.9 a	21.5 a
ANOVA: Treatment (P > F)			1.0000	0.0001	0.0012	0.0001	0.0001	0.0001
Days after treatment		7-d	6	7	2	1	2	1
		14-d	12	7	2	7	2	9
		21-d	12	21	9	16	2	9

[z]Treatments were initiated on 10 May prior to disease developing in the trial area.. All treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2.0 gal 1000-ft^{-2} at 40 psi.

[y]PBI Gordon Program 1 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.); 5 July: Chipco 26GT (3.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.); 3 August: Affirm (0.9 oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[x]PBI Gordon Program 2 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.); 5 July: Chipco 26GT (3.0 fl.oz.) + Subdue Maxx (1.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.); 3 August: Affirm (0.9 oz.) + Segway (0.45 fl.oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[w]PBI Gordon Program 3 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.) + Heritage (0.4 oz.); 5 July: Chipco 26GT (3.0 fl.oz.) + Subdue Maxx (1.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.) + Fame (0.36 fl.oz.); 3 August: Affirm (0.9 oz.) + Segway (0.45 fl.oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[v]Bayer Program consisted of the following treatments. 10 May: Mirage (2.0 fl.oz.); 23 May: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 7 June: Mirage (2.0 fl.oz.) + Exteris Stressgard (4.0 fl.oz.); 21 June: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 5 July: Signature Xtra (4.0 oz.) + Exteris Stressgard (4.0 fl.oz.); 18 July: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 3 August: Signature Xtra (4.0 oz.) + Exteris Stressgard (4.0 fl.oz.); 15 August: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 1 September: Interface (3.0 fl.oz.).

[u]BASF program consisted of the following treatments. 10 May: Tourney (0.18 oz.) + Daconil Action (3.0 fl.oz.); 23 May: Lexicon Instrinsic (0.34 fl.oz.); 7 June: Chipco 26GT (4.0 fl.oz.) + Signature Xtra (4.0 oz.).); 21 June: Lexicon Instrinsic (0.34 fl.oz.); 5 July: Daconil Action (3.0 fl.oz.) + Signature Xtra (4.0 oz.); 18 July: : Lexicon Instrinsic (0.34 fl.oz.); 3 August: Secure (0.5 fl.oz.) + Signature Xtra (4.0 oz.); 15 August: Trinity (1.0 fl.oz.); 1 September: Secure (0.5 fl.oz.). All applications were tank mixed and applied with Primo Maxx (0.125 fl.oz.)

[t]Dollar spot data were log-transformed. Means are de-transformed for presentation.

[s]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 1b. Effect of various fungicides on dollar spot incidence in a creeping bentgrass putting green at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment[z]	Rate per 1000ft²	Int[v]	Dollar Spot Incidence 13 Jul	25 Jul	11 Aug	22 Aug	11 Sep
			----------------------# dollar spot foci 18ft^{-2} ----------------------				
PBI Gordon Program 1	pgm[y]	14-d	1.1 cde	0.5 cde	4.3 cde	8.9 cd	7.2 de
PBI Gordon Program 2	pgm[x]	14-d	5.2 b	3.6 b	23.5 b	26.8 b	23.7 b
PBI Gordon Program 3	pgm[w]	14-d	7.8 b	3.6 b	9.9 bc	14.8 bc	19.0 bc
Kabuto	0.5 fl.oz.	14-d	1.0 cde	1.9 bcd	1.2 def	1.9 fg	6.3 de
Tekken	3.0 fl.oz.	14-d	0.3 de	0.3 de	0.2 f	0.2 gh	0.0 i
Exteris Stressgard	2.5 fl.oz.	14-d	2.5 bcd	1.4 b-e	1.0 ef	2.0 efg	3.9 def
Primo Maxx	0.125 fl.oz.	14-d	53.4 a	53.9 a	82.5 a	140.6 a	191.4 a
Primo Maxx	0.125 fl.oz.	14-d	0.2 de	0.0 e	0.0 f	0.0 h	0.4 hi
+Tekken	3.0 fl.oz.						
Tekken	3.0 fl.oz.	7-d	0.0 e	0.0 e	0.3 f	0.0 h	0.0 i
-Primo Maxx	0.125 fl.oz.						
Bayer Program	pgm[v]	14-d	2.5 bcd	0.2 de	0.9 ef	1.8 fg	0.9 ghi
Exteris Stressgard	4.0 fl.oz.	14-d	0.0 e	0.0 e	0.0 f	0.0 h	0.6 hi
Exteris Stressgard	4.0 fl.oz.	21-d	3.7 bc	0.3 de	1.4 def	6.5 cde	5.1 def
Traction (NUP-15014)	1.5 fl.oz.	14-d	0.0 e	0.0 e	0.0 f	0.0 h	0.0 i
Pinpoint	0.28 fl.oz.	14-d	4.0 bc	2.7 bc	8.0 bc	8.7 cd	27.5 b
Pinpoint	0.28 fl.oz.	14-d	0.0 e	0.2 de	1.2 def	0.3 gh	0.9 ghi
+Tourney	0.28 oz.						
Pinpoint	0.28 fl.oz.	14-d	0.3 de	0.3 de	0.3 f	0.0 h	0.0 i
+Rotator (NUP-15013)	0.5 fl.oz						
Pinpoint	0.28 fl.oz	14-d	3.8 bc	1.9 bcd	5.6 cd	4.7 def	9.2 cd
+Spectro 90	3.5 oz.						
BASF Program	pgm[u]	14-d	0.2 de	0.0 e	0.2 f	1.2 gh	3.1 efg
Oreon	6.0 fl.oz.	14-d	3.4 bc	3.1 b	3.7 cde	8.0 cd	19.2 bc
Secure	0.5 fl.oz	14-d	1.1 cde	0.4 de	1.4 def	1.5 fgh	1.8 fgh
Untreated			34.8 a	34.1 a	77.1 a	131.4 a	184.1 a
ANOVA: Treatment (P > F)			0.0001	0.00001	0.0001	0.0003	0.0001
Days after treatment		7-d	1	7	2	7	9
		14-d	8	7	8	7	9
		21-d	1	13	8	19	18

[z]Treatments were initiated on 10 May prior to disease developing in the trial area.. All treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2.0 gal 1000-ft^{-2} at 40 psi.

[y]PBI Gordon Program 1 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.); 5 July: Chipco 26GT (3.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.); 3 August: Affirm (0.9 oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[x]PBI Gordon Program 2 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.); 5 July: Chipco 26GT (3.0 fl.oz.) + Subdue Maxx (1.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.); 3 August: Affirm (0.9 oz.) + Segway (0.45 fl.oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[w]PBI Gordon Program 3 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.) + Heritage (0.4 oz.); 5 July: Chipco 26GT (3.0 fl.oz.) + Subdue Maxx (1.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.) + Fame (0.36 fl.oz.); 3 August: Affirm (0.9 oz.) + Segway (0.45 fl.oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[v]Bayer Program consisted of the following treatments. 10 May: Mirage (2.0 fl.oz.); 23 May: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 7 June: Mirage (2.0 fl.oz.) + Exteris Stressgard (4.0 fl.oz.); 21 June: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 5 July: Signature Xtra (4.0 oz.) + Exteris Stressgard (4.0 fl.oz.); 18 July: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 3 August: Signature Xtra (4.0 oz.) + Exteris Stressgard (4.0 fl.oz.); 15 August: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 1 September: Interface (3.0 fl.oz.).

[u]BASF program consisted of the following treatments. 10 May: Tourney (0.18 oz.) + Daconil Action (3.0 fl.oz.); 23 May: Lexicon Instrinsic (0.34 fl.oz.); 7 June: Chipco 26GT (4.0 fl.oz.) + Signature Xtra (4.0 oz.).); 21 June: Lexicon Instrinsic (0.34 fl.oz.); 5 July: Daconil Action (3.0 fl.oz.) + Signature Xtra (4.0 oz.); 18 July: : Lexicon Instrinsic (0.34 fl.oz.); 3 August: Secure (0.5 fl.oz.) + Signature Xtra (4.0 oz.); 15 August: Trinity (1.0 fl.oz.); 1 September: Secure (0.5 fl.oz.). All applications were tank mixed and applied with Primo Maxx (0.125 fl.oz.)

[t]Dollar spot data were log-transformed. Means are de-transformed for presentation.

[s]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. Effect of various fungicides on turfgrass quality in a creeping bentgrass putting green at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment[z]	Rate per 1000ft^2	Int	Turf Quality 30 May	9 Jun	30 Jun	13 Jul	25 Jul	11 Aug	22 Aug	11 Sep
			---------- 1-9; 6=min acceptable ----------							
PBI Gordon Program 1	pgm[y]	14-d	7.3 cd[t]	7.0 ef	8.0 a-d	7.5 bc	7.3 bc	6.5 d-g	6.3 def	7.0 b-e
PBI Gordon Program 2	pgm[x]	14-d	6.8 cde	7.5 cde	7.5 cd	6.8 cd	7.5 abc	5.5 g	6.0 ef	5.8 f
PBI Gordon Program 3	pgm[w]	14-d	7.0 cde	7.5 cde	7.8 bcd	7.0 bcd	7.8 abc	6.0 fg	6.3 def	6.0 ef
Kabuto	0.5 fl.oz.	14-d	6.5 de	7.0 ef	8.0 a-d	7.8 abc	7.0 cd	6.3 efg	6.8 cde	6.5 c-f
Tekken	3.0 fl.oz.	14-d	6.3 ef	7.0 ef	7.5 cd	6.8 cd	7.5 abc	6.5 d-g	6.0 ef	7.8 ab
Exteris Stressgard	2.5 fl.oz.	14-d	6.5 de	8.0 bcd	8.5 abc	7.8 abc	8.3 abc	7.3 b-e	7.3bcd	7.5 abc
Primo Maxx	0.125 fl.oz.	14-d	5.5 fg	6.5 f	5.0 e	4.8 f	4.0 f	4.0 h	4.0 g	3.3 g
Primo Maxx	0.125 fl.oz.	14-d	5.3 g	5.5 g	7.8 bcd	7.0 bcd	8.0 abc	7.3 b-e	6.0 ef	8.0 ab
+Tekken	3.0 fl.oz.									
Tekken	3.0 fl.oz.	7-d	5.3 g	5.5 g	8.5 abc	7.5 bc	8.0 abc	7.8 bc	6.3 def	8.0 ab
-Primo Maxx	0.125 fl.oz.									
Bayer Program	pgm[v]	14-d	8.3 ab	9.0 a	8.8 ab	7.5 bc	8.8 a	8.3 ab	8.8 a	8.3 a
Exteris Stressgard	4.0 fl.oz.	14-d	8.5 a	8.3 abc	9.0 a	8.8 a	8.5 ab	8.3 ab	8.3 ab	8.0 ab
Exteris Stressgard	4.0 fl.oz.	21-d	8.3 ab	7.5 cde	8.5 abc	7.5 bc	8.3 abc	7.5 bcd	6.5 c-f	7.5 abc
Traction (NUP-15014)	1.5 fl.oz.	14-d	6.8 cde	7.0 ef	8.3 abc	8.0 ab	8.8 a	8.0 ab	6.8 cde	7.8 ab
Pinpoint	0.28 fl.oz.	14-d	6.5 de	7.3 def	7.0 d	7.0 bcd	7.3 bc	6.5 d-g	6.5 c-f	5.8 f
Pinpoint	0.28 fl.oz.	14-d	6.8 cde	7.0 ef	7.8 bcd	7.8 abc	7.5 abc	6.8 c-f	6.0 ef	7.3 a-d
+Tourney	0.28 oz.									
Pinpoint	0.28 fl.oz.	14-d	7.0 cde	7.3 def	8.3 abc	7.8 abc	7.8 abc	7.8 bc	7.3 bcd	7.5 abc
+Rotator (NUP-15013)	0.5 fl.oz									
Pinpoint	0.28 fl.oz	14-d	7.5 bc	8.0 bcd	8.3 abc	7.3 bc	8.0 abc	7.3 b-e	7.0 cde	6.3 def
+Spectro 90	3.5 oz.									
BASF Program	pgm[u]	14-d	5.5 fg	8.8 ab	8.8 ab	7.3 bc	8.8 a	9.0 a	7.5 bc	8.3 a
Oreon	6.0 fl.oz.	14-d	5.3 g	5.3 g	5.8 e	6.0 de	5.8 de	6.3 efg	5.5 f	6.3 def
Secure	0.5 fl.oz	14-d	6.8 cde	7.3 def	8.3 abc	7.5 bc	8.3 abc	7.5 bcd	6.8 cde	7.3 a-d
Untreated			6.5 de	6.8 ef	5.3 e	5.5 ef	4.5 ef	3.8 h	3.8 g	3.0 g
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		7-d	7	2	1	1	7	2	7	9
		14-d	7	2	9	8	7	8	7	9
		21-d	21	9	9	1	13	8	19	9

[z]Treatments were initiated on 10 May prior to disease developing in the trial area.. All treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2.0 gal 1000-ft^{-2} at 40 psi.

[y]PBI Gordon Program 1 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.); 5 July: Chipco 26GT (3.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.); 3 August: Affirm (0.9 oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[x]PBI Gordon Program 2 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.); 5 July: Chipco 26GT (3.0 fl.oz.) + Subdue Maxx (1.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.); 3 August: Affirm (0.9 oz.) + Segway (0.45 fl.oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[w]PBI Gordon Program 3 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.) + Heritage (0.4 oz.); 5 July: Chipco 26GT (3.0 fl.oz.) + Subdue Maxx (1.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.) + Fame (0.36 fl.oz.); 3 August: Affirm (0.9 oz.) + Segway (0.45 fl.oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[v]Bayer Program consisted of the following treatments. 10 May: Mirage (2.0 fl.oz.); 23 May: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 7 June: Mirage (2.0 fl.oz.) + Exteris Stressgard (4.0 fl.oz.); 21 June: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 5 July: Signature Xtra (4.0 oz.) + Exteris Stressgard (4.0 fl.oz.); 18 July: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 3 August: Signature Xtra (4.0 oz.) + Exteris Stressgard (4.0 fl.oz.); 15 August: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 1 September: Interface (3.0 fl.oz.).

[u]BASF program consisted of the following treatments. 10 May: Tourney (0.18 oz.) + Daconil Action (3.0 fl.oz.); 23 May: Lexicon Instrinsic (0.34 fl.oz.); 7 June: Chipco 26GT (4.0 fl.oz.) + Signature Xtra (4.0 oz.).); 21 June: Lexicon Instrinsic (0.34 fl.oz.); 5 July: Daconil Action (3.0 fl.oz.) + Signature Xtra (4.0 oz.); 18 July: : Lexicon Instrinsic (0.34 fl.oz.); 3 August: Secure (0.5 fl.oz.) + Signature Xtra (4.0 oz.); 15 August: Trinity (1.0 fl.oz.); 1 September: Secure (0.5 fl.oz.). All applications were tank mixed and applied with Primo Maxx (0.125 fl.oz.)

[t]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 3a. Effect of various fungicides on phytotoxicity in a creeping bentgrass putting green at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment[z]	Rate per 1000ft^2	Int	Phytotoxicity 22 May	30 May	2 Jun	9 Jun	12 Jun	15 Jun	19 Jun
			---- 0-5; 2=max acceptable ----						
PBI Gordon Program 1	pgm[y]	14-d	0.0 b[t]	0.5 ef	0.0 g	0.0 d	0.0 e	0.0 d	0.0 c
PBI Gordon Program 2	pgm[x]	14-d	0.0 b	0.0 f	0.0 g	0.0 d	0.0 e	0.0 d	0.0 c
PBI Gordon Program 3	pgm[w]	14-d	0.0 b	0.0 f	0.0 g	0.0 d	0.0 e	0.0 d	0.0 c
Kabuto	0.5 fl.oz.	14-d	0.0 b	1.0 de	1.8 cd	0.3 d	0.3 e	0.0 d	0.0 c
Tekken	3.0 fl.oz.	14-d	0.0 b	0.3 f	1.3 de	0.5 d	0.3 e	0.0 d	0.0 c
Exteris Stressgard	2.5 fl.oz.	14-d	0.0 b	0.3 f	0.8 ef	0.3 d	0.0 e	0.0 d	0.0 c
Primo Maxx	0.125 fl.oz.	14-d	0.0 b	1.8 c	1.8 cd	1.5 c	1.0 cd	0.0 d	0.0 c
Primo Maxx	0.125 fl.oz.	14-d	0.0 b	2.0 bc	2.3 bc	2.5 ab	2.0 b	1.2 b	0.7 b
+Tekken	3.0 fl.oz.								
Tekken	3.0 fl.oz.	7-d	0.0 b	2.5 ab	2.5 ab	2.0 bc	1.5 bc	0.7 c	0.2 c
-Primo Maxx	0.125 fl.oz.								
Bayer Program	pgm[v]	14-d	0.0 b	0.0 f	0.0 g	0.0 d	0.0 e	0.0 d	0.0 c
Exteris Stressgard	4.0 fl.oz.	14-d	0.0 b	0.0 f	0.0 g	0.0 d	0.0 e	0.0 d	0.0 c
Exteris Stressgard	4.0 fl.oz.	21-d	0.0 b	0.0 f	0.0 g	0.0 d	0.3 e	0.0 d	0.0 c
Traction (NUP-15014)	1.5 fl.oz.	14-d	0.0 b	0.3 f	0.0 g	0.0 d	0.3 e	0.0 d	0.0 c
Pinpoint	0.28 fl.oz.	14-d	0.0 b	0.3 f	0.3 fg	0.0 d	0.5 de	0.0 d	0.2 c
Pinpoint	0.28 fl.oz.	14-d	0.0 b	0.3 f	0.8 ef	0.3 d	0.3 e	0.0 d	0.0 c
+Tourney	0.28 oz.								
Pinpoint	0.28 fl.oz.	14-d	0.0 b	0.5 ef	0.3 fg	0.3 d	0.0 e	0.0 d	0.0 c
+Rotator (NUP-15013)	0.5 fl.oz								
Pinpoint	0.28 fl.oz	14-d	0.0 b	0.0 f	0.0 g	0.0 d	0.0 e	0.0 d	0.0 c
+Spectro 90	3.5 oz.								
BASF Program	pgm[u]	14-d	0.0 b	1.5 cd	1.0 e	0.0 d	0.0 e	0.0 d	0.0 c
Oreon	6.0 fl.oz.	14-d	1.8 a	2.8 a	3.0 a	2.8 a	4.0 a	3.0 a	1.2 a
Secure	0.5 fl.oz	14-d	0.0 b	0.0 f	0.0 g	0.0 d	0.0 e	0.0 d	0.0 c
Untreated			0.0 b	0.3 f	0.0 g	0.0 d	0.3 e	0.0 d	0.0 c
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		7-d	6	7	3	2	5	1	5
		14-d	12	7	10	2	5	7	11
		21-d	12	21	3	9	12	16	20

[z] Treatments were initiated on 10 May prior to disease developing in the trial area.. All treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2.0 gal 1000-ft^{-2} at 40 psi.

[y]PBI Gordon Program 1 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.); 5 July: Chipco 26GT (3.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.); 3 August: Affirm (0.9 oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[x]PBI Gordon Program 2 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.); 5 July: Chipco 26GT (3.0 fl.oz.) + Subdue Maxx (1.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.); 3 August: Affirm (0.9 oz.) + Segway (0.45 fl.oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[w]PBI Gordon Program 3 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.) + Heritage (0.4 oz.); 5 July: Chipco 26GT (3.0 fl.oz.) + Subdue Maxx (1.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.) + Fame (0.36 fl.oz.); 3 August: Affirm (0.9 oz.) + Segway (0.45 fl.oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[v]Bayer Program consisted of the following treatments. 10 May: Mirage (2.0 fl.oz.); 23 May: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 7 June: Mirage (2.0 fl.oz.) + Exteris Stressgard (4.0 fl.oz.); 21 June: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 5 July: Signature Xtra (4.0 oz.) + Exteris Stressgard (4.0 fl.oz.); 18 July: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 3 August: Signature Xtra (4.0 oz.) + Exteris Stressgard (4.0 fl.oz.); 15 August: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 1 September: Interface (3.0 fl.oz.).

[u]BASF program consisted of the following treatments. 10 May: Tourney (0.18 oz.) + Daconil Action (3.0 fl.oz.); 23 May: Lexicon Instrinsic (0.34 fl.oz.); 7 June: Chipco 26GT (4.0 fl.oz.) + Signature Xtra (4.0 oz.).); 21 June: Lexicon Instrinsic (0.34 fl.oz.); 5 July: Daconil Action (3.0 fl.oz.) + Signature Xtra (4.0 oz.); 18 July: : Lexicon Instrinsic (0.34 fl.oz.); 3 August: Secure (0.5 fl.oz.) + Signature Xtra (4.0 oz.); 15 August: Trinity (1.0 fl.oz.); 1 September: Secure (0.5 fl.oz.). All applications were tank mixed and applied with Primo Maxx (0.125 fl.oz.)

[t]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 3b. Effect of various fungicides on phytotoxicity in a creeping bentgrass putting green at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment[z]	Rate per 1000ft²	Int	Phytotoxicity 22 Jun	29 Jun	25 Jul	11 Aug	22 Aug
			----------------------- 0-5; 2=max acceptable -----------------------				
PBI Gordon Program 1	pgm[y]	14-d	0.0 c[t]	0.0 c	0.0 b	0.3 c	0.0 d
PBI Gordon Program 2	pgm[x]	14-d	0.0 c	0.0 c	0.0 b	0.0 c	0.0 d
PBI Gordon Program 3	pgm[w]	14-d	0.0 c	0.0 c	0.0 b	0.0 c	0.0 d
Kabuto	0.5 fl.oz.	14-d	0.0 c	0.0 c	0.0 b	0.0 c	0.0 d
Tekken	3.0 fl.oz.	14-d	0.0 c	0.3 c	0.0 b	0.0 c	0.5 c
Exteris Stressgard	2.5 fl.oz.	14-d	0.0 c	0.3 c	0.0 b	0.0 c	0.0 d
Primo Maxx	0.125 fl.oz.	14-d	0.0 c	0.8 b	0.0 b	0.0 c	1.0 b
Primo Maxx	0.125 fl.oz.	14-d	0.4 b	1.3 a	1.1 a	1.0 b	2.0 a
+Tekken	3.0 fl.oz.						
Tekken	3.0 fl.oz.	7-d	0.0 c	0.8 b	0.3 b	0.3 c	1.3 b
-Primo Maxx	0.125 fl.oz.						
Bayer Program	pgm[v]	14-d	0.0 c	0.0 c	0.0 b	0.0 c	0.0 d
Exteris Stressgard	4.0 fl.oz.	14-d	0.0 c	0.0 c	0.0 b	0.0 c	0.0 d
Exteris Stressgard	4.0 fl.oz.	21-d	0.0 c	0.3 c	0.0 b	0.0 c	0.0 d
Traction (NUP-15014)	1.5 fl.oz.	14-d	0.0 c	0.0 c	0.1 b	0.0 c	0.0 d
Pinpoint	0.28 fl.oz.	14-d	0.0 c	0.0 c	0.0 b	0.0 c	0.0 d
Pinpoint	0.28 fl.oz.	14-d	0.0 c	0.0 c	0.0 b	0.0 c	0.3 cd
+Tourney	0.28 oz.						
Pinpoint	0.28 fl.oz.	14-d	0.0 c	0.0 c	0.0 b	0.0 c	0.0 d
+Rotator (NUP-15013)	0.5 fl.oz						
Pinpoint	0.28 fl.oz	14-d	0.0 c	0.0 c	0.1 b	0.0 c	0.0 d
+Spectro 90	3.5 oz.						
BASF Program	pgm[u]	14-d	0.0 c	0.3 c	0.1 b	0.0 c	1.0 b
Oreon	6.0 fl.oz.	14-d	3.5 a	1.5 a	1.3 a	1.8 a	2.3 a
Secure	0.5 fl.oz	14-d	0.0 c	0.3 c	0.0 b	0.0 c	0.0 d
Untreated			0.0 c	0.0 c	0.0 b	0.0 c	0.0 d
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		7-d	1	8	7	2	7
		14-d	1	8	7	8	7
		21-d	1	8	13	8	19

[z] Treatments were initiated on 10 May prior to disease developing in the trial area.. All treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2.0 gal 1000-ft^{-2} at 40 psi.

[y]PBI Gordon Program 1 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.); 5 July: Chipco 26GT (3.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.); 3 August: Affirm (0.9 oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[x]PBI Gordon Program 2 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.); 5 July: Chipco 26GT (3.0 fl.oz.) + Subdue Maxx (1.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.); 3 August: Affirm (0.9 oz.) + Segway (0.45 fl.oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[w]PBI Gordon Program 3 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.) + Heritage (0.4 oz.); 5 July: Chipco 26GT (3.0 fl.oz.) + Subdue Maxx (1.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.) + Fame (0.36 fl.oz.); 3 August: Affirm (0.9 oz.) + Segway (0.45 fl.oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[v]Bayer Program consisted of the following treatments. 10 May: Mirage (2.0 fl.oz.); 23 May: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 7 June: Mirage (2.0 fl.oz.) + Exteris Stressgard (4.0 fl.oz.); 21 June: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 5 July: Signature Xtra (4.0 oz.) + Exteris Stressgard (4.0 fl.oz.); 18 July: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 3 August: Signature Xtra (4.0 oz.) + Exteris Stressgard (4.0 fl.oz.); 15 August: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 1 September: Interface (3.0 fl.oz.).

[u]BASF program consisted of the following treatments. 10 May: Tourney (0.18 oz.) + Daconil Action (3.0 fl.oz.); 23 May: Lexicon Instrinsic (0.34 fl.oz.); 7 June: Chipco 26GT (4.0 fl.oz.) + Signature Xtra (4.0 oz.).); 21 June: Lexicon Instrinsic (0.34 fl.oz.); 5 July: Daconil Action (3.0 fl.oz.) + Signature Xtra (4.0 oz.); 18 July: : Lexicon Instrinsic (0.34 fl.oz.); 3 August: Secure (0.5 fl.oz.) + Signature Xtra (4.0 oz.); 15 August: Trinity (1.0 fl.oz.); 1 September: Secure (0.5 fl.oz.). All applications were tank mixed and applied with Primo Maxx (0.125 fl.oz.)

[t]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 4. Effect of various fungicides on normalized difference vegetative index in a creeping bentgrass putting green at the Plant Science Research and Education Facility in Storrs, CT during 2017.

			NDVI		
Treatment[z]	Rate per 1000ft^2	Int	8 Jun	13 Jul	11 Aug
			------------Vegetation Index-------------		
PBI Gordon Program 1	pgm[y]	14-d	0.740	0.758	0.724 h[t]
PBI Gordon Program 2	pgm[x]	14-d	0.752	0.781	0.769 a
PBI Gordon Program 3	pgm[w]	14-d	0.750	0.769	0.752 b-f
Kabuto	0.5 fl.oz.	14-d	0.729	0.752	0.737 fgh
Tekken	3.0 fl.oz.	14-d	0.738	0.769	0.744 d-g
Exteris Stressgard	2.5 fl.oz.	14-d	0.734	0.762	0.744 d-g
Primo Maxx	0.125 fl.oz.	14-d	0.737	0.769	0.748 b-g
Primo Maxx	0.125 fl.oz.	14-d	0.742	0.770	0.741 efg
+Tekken	3.0 fl.oz.				
Tekken	3.0 fl.oz.	7-d	0.737	0.764	0.735 gh
-Primo Maxx	0.125 fl.oz.				
Bayer Program	pgm[v]	14-d	0.747	0.767	0.758 a-d
Exteris Stressgard	4.0 fl.oz.	14-d	0.735	0.778	0.745 c-g
Exteris Stressgard	4.0 fl.oz.	21-d	0.744	0.772	0.752 b-f
Traction (NUP-15014)	1.5 fl.oz.	14-d	0.732	0.775	0.746 b-g
Pinpoint	0.28 fl.oz.	14-d	0.740	0.774	0.755 a-e
Pinpoint	0.28 fl.oz.	14-d	0.728	0.771	0.740 e-h
+Tourney	0.28 oz.				
Pinpoint	0.28 fl.oz.	14-d	0.744	0.775	0.741 efg
+Rotator (NUP-15013)	0.5 fl.oz				
Pinpoint	0.28 fl.oz	14-d	0.739	0.771	0.760 abc
+Spectro 90	3.5 oz.				
BASF Program	pgm[u]	14-d	0.745	0.767	0.761 ab
Oreon	6.0 fl.oz.	14-d	0.730	0.771	0.745 c-g
Secure	0.5 fl.oz	14-d	0.730	0.780	0.748 b-g
Untreated			0.733	0.771	0.742 d-g
ANOVA: Treatment (P > F)			0.6951	0.3538	0.0003
Days after treatment		7-d	1	1	2
		14-d	1	8	8
		21-d	8	1	8

[z]Treatments were initiated on 10 May prior to disease developing in the trial area.. All treatments were applied using a hand held CO_2 powered spray boom outfitted with a single AI9508E flat fan nozzle calibrated to deliver 2.0 gal 1000-ft^{-2} at 40 psi.

[y]PBI Gordon Program 1 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.); 5 July: Chipco 26GT (3.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.); 3 August: Affirm (0.9 oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[x]PBI Gordon Program 2 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.); 5 July: Chipco 26GT (3.0 fl.oz.) + Subdue Maxx (1.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.); 3 August: Affirm (0.9 oz.) + Segway (0.45 fl.oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[w]PBI Gordon Program 3 consisted of the following treatments. 10 May: Daconil Ultrex (3.2 oz.) + Kabuto (0.5 fl.oz.); 23 May: Kabuto (0.5 fl.oz.); 7 June: Secure (0.5 fl.oz.); 21 June: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.) + Heritage (0.4 oz.); 5 July: Chipco 26GT (3.0 fl.oz.) + Subdue Maxx (1.0 fl.oz.); 18 July: Tekken (3.0 fl.oz.) + Segway (0.45 fl.oz.) + Fame (0.36 fl.oz.); 3 August: Affirm (0.9 oz.) + Segway (0.45 fl.oz.); 15 August: Tekken (3.0 fl.oz.); 1 September: Chipco 26GT (3.0 fl.oz.).

[v]Bayer Program consisted of the following treatments. 10 May: Mirage (2.0 fl.oz.); 23 May: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 7 June: Mirage (2.0 fl.oz.) + Exteris Stressgard (4.0 fl.oz.); 21 June: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 5 July: Signature Xtra (4.0 oz.) + Exteris Stressgard (4.0 fl.oz.); 18 July: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 3 August: Signature Xtra (4.0 oz.) + Exteris Stressgard (4.0 fl.oz.); 15 August: Signature Xtra (4.0 oz.) + Daconil Ultrex (3.2 oz.); 1 September: Interface (3.0 fl.oz.).

[u]BASF program consisted of the following treatments. 10 May: Tourney (0.18 oz.) + Daconil Action (3.0 fl.oz.); 23 May: Lexicon Instrinsic (0.34 fl.oz.); 7 June: Chipco 26GT (4.0 fl.oz.) + Signature Xtra (4.0 oz.).); 21 June: Lexicon Instrinsic (0.34 fl.oz.); 5 July: Daconil Action (3.0 fl.oz.) + Signature Xtra (4.0 oz.); 18 July: : Lexicon Instrinsic (0.34 fl.oz.); 3 August: Secure (0.5 fl.oz.) + Signature Xtra (4.0 oz.); 15 August: Trinity (1.0 fl.oz.); 1 September: Secure (0.5 fl.oz.). All applications were tank mixed and applied with Primo Maxx (0.125 fl.oz.)

[t]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 WITH VARIOUS FUNGICIDES ON A CREEPING BENTGRASS FAIRWAY TURF, 2017

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INTRODUCTION

Dollar spot is a common disease of cool-season turfgrasses caused by the fungal pathogen *Sclerotinia homoeocarpa*. On golf course fairways it is characterized by light, straw-colored spots that may coalesce into larger irregularly shaped areas. It is particularly active during periods of warm daytime temperatures (80°F), warm nighttime temperatures (60°F), and high humidity. It can be managed in part with cultural practices such as maintaining moderate nitrogen fertility and reducing leaf wetness period. However, the use of fungicides is often still necessary on high priority areas such as greens, tees and fairways. The objective of this study was to evaluate the efficacy of new and existing fungicides in controlling dollar spot on a creeping bentgrass fairway turf.

MATERIALS & METHODS

A field study was conducted on a 'Nintey-six Two' 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. Minimal nitrogen was applied to the study area to encourage dollar spot development. A total of 0.55 lb N $1000\text{-}ft^{-2}$ was applied as water soluble sources from May through August. The study area was inoculated with *Sclerotinia homoeocarpa* infested, dried Kentucky bluegrass seed at 3.6 oz. $1000\text{-}ft^{-2}$ on 29 June, 2016. Overhead irrigation was applied as needed to prevent drought stress.

Treatments consisted of new and exisiting fungicide formulations, currently available products applied individually, as tank mixes, and/or in rotational programs. Initial applications for most treatments were made on 17 May prior to disease developing in the trial area. Subsequent applications were made at specified intervals through 9 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 1.0 gal $1000\text{-}ft^{-2}$ at 40 psi. Plots measured 3 x 6 ft and were arranged in a randomized complete block design with four replications.

Dollar spot incidence was assessed as a count of individual dollar spot infection centers within each plot from 22 May to 22 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. All data were subjected to an analysis of variance and means were separated using Fisher's protected least significant difference test. Dollar spot data were log-transformed, and means were detransformed for presentation.

RESULTS AND DISCUSSION

Dollar Spot Incidence

Dollar spot developed on 9 June and increased rapidly throughout the month with 83 dollar spot infection centers (DSIC) in untreated control plots forming by 19 June (Table 1a). All treatments provided good dollar spot control during this time. Disease incidence increased steadily in untreated plots throughout the summer as conditions conducive to dollar spot peristed with 131 DSIC as of 30 June, 277 DSIC as of 25 July, and 358 DSIC by 22 August (Tables 1a and 1b).

UC17-5 and UC17-2 applied individually, alternated every 21-d, or tank-mixed at a reduced rate provided excellent dollar spot control (< 5 DSIC $plot^{-1}$) throughtout the duration of the trial.

Bayer Program 1, a 14-d rotational program consisting of various fungicides provided very good (< 10 DSIC $plot^{-1}$) control of dollar spot for the duration of the study. Conversely, Bayer Program 2, a 21-d version of Program 1, did not provide acceptable dollar spot control (>25 DSIC $plot^{-1}$) during July and August, suggesting that increased rates of these fungicides may be required to provide 21-d control particularly during high disease pressure (Table 1a and 1b).

Exteris Stressgard, a premix containing fluopyram (a SDHI), trifloxystrobin (a strobilurin), and Stressgard was applied at various rates and intervals in this trial. Exteris Stressgard applied at the current label rate (4.135 fl.oz.) every 21-d provided good to acceptable dollar spot control during July and August with between 5 and 18 DSIC $plot^{-1}$. Exteris Stressgard was tested at higher rates (5.0 and 6.0 fl.oz) to determine efficacy at an extended application interval (28-d). Both high-rate-extended-interval treatments provided very good control of disease during July and August.

BASF programs 1 and 2 consisted of various classes of fungicides applied on a 21-d rotation (Table 1a and 1b). Program 1 generally provided very good (< 10 DSIC $plot^{-1}$) dollar spot control for the duration of the study. Program 2 provided acceptable control for the duration of the study, but occasionally saw disease approach 20 DSIC $plot^{-1}$ during July and August. BASF Program 3 consisted of various classes of fungicides applied on a 28-d basis tank-mixed with Anuew, a plant growth regulator. While it provided excellent control through the end of July, disease increased to unacceptable (> 25 DSIC $plot^{-1}$) levels during August.

Tekken, a premix of isofetamid and tebuconazole, was applied alone and in a rotation with Secure and 26GT. Generally, it provided good (≤ 15 DSIC $plot^{-1}$) control when

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applied alone on a 21-d basis, however in the rotational program dollar spot increased to unacceptable levels by August following an application of 26GT .

Pinpoint is a new strobilurin (Q_oI) fungicide which is unique among other fungicides in this chemical class due to its activity against the causal agent of dollar spot. When applied alone on either a 14-d or 21-d basis it did not provide acceptable dollar spot control, with both treatments averaging over 80 DSIC plot^{-1} as of late August. It did provide acceptable control when tank-mixed with either Tourney or Spectro 90 on a 14-d basis. It provided near complete control when tank mixed with Rotator, a new fungicide containing fluazinam. Secure, another fungicide containing fluazinam, provided acceptable levels of control when applied alone on a 21-d basis, averaging 5 to 22 DSIC plot^{-1} during July and August. Traction, a premix containing fluazinam and tebuconazole, provided complete dollar spotcontrol of for the duration of the study when applied on a 14-d basis.

Various SDHI fungicides were applied including Xzemplar (0.21 fl.oz., 21-d), Kabuto (0.5 fl.oz., 14-d) and Emerald (0.18 oz., 21-d). Xzemplar and Emerald provided very good to excellent control for the duration of the study. Kabuto provided excellent control during June, and although disease increased in these plots during July and August disease remained at acceptable levels. In conjunction with past years in which Kabuto has been more robustly tested at a variety of intervals, a 14-d interval appears to be the optimum duration of control for this product at this rate.

Oreon, a pre-mix fungicide containing PCNB and tebuconazole provided little dollar spot control during July and August.

Turf Quality and Phytotoxicity

Turf quality (Table 2a and 2b) was generally affected by disease incidence, although there was some phytotoxicity (Table 3) observed in BASF Program 3 following the application of Anuew, a plant growth regulator. Although the phytotoxicity was initially unacceptable (>2) on 9 June, it quickly faded to acceptable levels and was not observed again during July or August. Plots treated with Oreon also exhibited some chlorosis following treatment application. This chlorosis was typically unacceptable in the first week following application although it faded to acceptable levels by the next application.

As of 29 June, turf quality was especially high on plots treated with Exteris Stressgard (all rates), Kabuto, Tekken, Emerald, Pinpoint + Rotator, and Bayer Program 1. Quality generally remained high on these plots for the duration of the study. As of 11 August, quality was especially high on plots treated with UC17-2, Xzemplar, Traction, Pinpoint + Rotator, and Bayer Program 1.

Table 1a. Dollar spot incidence influenced by various fungicides on a creeping bentgrass fairway turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment[z]	Rate per $1000ft^2$	Int	22 May	9 Jun	19 Jun	23 Jun	30 Jun
			Dollar Spot Incidence				
			# of dollar spot infection centers 18 ft^{-2}				
UC17-5	0.5 fl.oz.	21-d	0.0	0.5	0.0[t] d[s]	0.6 de	1.5 fgh
UC17-2	0.16 fl.oz.	21-d	0.0	1.3	0.0 d	0.0 e	0.2 h
UC17-2	0.08 fl.oz.	21-d	0.0	1.0	0.0 d	0.0 e	0.0 h
+UC17-5	0.5 fl.oz.						
UC17-2	0.16 fl.oz.	21-d	0.0	0.0	0.0 d	0.0 e	0.0 h
-UC17-5	0.5 fl.oz.						
Bayer Program 1	pgm[y]	14-d	0.0	0.0	0.2 cd	0.4 de	0.8 gh
Bayer Program 2	pgm[x]	21-d	0.0	2.5	0.0 d	1.0 cde	8.0 cde
Exteris Stressgard	4.135 fl.oz.	21-d	0.0	0.0	0.0 d	0.2 de	0.3 h
Exteris Stressgard	5.0 fl.oz.	28-d	0.0	0.0	0.0 d	0.0 e	0.0 h
Exteris Stressgard	6.0 fl.oz.	28-d	0.0	1.3	1.3 b	0.2 de	0.2 h
Xzemplar	0.21 fl.oz.	21-d	0.0	0.0	0.0 d	0.0 e	0.0 h
Kabuto	0.5 fl.oz.	14-d	0.0	1.0	0.0 d	0.0 e	0.0 h
Tekken	3.0 fl.oz.	21-d	0.0	0.0	0.0 d	0.2 de	1.6 fgh
Tekken	3.0 fl.oz.	21-d	0.0	0.0	0.0 d	0.0 e	0.6 h
-Secure	0.5 fl.oz.						
-26GT	4.0 fl.oz.						
BASF Program 1	pgm[w]	21-d	0.0	0.8	0.4 bcd	0.3 de	5.8 def
BASF Program 2	pgm[v]	21-d	0.0	0.0	0.0 d	0.8 cde	4.2 efg
BASF Program 3	pgm[u]	28-d	0.0	1.3	0.0 d	0.2 de	0.0 h
Emerald	0.18 oz.	21-d	0.0	1.3	0.0 d	0.2 de	0.6 h
Honor	1.1 oz.	21-d	0.0	0.0	0.0 d	0.3 de	10.7 cde
Secure	0.5 fl.oz.	21-d	0.0	0.0	0.4 bcd	1.4 cd	8.8 cde
Traction (NUP-15014)	1.5 fl.oz.	14-d	0.0	1.0	0.0 d	0.0 e	0.0 h
Pinpoint	0.28 fl.oz.	14-d	0.0	0.0	0.3 bcd	1.4 cd	10.7 cde
Pinpoint	0.28 fl.oz.	14-d	0.0	0.8	0.0 d	0.3 de	8.5 cde
+Tourney	0.28 oz.						
Pinpoint	0.28 fl.oz.	14-d	0.0	0.3	0.0 d	0.0 e	0.0 h
+Rotator (NUP-15013)	0.5 fl.oz.						
Pinpoint	0.28 fl.oz.	14-d	0.0	0.0	0.0 d	0.0 e	0.3 h
+Spectro 90	3.5 oz.						
Pinpoint	0.31 fl.oz.	21-d	0.0	1.0	0.8 bcd	2.8 c	25.9 bc
Daconil Ultrex	3.2 oz.	14-d	0.0	0.0	1.0 bc	0.7 de	4.9 def
Daconil Weatherstik	2.0 fl.oz.	14-d	0.0	1.0	0.6 bcd	0.6 de	16.4 bcd
Daconil Action	3.0 fl.oz.	14-d	0.0	0.0	0.2 cd	0.3 de	4.0 efg
Oreon	6.0 fl.oz.	21-d	0.0	1.3	1.3 b	15.4 b	43.0 b
+Par	0.18 fl.oz.						
Untreated			0.0	3.0	83.1 a	104.9 a	131.1 a
ANOVA: Treatment (P > F)			1.0000	0.2645	0.0001	0.0001	0.0001
Days after treatment		14-d	5	8	5	9	1
		21-d	5	2	12	16	1
		28-d	5	15	5	9	16

[z]Treatments were initiated on 17 May prior to disease developing in the trial area. Subsequent 14-d applications were made on 1, 14, and 29 June, 12 and 26 July, and 9 August. 21-d applications were made 7 and 29 June, 21 July, and 9 August. 28-d applications were made 14 June, 12 July, and 9 August. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9504E flat fan nozzle calibrated to deliver 1.0 gal 1000-ft-2 at 40 psi.

[y]Bayer Program 1 consisted of the following treatments. 17 May: Tartan Stressgard (1.5 fl.oz.); 1 June: Exteris Stressgard (4.0 fl.oz.); 14 June: Mirage Stressgard (1.5 fl.oz.); 29 June: Exteris Stressgard (4.0 fl.oz.); 12 July: Mirage Stressgard (1.5 fl.oz.); 26 July: Interface (3.0 fl.oz.); 9 August: Exteris Stressgard (4.0 fl.oz.).

[x]Bayer Program 2 consisted of the following treatments. 17 May: Tartan Stressgard (1.5 fl.oz.); 7 June: Exteris Stressgard (4.0 fl.oz.); 29 June: Mirage Stressgard (1.5 fl.oz.); 19 July: Exteris Stressgard (4.0 fl.oz.); 9 August: Interface (3.0 fl.oz.).

[w]BASF Program 1 consisted of the following treatments. 17 May: Emerald (0.18 oz.); 7 June: Tourney (0.37 oz.); 29 June: Xzemplar (0.21 fl.oz.); 19 July: Honor (1.1 oz.); 9 August: 26 GT (4.0 fl.oz.)

[v]BASF Program 2 consisted of the following treatments. 17 May: Emerald (0.18 oz.); 7 June: Tourney (0.37 oz.); 29 June: Secure (0.5 fl.oz.); 19 July: Xzemplar (0.21 fl.oz.); 9 August: Mirage Stressgard (1.5 fl.oz.)

[u]BASF Program 3 consisted of the following treatments. 17 May: Tourney (0.37 oz.) + Daconil Weatherstik (2.0 fl.oz.); 14 June: Xzemplar (0.26 fl.oz.) + Secure (0.5 fl.oz.); 12 July: Honor (1.1 oz.) + Daconil Weatherstik (2.0 fl.oz.); 9 August: Trinity (2.0 fl.oz.) + Secure (0.5 fl.oz.). Anuew (0.18 oz) was tank-mixed and applied at each application date.

[t]Dollar spot data were log-transformed on 19 Jun, 23 Jun, 30 Jun, 13 Jul. Means are de-transformed for presentation.

[s]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 1b. Dollar spot incidence influenced by various fungicides on a creeping bentgrass fairway turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment[z]	Rate per 1000ft²	Int	Dollar Spot Incidence 13 Jul	25 Jul	11 Aug	22 Aug	11 Sept
			----------------------- # of dollar spot infection centers 18 ft^{-2}				--------------------
UC17-5	0.5 fl.oz.	21-d	0.9[t] jkl[s]	3.7 i-l	3.6 i-m	2.4 ij	32.8 e-h
UC17-2	0.16 fl.oz.	21-d	0.0 l	1.8 klm	0.0 p	0.4 jk	1.6 lm
UC17-2 +UC17-5	0.08 fl.oz. 0.5 fl.oz.	21-d	0.2 kl	0.2 m	0.0 p	0.0 k	0.2 m
UC17-2 -UC17-5	0.16 fl.oz. 0.5 fl.oz.	21-d	0.0 l	0.3 lm	0.2 op	0.8 jk	1.6 lm
Bayer Program 1	pgm[y]	14-d	3.1 f-j	3.1 j-m	0.6 m-p	0.3 jk	1.1 lm
Bayer Program 2	pgm[x]	21-d	42.3 bc	90.6 abc	51.6 bc	26.0 ef	125.5 bcd
Exteris Stressgard	4.135 fl.oz.	21-d	11.4 def	18.6 d-h	5.8 f-l	5.2 hi	13.3 ij
Exteris Stressgard	5.0 fl.oz.	28-d	9.5 efg	6.1 g-k	12.6 d-i	0.8 jk	5.8 jk
Exteris Stressgard	6.0 fl.oz.	28-d	7.2 e-h	3.4 i-m	10.6 e-k	0.9 jk	2.9 kl
Xzemplar	0.21 fl.oz.	21-d	0.6 jkl	2.2 klm	0.7 m-p	1.0 jk	5.2 jk
Kabuto	0.5 fl.oz.	14-d	0.3 jkl	11.1 f-j	3.0 j-n	19.3 efg	45.7 efg
Tekken	3.0 fl.oz.	21-d	3.1 f-j	12.1 f-j	10.8 e-j	14.5 e-h	46.6 efg
Tekken -Secure -26GT	3.0 fl.oz. 0.5 fl.oz. 4.0 fl.oz.	21-d	0.0 l	12.4 f-j	24.6 b-e	41.0 cde	71.4 c-f
BASF Program 1	pgm[w]	21-d	1.2 i-l	7.9 f-k	4.2 h-m	10.5 fgh	37.3 e-h
BASF Program 2	pgm[v]	21-d	2.6 g-k	20.7 d-h	2.2 l-p	20.5 efg	56.2 d-g
BASF Program 3	pgm[u]	28-d	1.3 i-l	6.0 g-k	38.8 bcd	28.1 def	55.5 d-g
Emerald	0.18 oz.	21-d	1.8 h-l	5.2 h-k	3.4 i-m	10.6 fgh	18.2 hi
Honor	1.1 oz.	21-d	5.8 f-i	23.1 d-g	5.8 f-l	25.1 efg	29.8 ghi
Secure	0.5 fl.oz.	21-d	5.5 f-i	22.9 d-g	15.6 c-h	17.5 e-h	74.6 cde
Traction (NUP-15014)	1.5 fl.oz.	14-d	0.0 l	0.5 lm	0.3 nop	0.0 k	1.7 lm
Pinpoint	0.28 fl.oz.	14-d	33.3 cd	55.5 b-e	19.4 b-g	82.3 bcd	137.5 bc
Pinpoint +Tourney	0.28 fl.oz. 0.28 oz.	14-d	9.3 efg	14.6 e-i	5.1 g-l	21.2 efg	61.1 c-g
Pinpoint +Rotator (NUP-15013)	0.28 fl.oz. 0.5 fl.oz.	14-d	0.2 kl	0.2 m	0.2 op	0.0 k	1.4 lm
Pinpoint +Spectro 90	0.28 fl.oz. 3.5 oz.	14-d	6.6 e-h	8.8 f-k	2.5 k-o	7.7 ghi	31.1 f-i
Pinpoint	0.31 fl.oz.	21-d	52.4 bc	65.5 bcd	37.5 b-e	86.8 bcd	124.9 bcd
Daconil Ultrex	3.2 oz.	14-d	32.6 cd	28.3 b-f	19.8 b-f	30.4 def	72.6 c-f
Daconil Weatherstik	2.0 fl.oz.	14-d	50.9 bc	48.6 b-e	58.6 b	101.0 bc	111.3 bcd
Daconil Action	3.0 fl.oz.	14-d	22.5 cde	25.4 c-f	20.9 b-f	19.8 efg	72.2 c-f
Oreon +Par	6.0 fl.oz. 0.18 fl.oz.	21-d	118.2 ab	106.9 ab	64.0 b	215.1 ab	256.8 ab
Untreated			203.2 a	277.0 a	261.7 a	358.2 a	398.5 a
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		14-d	1	13	2	13	33
		21-d	14	6	2	13	33
		28-d	1	13	2	13	33

[z] Treatments were initiated on 17 May prior to disease developing in the trial area. Subsequent 14-d applications were made on 1, 14, and 29 June, 12 and 26 July, and 9 August. 21-d applications were made 7 and 29 June, 21 July, and 9 August. 28-d applications were made 14 June, 12 July, and 9 August. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9504E flat fan nozzle calibrated to deliver 1.0 gal 1000-ft-2 at 40 psi. .

[y]Bayer Program 1 consisted of the following treatments. 17 May: Tartan Stressgard (1.5 fl.oz.); 1 June: Exteris Stressgard (4.0 fl.oz.); 14 June: Mirage Stressgard (1.5 fl.oz.); 29 June: Exteris Stressgard (4.0 fl.oz.); 12 July: Mirage Stressgard (1.5 fl.oz.); 26 July: Interface (3.0 fl.oz.); 9 August: Exteris Stressgard (4.0 fl.oz.).

[x]Bayer Program 2 consisted of the following treatments. 17 May: Tartan Stressgard (1.5 fl.oz.); 7 June: Exteris Stressgard (4.0 fl.oz.); 29 June: Mirage Stressgard (1.5 fl.oz.); 19 July: Exteris Stressgard (4.0 fl.oz.); 9 August: Interface (3.0 fl.oz.).

[w]BASF Program 1 consisted of the following treatments. 17 May: Emerald (0.18 oz.); 7 June: Tourney (0.37 oz.); 29 June: Xzemplar (0.21 fl.oz.); 19 July: Honor (1.1 oz.); 9 August: 26 GT (4.0 fl.oz.)

[v]BASF Program 2 consisted of the following treatments. 17 May: Emerald (0.18 oz.); 7 June: Tourney (0.37 oz.); 29 June: Secure (0.5 fl.oz.); 19 July: Xzemplar (0.21 fl.oz.); 9 August: Mirage Stressgard (1.5 fl.oz.)

[u]BASF Program 3 consisted of the following treatments. 17 May: Tourney (0.37 oz.) + Daconil Weatherstik (2.0 fl.oz.); 14 June: Xzemplar (0.26 fl.oz.) + Secure (0.5 fl.oz.); 12 July: Honor (1.1 oz.) + Daconil Weatherstik (2.0 fl.oz.); 9 August: Trinity (2.0 fl.oz.) + Secure (0.5 fl.oz.). Anuew (0.18 oz) was tank-mixed and applied at each application date.

[t]Dollar spot data were log-transformed on 25 Jul, 11 Aug. Means are de-transformed for presentation.

[s]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 2a. Turf quality influenced by various fungicides on a creeping bentgrass fairway turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment[z]	Rate per 1000ft²	Int	Turf Quality 22 May	9 Jun	23 Jun	29 Jun
			------------------- 1-9; 6=min acceptable			----------------------
UC17-5	0.5 fl.oz.	21-d	6.0 de[t]	6.8 cd	8.0 abc	7.3 b-f
UC17-2	0.16 fl.oz.	21-d	6.0 de	6.8 cd	7.3 c-f	7.3 b-f
UC17-2	0.08 fl.oz.	21-d	6.0 de	7.5 bc	7.8 a-d	7.0 c-f
+UC17-5	0.5 fl.oz.					
UC17-2	0.16 fl.oz.	21-d	6.0 de	7.3 cd	7.5 b-e	7.0 c-f
-UC17-5	0.5 fl.oz.					
Bayer Program 1	pgm[y]	14-d	6.0 de	8.3 ab	7.3 c-f	8.3 ab
Bayer Program 2	pgm[x]	21-d	6.0 de	7.0 cd	6.5 fg	6.5 efg
Exteris Stressgard	4.135 fl.oz.	21-d	7.0 b	8.8 a	8.0 abc	8.5 a
Exteris Stressgard	5.0 fl.oz.	28-d	7.3 b	7.3 cd	8.3 ab	7.8 a-d
Exteris Stressgard	6.0 fl.oz.	28-d	8.0 a	7.3 cd	8.5 a	8.0 abc
Xzemplar	0.21 fl.oz.	21-d	6.3 cd	7.0 cd	7.0 def	7.3 b-f
Kabuto	0.5 fl.oz.	14-d	6.3 cd	7.0 cd	7.5 b-e	7.8 a-d
Tekken	3.0 fl.oz.	21-d	6.0 de	7.3 cd	7.8 a-d	7.8 a-d
Tekken	3.0 fl.oz.	21-d	6.0 de	6.8 cd	6.8 ef	7.0 c-f
-Secure	0.5 fl.oz.					
-26GT	4.0 fl.oz.					
BASF Program 1	pgm[w]	21-d	5.8 ef	6.8 cd	7.0 def	6.5 efg
BASF Program 2	pgm[v]	21-d	5.8 ef	6.5 d	7.3 c-f	6.3 fgh
BASF Program 3	pgm[u]	28-d	5.0 g	5.0 e	5.8 g	6.3 fgh
Emerald	0.18 oz.	21-d	6.5 c	7.0 cd	7.8 a-d	7.5 a-e
Honor	1.1 oz.	21-d	5.8 ef	6.8 cd	6.8 ef	6.3 fgh
Secure	0.5 fl.oz.	21-d	6.0 de	6.8 cd	7.3 c-f	6.8 def
Traction (NUP-15014)	1.5 fl.oz.	14-d	6.0 de	7.0 cd	7.8 a-d	7.0 c-f
Pinpoint	0.28 fl.oz.	14-d	6.0 de	7.0 cd	6.5 fg	6.3 fgh
Pinpoint	0.28 fl.oz.	14-d	6.0 de	6.8 cd	7.3 c-f	6.3 fgh
+Tourney	0.28 oz.					
Pinpoint	0.28 fl.oz.	14-d	6.0 de	7.3 cd	8.3 ab	8.0 abc
+Rotator (NUP-15013)	0.5 fl.oz.					
Pinpoint	0.28 fl.oz.	14-d	5.5 f	7.3 cd	7.5 b-e	6.8 fgh
+Spectro 90	3.5 oz.					
Pinpoint	0.31 fl.oz.	21-d	6.0 de	7.3 cd	6.8 ef	5.5 gh
Daconil Ultrex	3.2 oz.	14-d	6.0 de	7.0 cd	7.0 def	6.3 fgh
Daconil Weatherstik	2.0 fl.oz.	14-d	6.0 de	7.0 cd	7.5 b-e	5.5 gh
Daconil Action	3.0 fl.oz.	14-d	6.3 cd	7.5 bc	7.3 c-f	5.5 gh
Oreon	6.0 fl.oz.	21-d	6.3 cd	7.0 cd	5.8 g	5.3 h
+Par	0.18 fl.oz.					
Untreated			6.0 de	6.5 cd	4.3 h	4.0 i
ANOVA: Treatment (P > F)			0.0001	0.0001	0.00001	0.0001
Days after treatment		14-d	5	8	9	4
		21-d	5	2	16	21
		28-d	5	15	9	15

[z] Treatments were initiated on 17 May prior to disease developing in the trial area. Subsequent 14-d applications were made on 1, 14, and 29 June, 12 and 26 July, and 9 August. 21-d applications were made 7 and 29 June, 21 July, and 9 August. 28-d applications were made 14 June, 12 July, and 9 August. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9504E flat fan nozzle calibrated to deliver 1.0 gal 1000-ft-2 at 40 psi. .

[y]Bayer Program 1 consisted of the following treatments. 17 May: Tartan Stressgard (1.5 fl.oz.); 1 June: Exteris Stressgard (4.0 fl.oz.); 14 June: Mirage Stressgard (1.5 fl.oz.); 29 June: Exteris Stressgard (4.0 fl.oz.); 12 July: Mirage Stressgard (1.5 fl.oz.); 26 July: Interface (3.0 fl.oz.); 9 August: Exteris Stressgard (4.0 fl.oz.).

[x]Bayer Program 2 consisted of the following treatments. 17 May: Tartan Stressgard (1.5 fl.oz.); 7 June: Exteris Stressgard (4.0 fl.oz.); 29 June: Mirage Stressgard (1.5 fl.oz.); 19 July: Exteris Stressgard (4.0 fl.oz.); 9 August: Interface (3.0 fl.oz.).

[w]BASF Program 1 consisted of the following treatments. 17 May: Emerald (0.18 oz.); 7 June: Tourney (0.37 oz.); 29 June: Xzemplar (0.21 fl.oz.); 19 July: Honor (1.1 oz.); 9 August: 26 GT (4.0 fl.oz.)

[v]BASF Program 2 consisted of the following treatments. 17 May: Emerald (0.18 oz.); 7 June: Tourney (0.37 oz.); 29 June: Secure (0.5 fl.oz.); 19 July: Xzemplar (0.21 fl.oz.); 9 August: Mirage Stressgard (1.5 fl.oz.)

[u]BASF Program 3 consisted of the following treatments. 17 May: Tourney (0.37 oz.) + Daconil Weatherstik (2.0 fl.oz.); 14 June: Xzemplar (0.26 fl.oz.) + Secure (0.5 fl.oz.); 12 July: Honor (1.1 oz.) + Daconil Weatherstik (2.0 fl.oz.); 9 August: Trinity (2.0 fl.oz.) + Secure (0.5 fl.oz.). Anuew (0.18 oz) was tank-mixed and applied at each application date.

[t]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 2b. Turf quality influenced by various fungicides on a creeping bentgrass fairway turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment[z]	Rate per 1000ft²	Int	Turf Quality 13 Jul	25 Jul	11 Aug	22 Aug	11 Sept
			1-9; 6=min acceptable				
UC17-5	0.5 fl.oz.	21-d	7.8 ab[t]	7.3 a-e	7.3 bcd	7.5 abc	5.5 cde
UC17-2	0.16 fl.oz.	21-d	7.8 ab	8.0 abc	8.0 ab	8.3 ab	8.0 ab
UC17-2	0.08 fl.oz.	21-d	8.0 a	8.3 ab	7.8 abc	7.5 abc	8.8 a
+UC17-5	0.5 fl.oz.						
UC17-2	0.16 fl.oz.	21-d	7.3 a-d	8.0 abc	7.5 abc	7.8 abc	8.0 ab
-UC17-5	0.5 fl.oz.						
Bayer Program 1	pgm[y]	14-d	6.5 a-f	7.8 abc	8.5 a	8.5 a	8.3 ab
Bayer Program 2	pgm[x]	21-d	5.0 f-i	5.0 hi	4.3 i	5.8 e-h	3.8 gh
Exteris Stressgard	4.135 fl.oz.	21-d	7.3 a-d	6.3 d-h	7.0 b-e	7.8 abc	6.0 c
Exteris Stressgard	5.0 fl.oz.	28-d	6.5 a-f	7.5 a-d	6.3 d-g	7.3 bcd	7.3 b
Exteris Stressgard	6.0 fl.oz.	28-d	6.8 a-e	7.8 abc	6.0 e-h	8.3 ab	7.5 b
Xzemplar	0.21 fl.oz.	21-d	6.3 b-g	7.8 abc	8.0 ab	7.8 abc	7.3 b
Kabuto	0.5 fl.oz.	14-d	7.5 abc	7.0 b-f	7.3 bcd	5.5 f-i	5.0 c-f
Tekken	3.0 fl.oz.	21-d	7.5 abc	6.8 c-g	6.8 c-f	6.0 efg	5.0 c-f
Tekken	3.0 fl.oz.	21-d	7.3 a-d	7.3 a-e	5.5 gh	5.0 g-j	4.3 fgh
-Secure	0.5 fl.oz.						
-26GT	4.0 fl.oz.						
BASF Program 1	pgm[w]	21-d	7.5 abc	7.3 a-e	6.8 c-f	6.0 efg	5.5 cde
BASF Program 2	pgm[v]	21-d	7.0 a-e	6.0 e-h	7.3 bcd	5.8 e-h	4.8 d-g
BASF Program 3	pgm[u]	28-d	7.3 a-d	7.0 b-f	5.0 hi	5.0 g-j	5.0 c-f
Emerald	0.18 oz.	21-d	6.5 a-f	7.5 a-d	6.8 c-f	5.8 e-h	5.8 cd
Honor	1.1 oz.	21-d	7.3 a-d	5.5 f-i	7.3 bcd	6.0 efg	4.8 d-g
Secure	0.5 fl.oz.	21-d	6.8 a-e	6.0 e-h	6.3 d-g	6.3 def	4.5 e-h
Traction (NUP-15014)	1.5 fl.oz.	14-d	7.8 ab	8.5 a	8.5 a	7.8 abc	8.0 ab
Pinpoint	0.28 fl.oz.	14-d	5.5 e-h	5.5 ghi	6.0 e-h	4.5 ij	3.5 hi
Pinpoint	0.28 fl.oz.	14-d	6.0 c-g	6.3 d-h	7.0 b-e	6.0 efg	5.0 c-f
+Tourney	0.28 oz.						
Pinpoint	0.28 fl.oz.	14-d	7.8 ab	8.5 a	8.0 ab	8.0 ab	8.8 a
+Rotator (NUP-15013)	0.5 fl.oz.						
Pinpoint	0.28 fl.oz.	14-d	7.3 a-d	7.3 a-e	7.0 b-e	6.8 cde	5.8 cd
+Spectro 90	3.5 oz.						
Pinpoint	0.31 fl.oz.	21-d	4.8 ghi	5.3 hi	5.0 hi	4.8 hij	3.5 hi
Daconil Ultrex	3.2 oz.	14-d	6.0 c-g	5.8 f-i	8.5 fgh	5.5 f-i	4.5 e-h
Daconil Weatherstik	2.0 fl.oz.	14-d	5.5 e-h	5.3 hi	4.3 i	4.0 jk	4.0 fgh
Daconil Action	3.0 fl.oz.	14-d	5.8 d-h	6.3 d-h	5.3 ghi	5.3 f-i	4.5 e-h
Oreon	6.0 fl.oz.	21-d	3.5 i	4.5 ij	3.0 j	3.3 k	2.5 i
+Par	0.18 fl.oz.						
Untreated			4.3 hi	3.7 j	1.5 k	1.3 l	1.3 j
ANOVA: Treatment (P > F)			0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		14-d	1	13	2	13	33
		21-d	14	6	2	13	33
		28-d	1	13	2	13	33

[z] Treatments were initiated on 17 May prior to disease developing in the trial area. Subsequent 14-d applications were made on 1, 14, and 29 June, 12 and 26 July, and 9 August. 21-d applications were made 7 and 29 June, 21 July, and 9 August. 28-d applications were made 14 June, 12 July, and 9 August. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9504E flat fan nozzle calibrated to deliver 1.0 gal 1000-ft-2 at 40 psi.

[y] Bayer Program 1 consisted of the following treatments. 17 May: Tartan Stressgard (1.5 fl.oz.); 1 June: Exteris Stressgard (4.0 fl.oz.); 14 June: Mirage Stressgard (1.5 fl.oz.); 29 June: Exteris Stressgard (4.0 fl.oz.); 12 July: Mirage Stressgard (1.5 fl.oz.); 26 July: Interface (3.0 fl.oz.); 9 August: Exteris Stressgard (4.0 fl.oz.).

[x] Bayer Program 2 consisted of the following treatments. 17 May: Tartan Stressgard (1.5 fl.oz.); 7 June: Exteris Stressgard (4.0 fl.oz.); 29 June: Mirage Stressgard (1.5 fl.oz.); 19 July: Exteris Stressgard (4.0 fl.oz.); 9 August: Interface (3.0 fl.oz.).

[w] BASF Program 1 consisted of the following treatments. 17 May: Emerald (0.18 oz.); 7 June: Tourney (0.37 oz.); 29 June: Xzemplar (0.21 fl.oz.); 19 July: Honor (1.1 oz.); 9 August: 26 GT (4.0 fl.oz.)

[v] BASF Program 2 consisted of the following treatments. 17 May: Emerald (0.18 oz.); 7 June: Tourney (0.37 oz.); 29 June: Secure (0.5 fl.oz.); 19 July: Xzemplar (0.21 fl.oz.); 9 August: Mirage Stressgard (1.5 fl.oz.)

[u] BASF Program 3 consisted of the following treatments. 17 May: Tourney (0.37 oz.) + Daconil Weatherstik (2.0 fl.oz.); 14 June: Xzemplar (0.26 fl.oz.) + Secure (0.5 fl.oz.); 12 July: Honor (1.1 oz.) + Daconil Weatherstik (2.0 fl.oz.); 9 August: Trinity (2.0 fl.oz.) + Secure (0.5 fl.oz.). Anuew (0.18 oz) was tank-mixed and applied at each application date.

[t] 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 3. Phytotoxicity influenced by various fungicides on a creeping bentgrass fairway turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft²	Int	22 May	9 Jun	23 Jun	30 Jun	25 Jul	11 Aug	15 Aug
			Phytotoxicity						
			0-5;2=max acceptable						
UC17-5	0.5 fl.oz.	21-d	0.0	0.0 c[t]	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
UC17-2	0.16 fl.oz.	21-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
UC17-2 +UC17-5	0.08 fl.oz. 0.5 fl.oz.	21-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
UC17-2 -UC17-5	0.16 fl.oz. 0.5 fl.oz.	21-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
Bayer Program 1	pgm	14-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
Bayer Program 2	pgm	21-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
Exteris Stressgard	4.135 fl.oz.	21-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
Exteris Stressgard	5.0 fl.oz.	28-d	0.0	0.0 c	0.0 c	0.3 e	0.0 b	0.0 b	0.0 b
Exteris Stressgard	6.0 fl.oz.	28-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
Xzemplar	0.21 fl.oz.	21-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
Kabuto	0.5 fl.oz.	14-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
Tekken	3.0 fl.oz.	21-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
Tekken -Secure -26GT	3.0 fl.oz. 0.5 fl.oz. 4.0 fl.oz.	21-d	0.0	0.0 c	0.5 b	0.0 e	0.0 b	0.0 b	0.0 b
BASF Program 1	pgm	21-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
BASF Program 2	pgm	21-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
BASF Program 3	pgm	28-d	0.0	2.3 a	1.8 a	1.3 a	0.0 b	0.0 b	0.0 b
Emerald	0.18 oz.	21-d	0.0	0.0 c	0.0 c	0.3 de	0.0 b	0.0 b	0.0 b
Honor	1.1 oz.	21-d	0.0	0.0 c	0.0 c	0.3 de	0.0 b	0.0 b	0.0 b
Secure	0.5 fl.oz.	21-d	0.0	0.0 c	0.3 bc	0.0 e	0.0 b	0.0 b	0.0 b
Traction (NUP-15014)	1.5 fl.oz.	14-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
Pinpoint	0.28 fl.oz.	14-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
Pinpoint +Tourney	0.28 fl.oz. 0.28 oz.	14-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
Pinpoint +Rotator (NUP-15013)	0.28 fl.oz. 0.5 fl.oz.	14-d	0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
Pinpoint +Spectro 90	0.28 fl.oz. 3.5 oz.	14-d	0.0	0.0 c	0.3 bc	1.0 ab	0.0 b	0.0 b	0.0 b
Pinpoint	0.31 fl.oz.	21-d	0.0	0.8 b	0.0 c	0.5 cd	0.0 b	0.0 b	0.0 b
Daconil Ultrex	3.2 oz.	14-d	0.0	0.0 c	0.0 c	0.3 de	0.0 b	0.0 b	0.0 b
Daconil Weatherstik	2.0 fl.oz.	14-d	0.0	0.0 c	0.0 c	0.3 de	0.0 b	0.0 b	0.0 b
Daconil Action	3.0 fl.oz.	14-d	0.0	0.0 c	0.0 c	0.8 bc	0.0 b	0.0 b	0.0 b
Oreon +Par	6.0 fl.oz. 0.18 fl.oz.	21-d	0.0	0.0 c	0.5 b	0.3 de	1.8 a	2.3 a	2.8 a
Untreated			0.0	0.0 c	0.0 c	0.0 e	0.0 b	0.0 b	0.0 b
ANOVA: Treatment (P > F)			1.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Days after treatment		14-d	5	8	9	1	13	2	6
		21-d	5	2	16	1	6	2	6
		28-d	5	15	9	16	13	2	6

[z] Treatments were initiated on 17 May prior to disease developing in the trial area. Subsequent 14-d applications were made on 1, 14, and 29 June, 12 and 26 July, and 9 August. 21-d applications were made 7 and 29 June, 21 July, and 9 August. 28-d applications were made 14 June, 12 July, and 9 August. All treatments were applied using a hand held CO2 powered spray boom outfitted with a single AI9504E flat fan nozzle calibrated to deliver 1.0 gal 1000-ft-2 at 40 psi.

[y]Bayer Program 1 consisted of the following treatments. 17 May: Tartan Stressgard (1.5 fl.oz.); 1 June: Exteris Stressgard (4.0 fl.oz.); 14 June: Mirage Stressgard (1.5 fl.oz.); 29 June: Exteris Stressgard (4.0 fl.oz.); 12 July: Mirage Stressgard (1.5 fl.oz.); 26 July: Interface (3.0 fl.oz.); 9 August: Exteris Stressgard (4.0 fl.oz.).

[x]Bayer Program 2 consisted of the following treatments. 17 May: Tartan Stressgard (1.5 fl.oz.); 7 June: Exteris Stressgard (4.0 fl.oz.); 29 June: Mirage Stressgard (1.5 fl.oz.); 19 July: Exteris Stressgard (4.0 fl.oz.); 9 August: Interface (3.0 fl.oz.).

[w]BASF Program 1 consisted of the following treatments. 17 May: Emerald (0.18 oz.); 7 June: Tourney (0.37 oz.); 29 June: Xzemplar (0.21 fl.oz.); 19 July: Honor (1.1 oz.); 9 August: 26 GT (4.0 fl.oz.)

[v]BASF Program 2 consisted of the following treatments. 17 May: Emerald (0.18 oz.); 7 June: Tourney (0.37 oz.); 29 June: Secure (0.5 fl.oz.); 19 July: Xzemplar (0.21 fl.oz.); 9 August: Mirage Stressgard (1.5 fl.oz.)

[u]BASF Program 3 consisted of the following treatments. 17 May: Tourney (0.37 oz.) + Daconil Weatherstik (2.0 fl.oz.); 14 June: Xzemplar (0.26 fl.oz.) + Secure (0.5 fl.oz.); 12 July: Honor (1.1 oz.) + Daconil Weatherstik (2.0 fl.oz.); 9 August: Trinity (2.0 fl.oz.) + Secure (0.5 fl.oz.). Anuew (0.18 oz) was tank-mixed and applied at each application date.

[t]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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PERFORMANCE OF FUNGICIDES FOR DOLLAR SPOT CONTROL WITH DIFFERENT ENVIRONMENTAL IMPACT QUOTIENTS (EIQ) IN A CREEPING BENTGRASS FAIRWAY TURF, 2017

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INTRODUCTION

Dollar spot is a common disease of cool-season turfgrasses caused by the fungal pathogen *Sclerotinia homoeocarpa*. On golf course fairways it is characterized by light, straw-colored spots that may coalesce into larger irregularly shaped areas. It is particularly active during periods of warm daytime temperatures (80°F), warm nighttime temperatures (60°F), and high humidity. It can be managed in part with cultural practices such as maintaining moderate nitrogen fertility and reducing leaf wetness period. However, the use of fungicides is often still necessary on high priority areas such as greens, tees and fairways. Environmental Impact Quotient (EIQ) is used to characterize the relative environmental and toxicological risk associated with various pesticides. Pesticides with EIQ values ≤ 25 are preferred by the New York State Best Management Practices for Golf Courses due to their reduced environmental impact increased safety. The objective of this study was to compare dollar spot disease control among low and high EIQ fungicides in a 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. Minimal nitrogen was applied to the study area to encourage dollar spot development. A total of 1.05 lb N $1000\text{-}ft^{-2}$ was applied as water soluble sources from April through August. Overhead irrigation was applied as needed to prevent drought stress.

Treatments consisted of various fungicides with EIQ values greater than or less than 25. Initial applications were made on 18 May prior to disease developing in the trial area. Subsequent applications were made at specified intervals through 10 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 1.0 gal $1000\text{-}ft^{-2}$ at 40 psi. Plots measured 3 x 6 ft and were arranged in a randomized complete block design with four replications.

Dollar spot incidence was assessed as a count of individual dollar spot infection centers within each plot from 3 June to 2 September. All data were subjected to an analysis of variance and means were separated using Fisher's protected least significant difference test. Dollar spot data were log-transformed, and means were de-transformed for presentation. A pre-planned contrast was performed to compare efficacy of all fungicides with EIQs greater than 25 versus those with EIQs less than 25.

RESULTS AND DISCUSSION

Dollar Spot Incidence

Dollar spot developed from a natural infestation on 9 June and increased steadily through 30 June, averaging 77 dollar spot infection centers (DSIC) $plot^{-1}$ on untreated control plots (Table 1). Thereafter, dollar spot severity increased rapidly, reaching a peak of 237 DSIC in untreated controls on 13 July, and remaining high through the end of the trial.

All fungicides reduced dollar spot compared to the untreated control throughout the trial. A group comparison of all fungicides with EIQs greater than 25 versus those with EIQs less than 25 showed dollar spot control was equivalent between these groups on every observation date. These results suggest that fungicides with low EIQs can be just as effective as those with high EIQs.

Comparisons of individual treatments did show dollar spot efficacy differed among individual fungicides. Secure (12.7 EIQ) and Interface (65.7 EIQ) consistently provided the greatest dollar spot control, maintaining disease at ≤ 1 DSIC throughtout the trial. Emerald (9.1 EIQ), Velista (16.0 EIQ), and Tartan (28.1 EIQ) provided good dollar spot control (≤ 10 DSIC), but were less effective than Secure and Interface on some observation dates.

Environmental Impact Quotient

Pesticides with EIQ values < 25 are generally considered to have a lower environmental impact. The single-application as well as yearly total EIQ for each treatment are presented in Table 1. Daconil Action had the highest single-app EIQ (165.1) and yearly total EIQ equal to 1155.7 following 7 applications on a 14-d interval. Conversely, Secure applied every 14-d had a yearly total EIQ of 88.9 for 7 applications. Emerald at 0.18 oz on a 21-d interval (5 applications) had the lowest yearly total EIQ of 45.5.

CONCLUSION

There are many effective fungicides available for controlling dollar spot on a creeping bentgrass fairways. Results from this trial demonstrate that relative EIQ values do not appear to be related to effectiveness of fungicides for controlling dollar spot. EIQ provides an opportunity to compare potential environmental impact when selecting fungicides. While many factors influence fungicide choices, selecting fungicides that have good disease control and lower EIQ values may be benefical to sustaining long-term golf course environmental quality.

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Table 1. Dollar spot incidence influenced by various fungicides on a creeping bentgrass fairway turf at the Plant Science Research and Education Facility in Storrs, CT during 2017.

Treatment	Rate per 1000ft²	Int[z]	Single App EIQ	Yearly Total EIQ	Dollar Spot Incidence 9 Jun	19 Jun	23 Jun	30 Jun	13 Jul	25 Jul	11 Aug	22 Aug
					# of dollar spot infection centers 18 ft^{-2}							
Emerald	0.18 oz.	21-d	9.1	45.5	0.0	0.0 c	0.0 b	0.3 b[y]	2.9 cd	5.2 cde	4.6 def	6.9 cd
Velista	0.5 oz.	21-d	16.0	80.0	0.0	0.0 c	0.0 b	0.2 b	0.6 de	1.7 efg	3.0 ef	6.0 cd
Tourney	0.37 oz.	21-d	12.1	60.5	0.0	0.0 c	0.0 b	0.2 b	5.3 bc	12.6 bc	7.7 cde	15.8 bc
Banner Maxx	1.0 fl.oz.	21-d	12.3	61.5	0.0	0.0 c	0.3 b	0.7 b	5.2 bc	10.9 bc	15.5 bcd	2.7 de
Trinity	1.5 fl.oz.	21-d	9.2	46.0	0.0	0.9 b	0.0 b	0.4 b	15.7 b	22.1 b	31.6 b	36.5 b
Secure	0.5 fl.oz.	14-d	12.7	88.9	0.0	0.0 c	0.0 b	0.0 b	0.8 de	0.4 fg	0.0 g	0.2 e
Chipco 26019	4.0 fl.oz.	21-d	61.5	307.5	0.0	0.0 c	0.0 b	0.2 b	2.9cd	7.9 bcd	20.5 bc	4.7 cd
Interface	4.0 fl.oz.	21-d	65.7	328.5	0.0	0.0 c	0.2 b	0.2 b	0.2 e	0.2 g	1.0 fg	0.0 e
Torque	0.6 fl.oz.	21-d	25.5	127.5	2.5	0.3 bc	0.0 b	0.3 b	5.4 bc	11.5 bc	24.2 bc	16.0 bc
Tartan	1.5 fl.oz.	21-d	28.1	140.5	0.0	0.2 bc	0.0 b	0.0 b	0.2 e	2.9 def	1.4 fg	0.2 e
Daconil Action	3.0 fl.oz.	14-d	165.1	1155.7	0.0	0.6 bc	0.2 b	0.0 b	5.4 bc	4.2 cde	22.5 bc	15.9 bc
Untreated					4.3	20.2 a	40.7 a	77.1 a	236.6 a	169.3 a	188.0 a	238.1 a
Source of variation:					*P > F*							
Treatment					NS	***	***	***	***	***	***	***
Planned F-test:												
EIQ < 25 *vs.* EIQ > 25					NS	NS	NS	NS	NS	NS	NS	NS
Days after treatment		14-d			8	4	8	1	14	12	1	12
		21-d			2	12	16	1	14	4	1	12

[z]Initial applications were made on 18 May prior to disease developing in the trial area. Subsequent applications were made every 14-d or 21-d through 10 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.
[y] Means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test ($\alpha = 0.05$).
*** indicates a statistical F-test at the 0.0001 probability level. NS indicates no significant difference.

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DETERMINING DISLODGEABLE FOLIAR RESIDUE LEVELS FOLLOWING THE APPLICATION OF TWO PESTICIDES USED TO MANAGE SPORTS TURF, 2017

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INTRODUCTION

The use of pesticides on athletic fields is often a contentious issue due to concerns regarding human health. Due to this concern, Connecticut has banned all pesticides on school grounds from Kindergarten through 8th grade to reduce the risk of exposure to children (State of Connecticut, 2009). Pesticide fate post application largely determines the potential for human exposure (Clark, 2007). In an effort to limit exposure to field users, pesticide labels may designate reentry time periods or state to keep unprotected persons or pets out of the treated area until sprays have dried. However, many are still concerned for field user safety. Quantification of residues post application will provide lawmakers with science-based information when drafting future legislation to minimize pesticide exposure.

The objective of this research was to quantify foliar residues on playing surfaces following the application of two herbicides in two formulations sampled at post application time intervals of 0, 1, 3, 5, 7, 9 & 14 days after treatment. Initial samples were collected prior to herbicide treatments.

MATERIALS AND METHODS

A two-year field study was conducted at the University of Connecticut Plant Science Research and Education Facility in Storrs, CT. The experiment was initiated on 12 July 2016 and repeated on 8 August 2017. The first year the study was performed on a three-year-old monostand of ‘Granite’ Kentucky bluegrass (*Poa pratensis* L.) on a Woodbridge, fine sandy loam soil. The following year the site was renovated and re-sodded with a blend of Kentucky bluegrass cultivars including; ‘Everest’ (40%), ‘Wildhorse’ (20%), ‘Corsair’ (20%), and ‘Award’ (20%). Turfgrass was actively growing and not under stress prior to applying the treatments. Nitrogen was applied at 24 kg ha^{-1} as urea (45-0-0) on 8 June 2016 and 49 kg ha^{-1} as Methex (40-0-0) on 27 July 2017. The study was mowed at 6.35 cm twice weekly and the clippings were returned. The last mowing occurred the morning before herbicides treatments were applied. Thereafter, entry into the research area was restricted and no mowing or irrigation occurred.

The study was arranged in a split-split plot design as a 2 × 2 × 8 factorial with three blocks measuring (1.8 m × 29.3 m). The main plot factor, formulation, included granular and liquid (1.8 m × 14.6 m). The subplot factor, herbicide, included a 3-way combination broadleaf herbicide (2,4-D, dicamba and mecoprop) and dithiopyr (1.8 m × 7.3 m). The sub-subplot factor was herbicide residue collected days after treatment (DAT), which included an initial, 0, 1, 3, 5, 7, 9, and 14 (0.9 m × 1.8 m). The combination herbicide was applied as a granular formulation of Ferti-lome Weed Out Broadleaf Control (PBI/Gordon Corporation, Kansas City, MO) or liquid formulation of Trimec Classic (PBI/Gordon Corporation, Kansas City, MO). Both formulations were applied at a rate of 1.5 kg ai ha^{-1}. Dithiopyr was applied as granular Dimension 0.1 G; plus fertilizer (0-0-7) (Dow AgroSciences, Indianapolis, IN) or liquid Dimension 2EW (Dow AgroSciences, Indianapolis, IN). Both formulations were applied at a rate of 0.2 kg ai ha^{-1}.

Granular herbicides were applied to plots using a hand-held shaker. Prior to the application of the granular 3-way combination herbicide, the plots were watered with 6.4 mm of irrigation to improve adhesion of the herbicide granules to the foliage. Granular and liquid dithiopyr were watered in after application with 12.7 mm of irrigation. All watering was in accordance to their respective labels and measured using a flow meter (Figure 1).

Figure 1. Wetting surface before the application of granular 2,4-D.

Liquid herbicides were applied with a Toro Multi Pro 1250 sprayer (The Toro Company, Bloomington, MN). The sprayer was calibrated to deliver the herbicides at 774 L ha^{-1} with AI11008 nozzles at 241 kPa traveling at 4.8 km h^{-1}. To prevent driving on treated turfgrass and contaminating adjacent plots, the sprayer traveled in a 1.8 m wide alleyway between blocks. Additionally, plywood boards were positioned to prevent spraying into adjacent plots. In 2016, all blocks were treated with a single herbicide before sampling was initiated. In 2017, treatment applications and samplings were completed for each subplot factor (herbicide) before moving to subsequent subplots to minimize variations between blocks associated with drying of the herbicide on the foliage.

Samples were collected to determine how persistent herbicide residues were on foliage over time. Initial samples were collected a week before herbicide treatments were applied. Day 0 samples were taken immediately following the application. On day 1, 3, 5, 7, 9, and 14 sample collection occurred between 5:00 am and 6:30 am. This timing has been determined to corresponds with peak daily residue recovery (Gannon and Jeffries, 2014).

Residue samples were collected on a percale cotton cloth covered with a 4 mm thick plastic sheet that was clamped by a Polyvinyl chloride (PVC) frame with internal dimensions of 0.9 m × 0.6 m, and placed on the turf canopy (Figure 2). A modified California roller was rolled twenty passes on top of the plastic; down and back counted as two separate passes (Williams et al., 2008). After each sample was rolled, the plastic was discarded and the frame was cleaned to minimize cross-contamination. The roller (13.6 kg) was 60 cm wide, 10 cm in diameter and foam-wrapped to help conform to small undulations on the surface of the ground. After collection, the cloth was carefully placed in an amber colored jar (500 mL, Fisher Scientific, Hampton, NH), and placed into a cooler. Samples were transferred to a -4º C freezer to minimize degradation of the active ingredients during storage.

Figure 2. Cloth sample after being rolled. Dew moisture visible on cloth.

The laboratory testing was conducted by the University of Massachusetts Pesticide Laboratory, Amherst, MA. Trimec Classic and Ferti-lome Weed-Out samples were tested for all three active ingredients; 2,4-D, dicamba and mecoprop. Both Dimensions formulations were tested for dithiopyr only.

An analysis of variance was completed to test for significant treatment effects (P <0.05) using the Mixed procedure in SAS statistical software 9.4 (SAS Institute. Cary, NC. 2004). Least square means were separated based on Fisher's protected least significant difference (LSD) test.

RESULTS AND DISCUSSION

The average dislodgeable pesticide residues extracted from each treatment are summarized in Table 1. Significant main effects were observed across all three factors for both years; active ingredient, formulation, and DAT. Significant interactions were also observed across all combinations of the three factors for 2016 and 2017. The results of the mean separation test are shown in Figures 3 - 10 and Table 1. In 2016, liquid 2,4-D and dicamba residues for Day 1 were significantly higher than Day 0, and no differences were observed between the remaining days after treatment. In 2017, Day 1 also had slightly higher values than Day 0, but were not statistically different. After Day 3, no differences were observed between DAT. Table 1 shows that in both years, the liquid formulation of the 3-way combination broadleaf herbicide had some of the highest levels of residues during the 14-day period. Rain events may have resulted in the sharp decline of residue on Day 3 in 2016, and Day 5 in 2017.

Generally, the granular formulations resulted in less residue retained in the canopy and/or non-detectable (ND) levels of the active ingredient sooner after application (Table 1). The exception was mecoprop (MCPP) in 2017 where no differences were observed between formulations after 0 DAT. In 2016, regardless of active ingredient, the granular formulation resulted in significantly less residue retained in the canopy immediately following application on Day 0 (Figures 3-6). In 2017, a similar trend was observed with the granular formulations of 2,4-D, MCPP, and dicamba all resulting in less residue in the canopy on Day 0 (Figures 7-9). The exception was dithiopyr where no differences were detected between formulations (Figure 10). During both years, the study was conducted, plots treated with granular formulations of 2,4-D and dicamba had significantly less residue compared to those treated with the liquid formulations one day after application (Table 1). During the first year of the study with a detection limit of 1.95 μg sample^{-1}, dithiopyr was ND as soon as one day after application regardless of formulation. In 2017, with a much lower detection limit (0.035 μg sample^{-1}), the granular formulation was ND 5 DAT and liquid formulation at 9 DAT (Table 1). However, following three consecutive ND, 0.4 μg was recovered on 14 DAT in the granular formulation.

Detection limits were improved for the active ingredients used in the experiment from 2016 to 2017. Dithiopyr had a detectable residue level of 1.95 μg sample^{-1} and 0.035 μg sample^{-1} in 2016 and 2017 respectively. The improved detection limits are likely the reason why dithiopyr residues were found through Day 14 in 2017. 2,4-D and MCPP had a detection limit of 0.39 and 0.035 μg sample^{-1} in 2016 and 2017 respectively. Dicamba had a detection limit of 3.9 and 0.35 μg sample^{-1} in 2016 and 2017. Any residue recovered below these limits was labeled ND. For statistical analysis purposes, all ND's were considered half the detection limit.

Additional research is needed to determine how the solubility of 2,4-D and dicamba can lead to residues dislodging into solution multiple days and weeks after treatment. According to these data (Table 1), the granular formulation of the 3-way combination broadleaf herbicide had lower residues recovered than liquid formulations. This was also observed in 2016 with the dithiopyr herbicides. This suggests that granular formulation of the 3-way combination broadleaf herbicide would be preferred over liquid formulation to minimize field closure times following the use of pesticides; however, this suggestion does not consider the efficacy of the herbicides tested, which is an important component to sports turf maintenance. These results can help improve recommendations for minimizing potential exposure risks and help lawmakers make science-based decisions concerning future legislation.

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Table 1. Average dislodgeable residues in Kentucky bluegrass following the application of herbicides in both formulations in 2016 and 2017.

			Days After Treatment						
Year	Formulation	a.i.	0	1	3	5	7	9	14
			---------- μg sample⁻¹ ----------						
2016	L	2,4-D	703.6b[f]	1251.9a	18.5c	4.3c	2.1c	8.1c	7.3c
	G	2,4-D	6.7c	4.0c	2.1c	ND	ND	ND	0.4c
	L	MCPP	210.1a	176.1a	3.9b	1.2b	0.4b	1.1b	1.8b
	G	MCPP	4.3b	ND	1.52b	ND	ND	ND	ND
	L	Dicamba	689.5b	1279.2a	14.2c	ND	ND	5.6c	6.7c
	G	Dicamba	5.8c	4.5c	ND	ND	ND	ND	ND
	L	Dithiopyr	26.4a	ND	ND	ND	ND	-[e]	-
	G	Dithiopyr	3.9b	ND	ND	ND	ND	-	-
2017	L	2,4-D	391.4a	433.7a	210.3b	2.50c	3.87c	1.15c	0.33c
	G	2,4-D	2.38c	16.13c	4.60c	0.43c	0.41c	0.25c	0.04c
	L	MCPP	127.3a	77.5ab	15.0b	0.21b	0.50b	0.15b	0.04b
	G	MCPP	0.56b	3.7b	1.16b	0.06b	0.19b	0.06b	0.04b
	L	Dicamba	371.5a	450.4a	209.2b	2.13c	4.13c	1.0c	ND
	G	Dicamba	1.90c	18.5c	4.01c	ND	ND	ND	ND
	L	Dithiopyr	24.9a	1.46b	0.11b	0.04b	0.04b	ND	ND
	G	Dithiopyr	14.5a	1.09b	0.11b	ND	ND	ND	0.04b

[a]Abbreviations: DAT, Days after treatment; G/L, Granular/Liquid; a.i., active ingredient; ND, Non-detectable
[b]Dithiopyr samples had a detection limit of 1.95 μg sample^{-1} (2016) and 0.035 μg sample^{-1} (2017).
[c]2,4-D and MCPP had a detection limit of 0.39 μg sample^{-1} (2016) and 0.035 μg sample^{-1} (2017).
[d]Dicamba had a detection limit of 3.9 μg sample^{-1} (2016) and 0.35 μg sample^{-1} (2017).
[e]Dashes '-' indicate no laboratory sampling took place because of four consecutive non-detects
[f] Statistical comparison within years and active ingredients; grouped within shaded rows. Data points with the same letter are not statistically different according to Fisher's protected LSD (P<0.05).

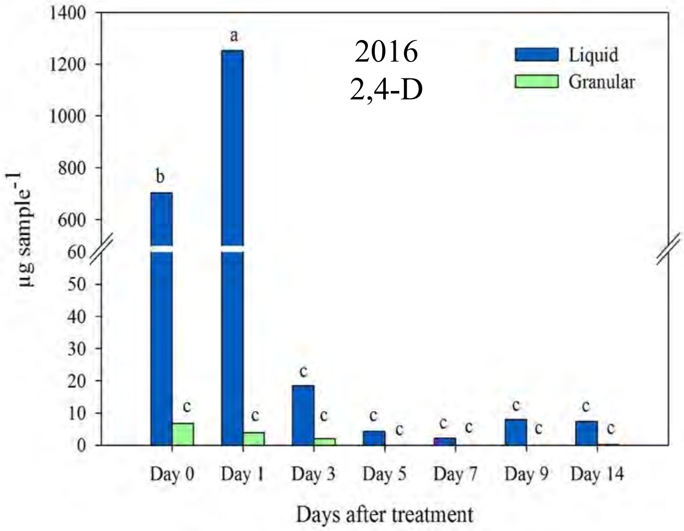

Figure 3. The effect of formulation and time on dislodgeable foliar residue levels of 2,4-D. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P*<0.05).

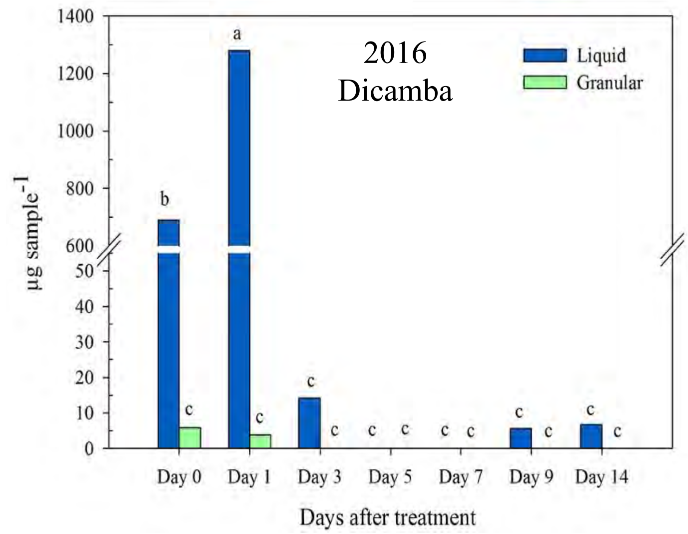

Figure 4. The effect of formulation and time on dislodgeable foliar residue levels of Dicamba. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P*<0.05)

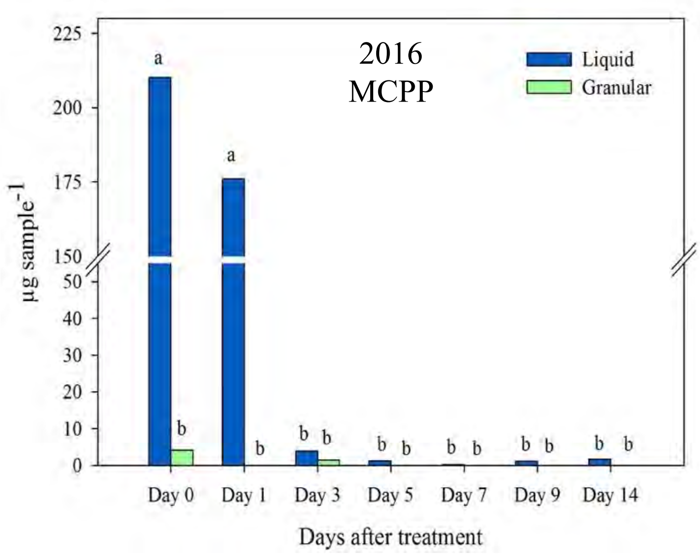

Figure 5. The effect of formulation and time on dislodgeable foliar residue levels of MCPP. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P*<0.05).

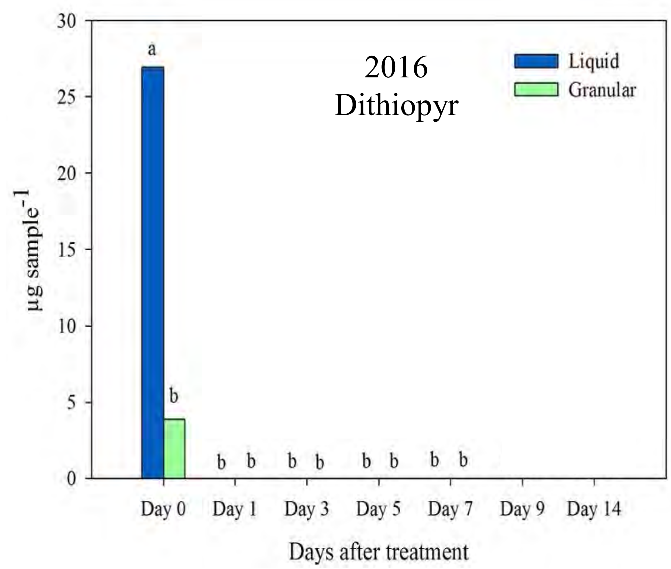

Figure 6. The effect of formulation and time on dislodgeable foliar residue levels of Dithiopyr. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P*<0.05).

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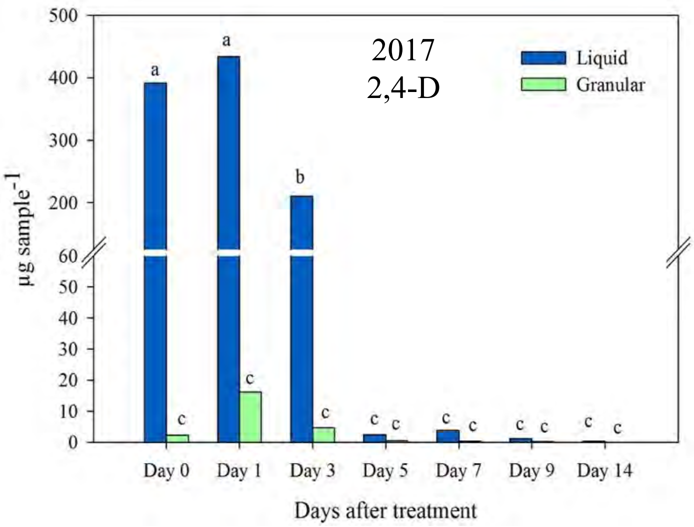


Figure 7. The effect of formulation and time on dislodgeable foliar residue levels of 2,4-D. Data points with the same letter are not statistically different according to Fisher's protected LSD (P<0.05).

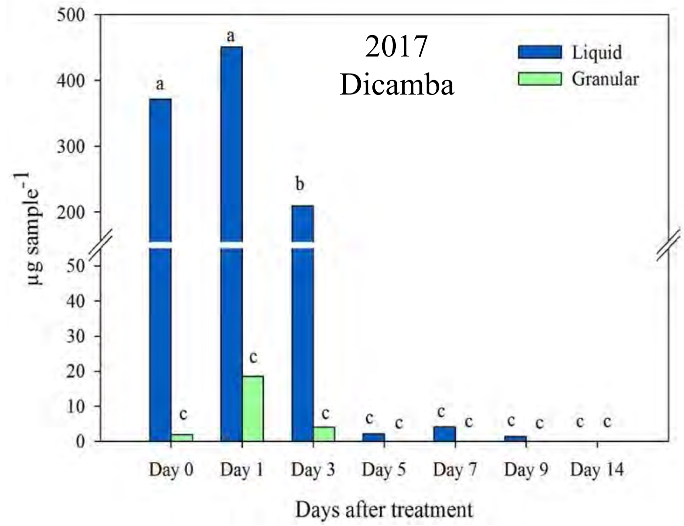
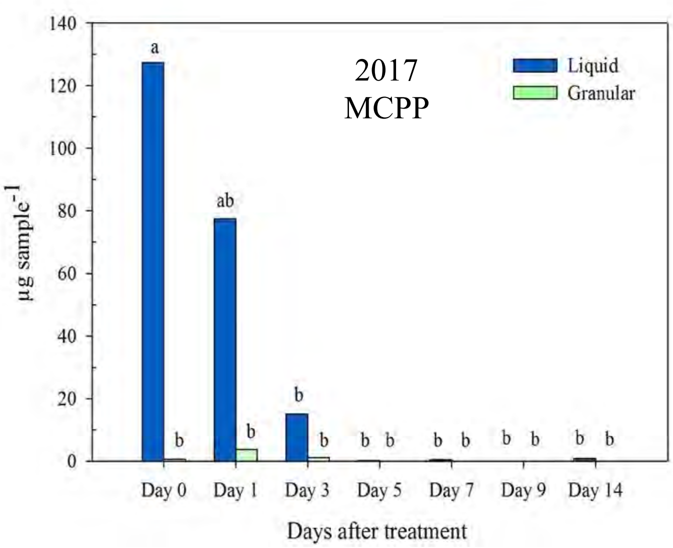


Figure 8. The effect of formulation and time on dislodgeable foliar residue levels of Dicamba. Data points with the same letter are not statistically different according to Fisher's protected LSD (P<0.05).



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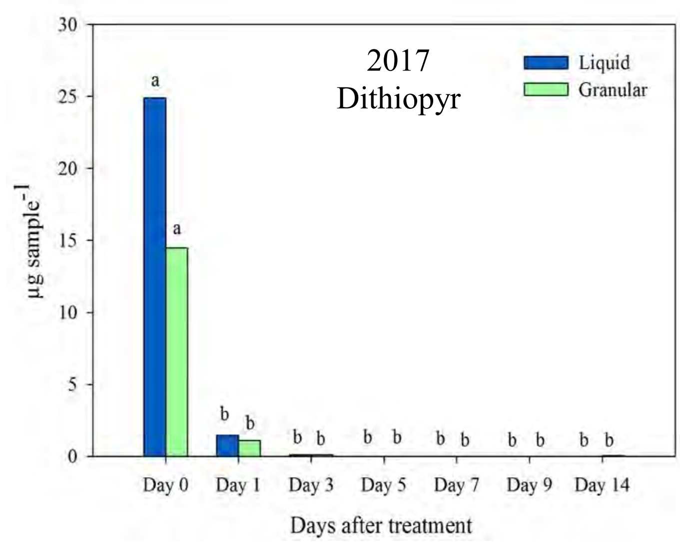

Figure 10. The effect of formulation and time on dislodgeable foliar residue levels of Dithiopyr. Data points with the same letter are not statistically different according to Fisher's protected LSD (P<0.05).

ORGANIC TURF AND NO-PESTICIDE TURF DEMONSTRATION FOR HOME LAWNS AND ATHLETIC FIELDS 2017

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INTRODUCTION

As of 1 July 2010, the state of Connecticut banned the use of all lawn care pesticides at public and private schools that service pre-K through 8th grades. This legislation has caused great concern for athletic field managers due to the nature of the traffic athletic fields endure and the liability associated with their use. However, very little research based information is available regarding managing athletic fields without the use of pesticides. This demonstration site was established to evaluate various systems of management.

Each system evaluated represents a specific type of management regime. The Integrated Pest Management system utilizes thresholds for management of pests. The calendar based system follows a step by step program based on application timing. The Integrated System Management is based on best management practices and places applications based on the principle of prevention and least potentially harmful applications. The pesticide-free applications are based on current Connecticut law and were managed without pesticides but utilize synthetic fertilizers. The Organic system utilized only organic treatments.

The high and low treatments for the organic and pesticide-free treatments evaluate the two extremes of applications because many turf managers and homeowners are limited by budget or time. The best management practices are not always a realistic plan of action. The high and low systems demonstrate the difference between the intensity of management and provide feasible recommendations.

The objectives were to; 1) reduce nitrogen and phosphorus applications, 2) identify advantages and disadvantages of each management system, and 3) create a hands-on demonstration site and education resource for training industry professionals how to manage turfgrass without pesticides.

MATERIALS AND METHODS

The research area was divided into two separate studies, an athletic field and home lawn, with each measuring 58 m × 30 m. Both studies were arranged as a randomized complete block design with three replications. Individual plots measured 6 m × 9 m.

The athletic field research area was seeded with a mixture of 35% ‘America’ Kentucky bluegrass (*Poa pratensis* L.), 35% ‘Granite’ Kentucky bluegrass, 15% ‘Karma’ perennial ryegrass (*Lolium perenne* L.), and 15% ‘Fiesta 4’ perennial ryegrass (% by weight). The home lawn research area was seeded with a mixture of 30% ‘America’ Kentucky bluegrass, 30% ‘Granite’ Kentucky bluegrass, 10% ‘Karma’ perennial ryegrass, 10% ‘Fiesta 4’ perennial ryegrass, 10% ‘Winward’ Chewings fescue (*Festuca rubra* L. ssp. *commutata*), and 10% ‘Garnet’ creeping red fescue (*Festuca rubra* L.) (% by weight). The eight treatments or “systems” evaluated for each study were: 1) Organic High (OH), 2) Organic Low (OL), 3) Pesticide-free High (PFH), 4) Pesticide-free Low (PFL), 5) Calendar Based (CAL), 6) Integrated Pest Management (IPM), 7) Integrated System Management (ISM), 8) None (mow only control).

The home lawn plots were mowed once per week at 8.9 cm with a zero-turn rotary mower (Scag Power Equipment, Mayville, WI). The athletic field plots were mowed at 6.6 cm two times per week with a zero-turn rotary mower (Scag Power Equipment, Mayville, WI). Fields were irrigated with a watering reel as needed.

Each management system received applications of fertilizer, insect and weed control appropriate for each treatment. The athletic field received 190 kg N ha^{-1} year^{-1} to the listed treatments; CAL, OH, PFH, IPM, and ISM. Treatments OL and PFL received 98 kg N ha^{-1} year^{-1}. The home lawn’s OL and PFL received 49 kg N ha^{-1} year^{-1}, while the CAL, OH, PFH, IPM, and ISM received 140 kg N ha^{-1} year^{-1}. Fertilizer totals were applied throughout 2016 & repeated in the 2017 growing season.

A Cady Traffic Simulator was used on the athletic field portion of the study to provide simulated athletic field wear to the field (Henderson et al. 2005) (Figure 1). The athletic fields received traffic events 2-3 times per week with a total of 98 events in the past two years. Each traffic event consisted of two perpendicular passes.

Figure 1. The Cady Traffic Simulator was used on the athletic field research area to simulate traffic.

Data collection for the home lawn study included; turfgrass color ratings, turfgrass quality ratings, turfgrass density ratings, percent green cover, volumetric water content (VWC) (Spectrum Technologies, Inc. Plainfield, IL), normalized difference vegetative index (NDVI) (Spectrum Technologies, Inc. Plainfield, IL), and percent weed cover. Surface hardness and rotational traction were also quantified. Turfgrass color, quality, and density were rated based on a scale from 1 to 9, where 1 represented the lowest quality rating, 6 was the minimum acceptable quality rating, and 9 was the optimum quality rating. This qualitative assessment was done once per month.

Digital image analysis was used to quantify color and percent green cover (Karcher and Richardson, 2005). These images were taken in controlled light conditions by using a light box. Three images were taken of each plot. The digital images were scanned by Sigma Scan software (Cranes Software International Ltd. Chicago, IL. 1991). NDVI data was collected by taking the average of 15 readings per plot for data analysis. VMC data was collected by taking the average of 12 readings per plot for data analysis. The DIA, VWC, and NDVI were taken every month starting in May.

Weed counts for each plot was obtained by using a grid with 240 intersections. The sum of intersections with weeds below each intersection was calculated as a percentage based on the 240 total intersections. The frame was counted in six separate locations within each plot to get an accurate number of weeds. Weed counts were conducted five times throughout the year in 2016 and 2017.

Lastly, the Clegg Impact Soil Tester was used to quantify surface hardness (ASTM, 2008). GMAX was measured 18 times per plot and averaged. Clegg measurements were taken three times in 2016 and seven times in 2017. Treatments were also assessed for rotational traction using the Canaway traction device (Canaway and Bell, 1986). This was done six times per plot.

An analysis of variance was completed to test for significant treatment effects ($P < 0.05$) using the Mixed procedure in SAS statistical software 9.4 (SAS Institute. Cary, NC. 2004). Least square means were separated based on Fisher's protected least significant difference (LSD) test.

RESULTS AND DISCUSSION

The home lawn study had considerable differences between treatments for percent weed cover when averaged across 2016 and 2017 (Figure 2). ISM, IPM and Calendar had nearly zero weeds with significance. Additionally, PFH and OH had significantly lower weed populations than PFL and OL. The athletic field showed a similar trend among treatments when averaged across 2016 and 2017 (Figure 3). However, ISM and IPM had significantly fewer weeds than CAL. The differences in percent weed cover between home lawn and athletic field is likely due to the changes in mowing height and simulated traffic stress.

The athletic field treatments exhibiting the highest turfgrass quality ratings when averaged across 2016 and 2017 were ISM, CAL and OH rated at 6.5, 6.2 and 5.9 respectively (Figure 4). During the spring months (May and June) averaged across both years, all treatments had quality ratings at 5.8 (PFL) and above, but ISM, CAL, and IPM had significantly higher quality than the other treatments (Figure 5). However, OH exhibited the highest turfgrass quality compared to other treatments in the fall months; September, October and November of 2016 and 2017 (Figure 6). It was evident that OH outperformed other treatments as trafficking wear accumulated in the fall of 2017 (Figure 6). CAL and ISM had significantly higher color ratings than the other treatments when averaged across 2016 and 2017.

The home lawn treatments CAL, ISM and IPM were rated 1st, 2nd and 3rd for turfgrass quality and color compared to other treatments (Figures 8 and 9). The CAL treatment had the highest turfgrass quality. The treatments PFH and OH were equivalent, but significantly higher than the low-cost alternatives for turfgrass quality and color ratings when averaged across both years.

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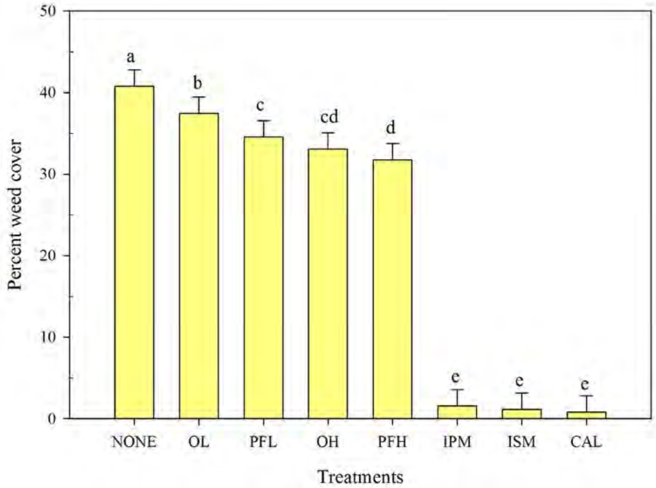

Figure 2. The effect of management strategies on hme lawn quantitative percent weed cover when averaged across 2016 and 2017. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P* <0.05). Integrated Systems Management (ISM), Integrated Pest Management (IPM), Calendar (CAL), Organic High (OH), Organic Low (OL), Pesticide Free High (PFH), Pesticide Free Low (PFL).

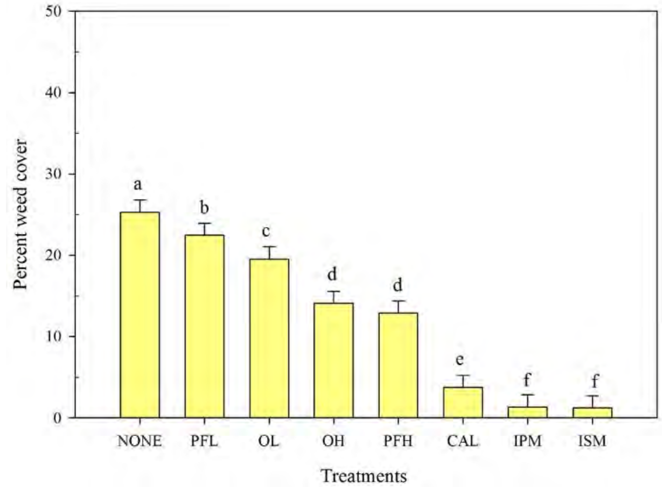

Figure 3. The effect of management strategies on athletic field quantitative percent weed cover when averaged across 2016 and 2017. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P* <0.05). Integrated Systems Management (ISM), Integrated Pest Management (IPM), Calendar (CAL), Organic High (OH), Organic Low (OL), Pesticide Free High (PFH), Pesticide Free Low (PFL).

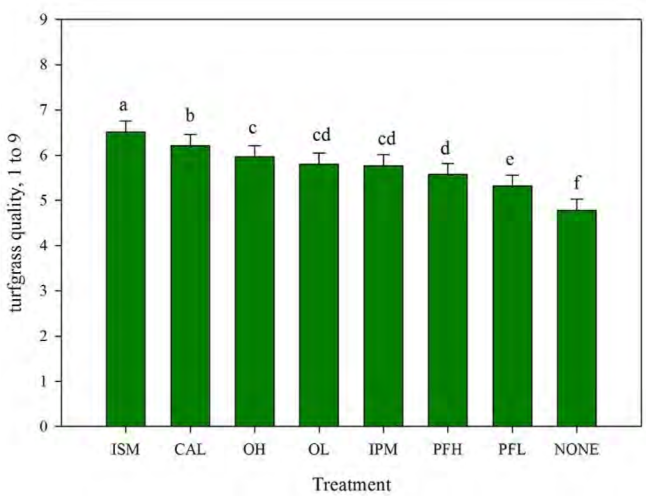

Figure 4. The effect of management strategies on athletic field qualitative turfgrass quality when averaged across 2016 and 2017. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P* <0.05). Integrated Systems Management (ISM), Integrated Pest Management (IPM), Calendar (CAL), Organic High (OH), Organic Low (OL), Pesticide Free High (PFH), Pesticide Free Low (PFL).

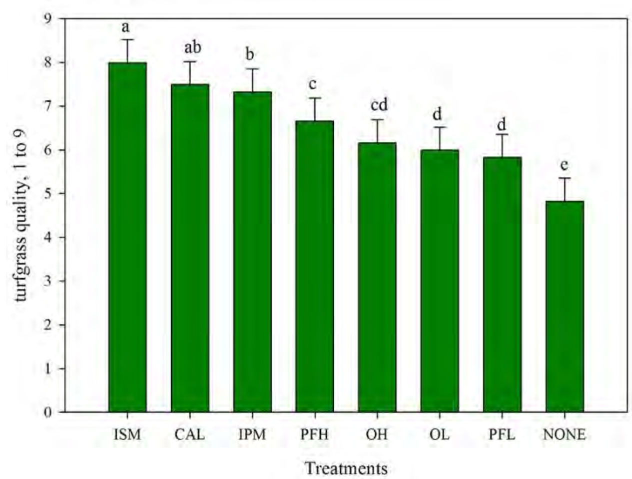

Figure 5. The effect of management strategies on athletic field qualitative turfgrass quality when averaged across the months of May and June. Data averaged across 2016 and 2017 (Spring season only). Data points with the same letter are not statistically different according to Fisher's protected LSD (*P* <0.05). Integrated Systems Management (ISM), Integrated Pest Management (IPM), Calendar (CAL), Organic High (OH), Organic Low (OL), Pesticide Free High (PFH), Pesticide Free Low (PFL).

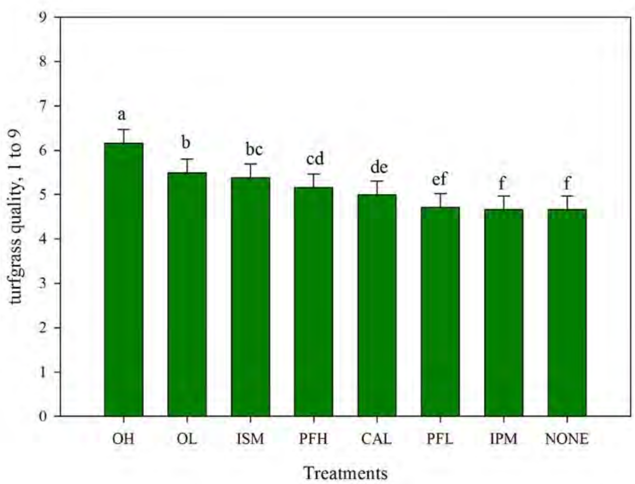

Figure 6. The effect of management strategies on athletic field qualitative turfgrass quality when averaged across the months of September, October and November. Data averaged across 2016 and 2017 (Fall season only). Data points with the same letter are not statistically different according to Fisher's protected LSD (*P* <0.05). Integrated Systems Management (ISM), Integrated Pest Management (IPM), Calendar (CAL), Organic High (OH), Organic Low (OL), Pesticide Free High (PFH), Pesticide Free Low (PFL).

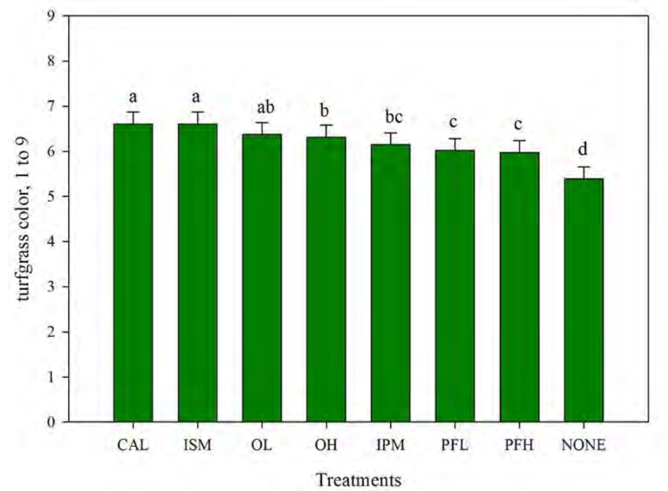

Figure 7. The effect of management strategies on athletic field qualitative turfgrass color when averaged across 2016 and 2017. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P* <0.05). Integrated Systems Management (ISM), Integrated Pest Management (IPM), Calendar (CAL), Organic High (OH), Organic Low (OL), Pesticide Free High (PFH), Pesticide Free Low (PFL).

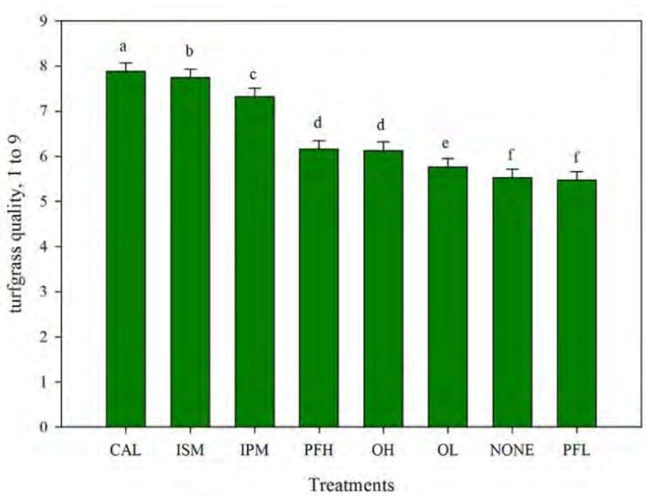

Figure 8. The effect of management strategies on home lawn qualitative turfgrass quality when averaged across 2016 and 2017. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P* <0.05). Integrated Systems Management (ISM), Integrated Pest Management (IPM), Calendar (CAL), Organic High (OH), Organic Low (OL), Pesticide Free High (PFH), Pesticide Free Low (PFL).

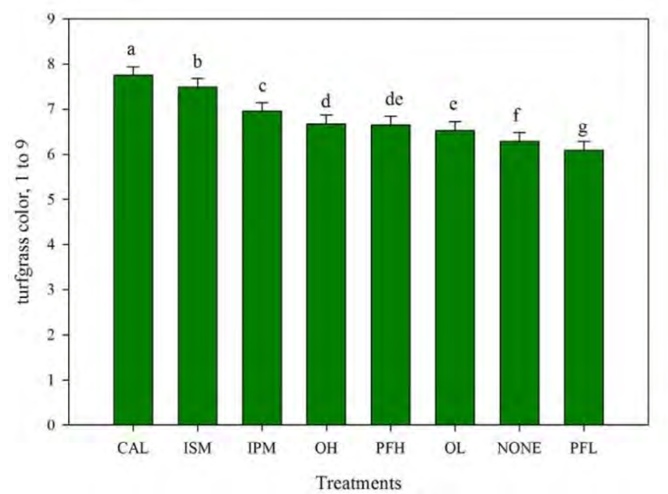

Figure 9. The effect of management strategies on home lawn qualitative turfgrass color when averaged across 2016 and 2017. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P* <0.05). Integrated Systems Management (ISM), Integrated Pest Management (IPM), Calendar (CAL), Organic High (OH), Organic Low (OL), Pesticide Free High (PFH), Pesticide Free Low (PFL).

OVERSEEDING STRATEGIES FOR NON-IRRIGATED, PESTICIDE-FREE ATHLETIC FIELDS, 2017

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INTRODUCTION

Athletic field managers have perceived reduced playing surface quality as a result of severe pesticide restrictions in Connecticut (Bartholomew et al., 2015). Considering these restrictions, there is a need for proven alternative methods that can increase turfgrass cover and reduce weed pressure without the use of pesticides. Aggressive and repetitive overseeding has been recommended as a critically important tool of the municipal turf manager to utilize in lieu of pesticides (Elford et al., 2008; Minner et al., 2008; Stier et al., 2008; Miller and Henderson, 2012; Henderson et al. 2013). However, many questions remain regarding the best turfgrass species, cultivar and seeding rate for overseeding in a non-irrigated situation.

The goal of this research is to develop the most effective overseeding strategies for non-irrigated, pesticide-free athletic fields in New England. The specific objectives are to determine the effects of turfgrass species, cultivar, and overseeding rate on turfgrass cover retention and demonstrate the effectiveness of aggressive overseeding.

MATERIALS AND METHODS

These studies, spanning two years, are currently being conducted on-site at multiple locations across Connecticut. These include Hebron Elementary School, Lebanon Middle School, and Shetucket Park in Windham, CT. The research area at each location was carefully placed in high wear portions of each non-irrigated athletic field.

The study was arranged in a 3 × 2 × 2 factorial in a randomized complete block design with three replications. The first factor, turfgrass species, had three levels: 1) perennial ryegrass (PRG, *Lolium perenne* L.), 2) tall fescue (TF, *Festuca arundinacea* Schreb.), and 3) Kentucky bluegrass (KBG, *Poa pratensis* L.). The second factor, overseeding rate, was either low or high, which is detailed in Table 1. The third factor, cultivar, had two levels: 1) previously tested cultivars that have met the Turfgrass Water Conservation Alliance (TWCA) criteria, and 2) untested cultivars that have not been certified with the TWCA criteria. Individual plots were 1.8 m x 2.7 m.

Two overseeding timings were selected per year (spring and fall) to take advantage of traditionally cooler temperatures and more frequent rainfall. Overseeding treatments were initiated at each location on 19 September 2016 and repeated per scheduled dates on 1 May 2017 and 23 August 2017. Before each overseeding event, initial qualitative assessments were taken of the total percentage green cover and turfgrass cover. Plots were core cultivated with a Toro 648 ProCore walk-behind unit (The Toro Company, Bloomington, MN) in one direction using 1.3 cm hollow-core tines on 5.1 cm spacing to a depth of 6.4 cm. The cores were broken-up and returned within their individual plots with a leaf rake. Seed was applied using handheld shakers in multiple directions. The seed was gently incorporated into the soil with the backside of a leaf rake. The research area was then rolled to ensure good seed to soil contact. Finally, the plot area was fertilized with a starter fertilizer (14-25-12) at the rate of 49 kg P_2O_5 ha^{-1}. Additional nitrogen was applied at a rate of 49 kg N ha^{-1} using a plastic-coated urea (43-0-0); bringing the total nitrogen applied at each overseeding event to 73 kg N ha^{-1}. The next seeding date is scheduled for early May 2018.

Data was collected at 2 and 4 weeks following overseeding events and monthly throughout the growing season. Qualitative ratings of percent green cover (weeds + turfgrass) and percent turfgrass cover were taken at all locations. Plots were rate for their overall color and quality based on a scale from 1 to 9, where 1 represented the lowest quality, 6 was the minimum acceptable quality, and 9 was the optimum quality. Starting in the spring 2017, Digital image analysis (DIA) was used to quantify dark green color and percent cover (Karcher and Richardson, 2005). The digital images were scanned by Sigma Scan software (Cranes Software International Ltd. Chicago, IL. 1991). Surface hardness was quantified using a Clegg Impact Hammer (2.25 kg). Soil volumetric water content was measured using a portable TDR probe (Spectrum Technologies, Inc. Plainfield, IL, VWC).

This study will continue for the spring and fall of 2018.

An analysis of variance was completed to test for significant treatment effects (P <0.05) using the Mixed procedure in SAS statistical software 9.4 (SAS Institute. Cary, NC. 2004). Least square means were separated based on Fisher's protected least significant difference (LSD) test.

RESULTS AND DISCUSSION

The results were averaged across all locations and seasons. PRG treatments had significantly greater percent turfgrass, percent green cover, and the fewest weeds (Figures 1-4). Four weeks after seeding in the fall 2016, PRG showed the most turfgrass cover compared to KBG and TF (Figure 1). PRG, regardless of cultivars, exhibited 50% reduction in weed populations compared to TF and KBG (Figure 4). Additionally, it was observed that the high rate of PRG produced the highest turfgrass cover compared to all combinations of species and seeding rate (Figure 5). The high seeding rate for TF and KBG showed no differences compared to the low seeding rate (Figure 5). Figure 7 shows that PRG had the highest percent turfgrass cover for each season compared to the other species. It is speculated that the decrease in turfgrass cover in the fall is related to the increase in traffic compared to the spring and summer. Kentucky bluegrass was not different from control treatments in percent turfgrass and weed cover across every season, rate and/or TWCA combination (Figures 3-7).

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Table 1. Turfgrass species, cultivars and seeding rates evaluated at the three locations.

Species	Cultivar	Low[a]	High	TWCA rating
		---- kg ha^{-1} ----		
Kentucky bluegrass	Full Moon	146	292	TWCA[b]
Kentucky bluegrass	Brooklawn	146	292	Non-TWCA
Perennial ryegrass	Manhattan 5	391	782	TWCA
Perennial ryegrass	Divine	391	782	Non-TWCA
Tall Fescue	Falcon 4	391	782	TWCA
Tall Fescue	Aztec	391	782	Non-TWCA

[b]Turfgrass Water Conservation Alliance

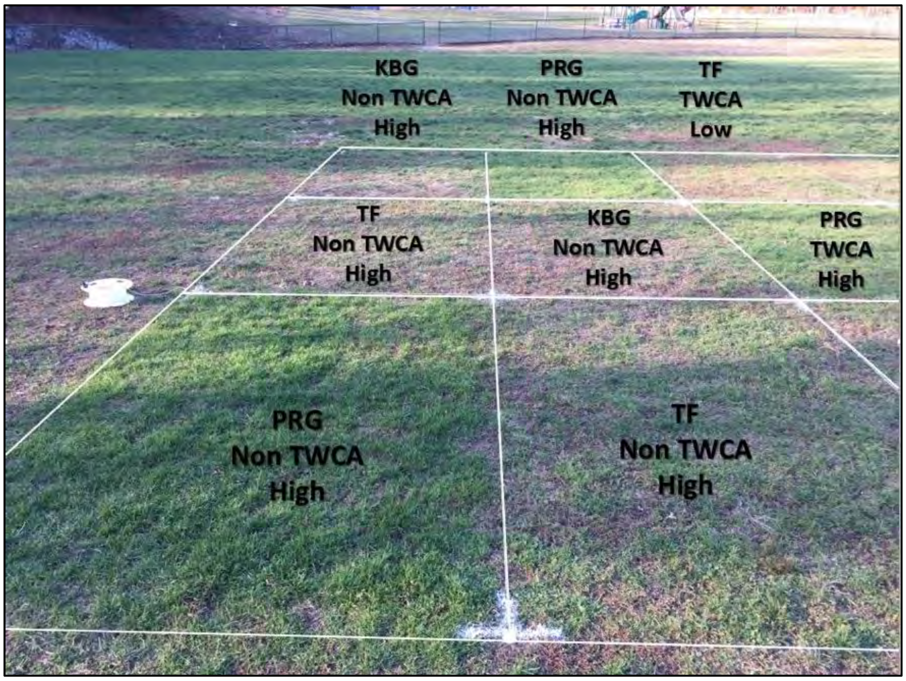

Figure 1. Shetucket Park in Windham, CT in October 2016. Four weeks after fall seeding, perennial ryegrass showed greater turfgrass cover than other turfgrass species.

Figure 2. Hebron Elementary in Hebron, CT in June 2017. Eight weeks after spring seeding, perennial ryegrass exhibited greater turfgrass cover than other turfgrass species and fewer weeds.

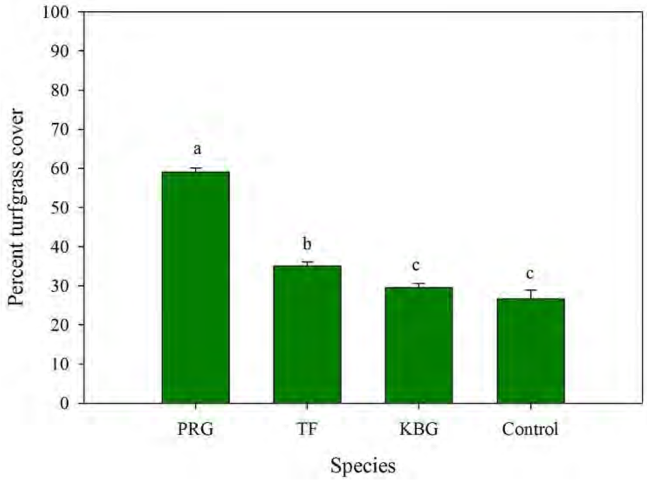

Figure 3. The effect of turfgrass species on qualitative percent turfgrass cover when averaged across all locations in 2016 and 2017. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P*<0.05).

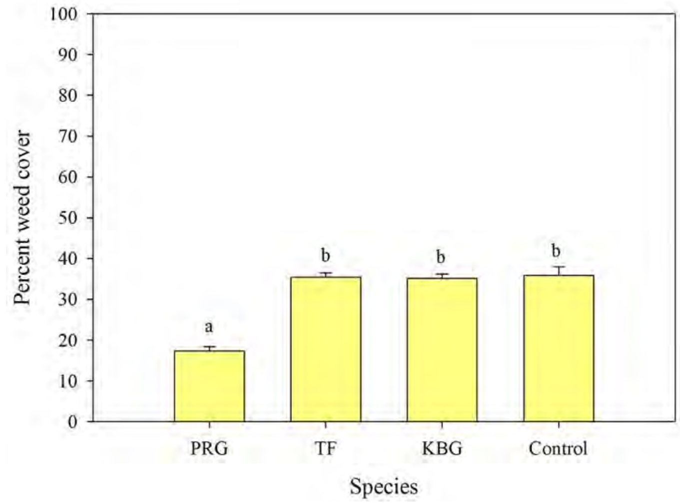

Figure 4. The effect of turfgrass species on qualitative percent weed cover when averaged across all locations in 2016 and 2017. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P*<0.05).

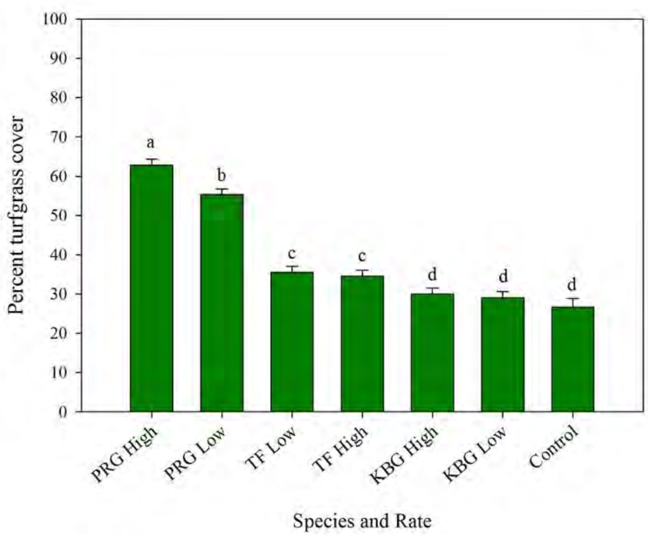

Figure 5. The effects of turfgrass species and seeding rates on qualitative percent turfgrass cover when averaged across all locations in 2016 and 2017. Data points with the same letter are not statistically different to Fisher's protected LSD (*P*<0.05). Low rate is considered the recommended rate and high rate is doubled the recommended rate.

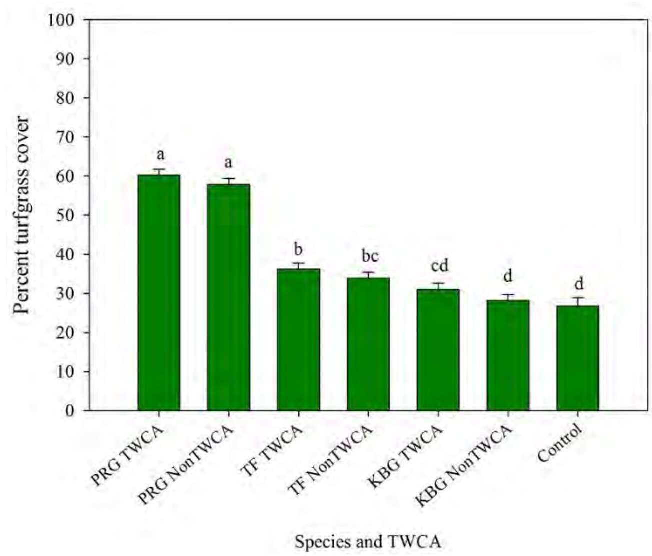

Figure 6. The effects of turfgrass species and TWCA on qualitative percent turfgrass cover when averaged across all locations in 2016 and 2017. Data points with the same letter are not statistically different according to Fisher's protected LSD (*P* <0.05). Turfgrass Water Conservation Alliance (TWCA).

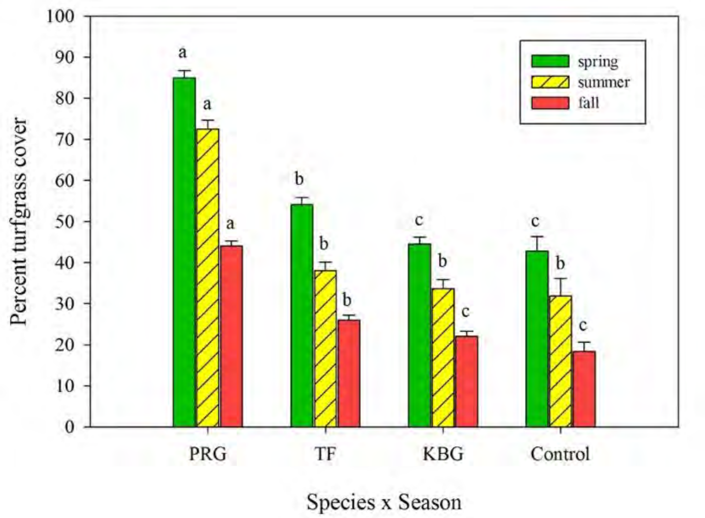

Figure 7. The effects of turfgrass species and seasons on qualitative percent turfgrass cover when averaged across all locations in 2016 and 2017. Mean separation indicates differences across season only. Data points with the same letter are not statistically different according to Fisher's protected LSD (P <0.05)

OPTIMIZING CREEPING BENTGRASS ESTABLISHMENT AND CONTROLLING ANNUAL BLUEGRASS IN GOLF COURSE FAIRWAY RENOVATIONS, 2017

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INTRODUCTION

Fairways represent the largest area of intensely managed turf on golf courses, with a median acreage of 24.8 acres for 18-hole facilities throughout the United States (Gelernter et al., 2017). Fairways in the Northeast region commonly are mixtures of older creeping bentgrass (CBG; *Agrostis stolonifera* L.) cultivars such as 'Penncross' and annual bluegrass (ABG; *Poa annua* L.)(Gelernter et al., 2017). Annual bluegrass is a common weedy species with prolific seeding and tolerance to low mowing heights. It is undesirable due to its high susceptibility to diseases, low heat and drought stress and unsightliness. Older CBG cultivars gernerally have low to moderate disease resistantance, and require regular fungicide applications to mangage diseases. Similarly, ABG also requires frequent fungicide applicactions due to its poor tolerance to many diseases, as well as increased irrigation during drought conditions to prevent serious permenent wilt and turf loss. Older mixed fairways also have large ABG seedbanks which enables this weedy species to persist. Newer cultivars of CBG are resistant to turf diseases such as dollar spot (*Sclerotinia homoeocarpa*) which eliminates most need for fungicide applications. Eliminating the ABG population allows for reduced irrigation and nitrogen inputs. It may be possible to reduce maintenance costs and pesticide, nutrient, and water inputs by renovating older fairways to newer, improved creeping bentgrass cultivars.

Renovating fairways is challenging, requiring course closure, eradication of the previous turf stand and a significant economic contribution. Due to these challenges, course owners are hesitant to convert fairways despite the benefits. Several studies have examined individual components of fairway renovations . However, no studies have evaluated combined the effects of renovation timing, method of eradication, and post renovation herbicidal control of ABG in a progrmatic approach to develop best management practices for golf course fairway renovations. Our objective is to identify eradication methods and herbicides over different renovation timings which optimize CBG establishment and minimize ABG contamination in golf course fairways.

MATERIALS & METHODS

This field study was initiated during July 2017, at the Plant Science Research and Education Facility in Storrs, CT. The study was conducted on a 30:70 mixed CBG and ABG fairway turf on a Woodbridge, fine sandy loam. The field was initially seeded with a CBG blend ('Penntrio') at 1 lb. 1000 ft^{-2} in August 2015. Thereafter, aeration cores containing ABG seed harvested from Wethersfield Country Club (Wethersfield, CT) where distributed over the field in September 2015, April 2016 and September 2016. Cores containing ABG seed were verticut into the existing CBG to establish a mixed population turf stand and ABG seedbank. Turf was mowed at 0.5 inch three days wk^{-1}. Nitrogen was applied every 14 days at 0.25 lbs. 1000 ft^2 from June to November 2017. Irrigation was applied as needed to avoid drought stress. Broadleaf weeds were controlled with Trimec Bentgrass formulation applied at 1.7 floz 1000 ft^2 on 22 September. Quicksilver was applied at 0.028 floz 1000 ft^2 to July renovated strips on 12 July and July and August renovated strips on 16 and 25 August.

Experimental Design and Treatment Design

The study was conducted as a split-strip plot design arranged as a 2 × 3 × 7 factorial. The main plot factor was eradicant which consisted of glyphosate-only or glyphosate followed by dazomet in 3 × 21 ft plots with a 5 ft border. The main factor plots where divided into horizontal and vertical strips. The horizontal factor was renovation month consisting of July, August and September in strips of 6 × 47 ft. The vertical factor consisted of six herbicides and a non-herbicidal control assigned to strips measuring 3 × 28 ft (Table 1).

Glyphosate (Roundup Pro Concentrate, Monsanto, St. Louis, MO) was applied at 4.8 pts acre^{-1} using a CO_2 pressured boom sprayer fit with AI11005 nozzles calibrated to deliver 1 gal 1000 ft^2 at 40 psi. Treatments where applied on 5 July, 4 August and 5 September 2017 corresponding to each renovation month in the study. The following day, all plots where core cultivated with 2.0 in. diameter hollow, side-eject tines at a depth of 1.5 with a 2.0 in. spacing. Cores where pulverized and incorporated with a rotary mower. Dazomet (Basamid Granular, Amvac, Newport Beach, CA) was then applied at 260 lb/acre with a drop spreader calibrated to distribute the material over the main plots in four passes. Thereafter, dazomet was water incorporated and subsequently irrigated according to label recommendations.

Herbicides were applied at rates and intervals recommended on product labels for newly seeded CBG. Initial application timing was based on the date at which >75% of seedlings reached the one-leaf stage. This occurred on 19 July, 21 August and 20 September for each renovation, respectively. All herbicides except paclobutrazol where applied with a handheld CO_2 pressurized sprayer outfitted with a single AI9504E flat fan nozzle calibrated to deliver 1.0 gal 1000 ft^{-2} at 40 psi. Paclobutrazol was applied with the same sprayer calibrated to deliver 2.0 gal 1000 ft^{-2} with an AI9508E nozzle to target the application to the crown and surface roots for optimal uptake. Bensulide was water incorporated with 0.5 inch of irrigation after application.

Seeding and Establishment

Plots were seeded with a blend of '007' and '13-M' (1:1, by weight), five days after glyphosate was applied during each renovation. Seed was applied using a slit seeder (Turfco Triwave 45, Turfco Manufacturing, Blaine, MN) calibrated to deliver 0.5 lb 1000 ft^{-2} in a single pass. Renovation month strips were seeded in two directions resulting in an overall seeding rate of 1.0 lb 1000 ft^{-2}. An above-ground, portable irrigation system with low volume heads, on a 9 ft. spacing, was positioned around each renovation month strip to water incorporate dazomet and ensure optimal soil surface moisture for CBG germination and establishment. Granular starter fertilizer (16-28-12) was applied at 50 lbs. P per $acre^{-1}$ to each renovation strip at seeding. Thereafter, N was applied at 0.25 lbs. 1000 ft^{-2} as urea every 14-d through mid-November. Subdue Maxx at 1 floz 1000 ft^2 was applied one week after seeding to protect against damping off, (caused by, *Pythium* spp). Mowing resumed one week after seed emergence at 0.5 inch, three days wk^{-1}.

Data collection and Statistical Analysis

Initial population counts where collected using the line-intercept grid count method (Gaussoin and Branham, 1989). Percent green cover was assessed using a digital image of each subplot within a 1.5 × 2.0 ft. aluminum lightbox containing LED bulbs which excluded ambient light and provided for a consistent exposure for all photos. The number of green pixels within each image was divided by the total number of pixels in the image using Sigma Scan v.3.0. (Systat Software Inc, San Jose, CA) based on the methods developed by Karcher and Richardson (2005). Two photographs were taken from each experimental unit with the average used for analysis. Percent green cover was determined weekly from one week before renovation until mid-November. Phytotoxicity of ABG and CBG was independently assessed on a 1-9 scale, three times wk^{-1} following the first herbicide treatment and ending on 17 November. The phytotoxicity scale developed for the study was 1= dead turf; 2= bleached tan or reddish brown; 3= bleached and slight green; 4= deep yellowing; 5= yellow or deep blue grey; 6= yellow green or blue grey; 7= lime green or slight blue grey; 8= slight off green coloring or slight blue coloring; and 9; no injury. 6 is minimally acceptable amount of phytotoxicity.

All data were subjected to an analysis of variance using the Glimmix procedure in SAS v.9.4 (Statistical Analysis System) and least square means were separated using Fisher's protected least significant difference test (α=0.5).

RESULTS

Creeping bentgrass population

CBG populations were not affected by main effects independently. However, two separate interactions including eradicant by renovation month (P=0.0402), and herbicide by renovation month (P=0.0058) did influence the amount of CBG observed on 17 Nov.

In the eradicant × renovation month interaction, glyphosate+dazomet increased CBG populations 5.6 to 12.6% compared to glyphosate-only, regardless of renovation month. (Figure 1). When glyphosate-only was used, the July renovation had the greatest CBG establishment at 82.9%. Lower CBG establishment occurred with each subsequent renovation month where 78.4% and 73.1% CBG was observed by 17 Nov in August and September, respectively. Conversely, when glyphosate+dazomet was applied, CBG establishment was consistent across all renovation months.

A herbicide × renovation month interaction indicated that herbicide effects on CBG populations differed based on renovation month on 17 Nov (Table 2). During the July renovation, all herbicides increased CBG 4.8 to 8.7% compared to no herbicide, except bensulide and both rates of ethofumesate. Few differences existed between herbicides during the July renovation. Bispyribac-sodium, benuslide+paclobutrazol, and paclobutrazol-alone, had 5.5 to 7.0% more CBG than plots treated with bensulide alone. Bispyribac-sodium also had 5.9% greater CBG than ethofumesate (1.47 fl.oz.) During the August renovation, all herbicides increased CBG compared to no herbicide. Bispyribac-sodium treated plots had 15.0% more CBG than no herbicide and 4.3 to 9.8% more than all other herbicides. No differences were observed among remaining, although they did increase CBG 5.1 to 10.6% compared to no herbicide. During the September renovation, CBG population in all herbicide treated plots was not different than no herbicide treated plots on 17 Nov. However, bispyribac-sodium decreased CBG 5.0% and 5.9% compared to ethofumesate (1.47 fl.oz.) and paclobutrazol-alone, respectively.

When comparing herbicides across renovation month, bispyribac-sodium and bensulide + paclobutrazol had less CBG in September than in July or August renovations. Ethofumesate (1.47 fl.oz.), bensulide-alone, and paclobutrazol-alone did not differ in CBG populations across renovation month. When no herbicide was used, the July renovation resulted in 4.0 to 6.0% more CBG establishment compared to August and September.

Annual bluegrass population

ABG populations were influenced by the eradicant main effect (P=0.0016) and an interaction between herbicide and renovation month (P=0.018) on 17 Nov.

Glyphosate + dazomet reduced ABG 8.0% compared to glyphosate-only, regardless of renovation month and herbicide (Figure 2). However, glyphosate+dazomet treated plots still contained 10.5% on 17 Nov, averaged over all renovation months and herbicides.

The herbicide × renovation month interaction indicated herbicide efficacy on ABG varied across renovation months. During the July renovation, bispyribac-sodium, paclobutrazol and bensulide+paclobutrazol had comparable ABG levels, and were the only herbicides to reduce ABG with a 6.9 to 8.9% reduction compared to no herbicide (Table 3). Bensulide, and both rates of ethofumesate did not differ from no herbicide. After the August renovation, all herbicide treated plots reduced ABG compared to no herbicide. Bispyribac-sodium reduced ABG 6.7 to 10.4% more than all other herbicides, except bensulide + paclobutrazol. Paclobutrazol-alone and ethofumesate (1.1 fl.oz.) were comparable to bensulide+paclobutrazol, but less effective at reducing ABG than bispyribac-sodium. During the September renovation, only bispryibac-sodium and both rates of ethofumesate reduced ABG compared to no herbicide with a 6.3 to 12.0% reduction. Bispryibac-sodium had 5.7% less ABG then ethofumesate (1.47 fl.oz.). All other herbicide treated plots had similar ABG populations than no herbicide. When no herbicide was applied, July and September renovations had lower ABG populations than August renovations on 17 Nov. Bispyribac-sodium applications resulted in the same amount of ABG, regardless of renovation month. Paclobutrazol had the lowest ABG population in July with a 5.4 to 7.6% decrease compared to August and September. Ethofumesate 1.47 floz. 1000 ft^2 had a 4.8%-4.9% reduction in ABG populations in July and September compared to August renovations.

Creeping bentgrass phytotoxicity

Phytotoxicty of CBG was evaluated at 1, 2, and 4 weeks after initial herbicide treatment (WAIT). The only significant effect observed was an interaction between renovation month and herbicide 4 WAIT (P<0.0001) (Table 4). Within the July renovation, bensulide and both rates of ethofumesate were no different than no herbicide treated turf, which had no CBG phytotoxicity symptoms. However, bensuilde + paclobutrazol, paclobutrazol and bispyribac-sodium increased CBG phytotoxicity compared to no herbicide. Bensulide + paclobutrazol had the most severe CBG phytotoxicity compared to all other herbicide treatments due to its blue-grey coloring and course texture. Paclobutrazol-alone and bispyribac-sodium both caused subtle CBG phytotoxicity compared to no herbicide with phytotoxicity ratings between 8.0 to 8.3 for CBG. However, bispryibac-sodium phytotoxicity differed from paclobutrazol in texture and exhibited an off green leaf color. During the August renovation, all herbicides except bensulide produced phytotoxicity of CBG compared to no herbicide at 4 WAIT. Paclobutrazol and bensulide + paclobutrazol caused the most severe phytotoxicity of CBG compared to no herbicide with ratings between 7.0 to 7.3. Conversely, bispyribac-sodium and ethofumesate (1.1 fl.oz.) had the least severe phytotoxicity compared to no herbicide with ratings between 8.1-8.3. Ethofumesate (1.47 fl.oz.) also produced phytotoxicity in the August renovation with a rating of 7.8 for CBG and was intermediate between herbicides causing the most severe and least phytotoxicity. Within the September renovation, all herbicide treated plots exhibited phytotoxicity except for bensulide which was no different than no herbicide. Bispyribac-sodium had the most severe phytotoxicity compared to no herbicide, and all others, with a rating of 7.1 for CBG due to the lime-green colored foliage. Bensulide + paclobutrazol, paclobutrazol-alone, and both rates of ethofumesate had equivalent, albeit minor, phytotoxicity symptoms compared to no herbicide with ratings between 7.8-8.0. However, paclobutrazol treated plots were blue-grey in color; whereas ethofumesate treated plots were off-green.

Across renovation months, both ethofumesate rates resulted in the least amount of phytotoxicity in July compared to August and September. Paclobutrazol caused the greatest phytotoxicity during the August renovation compared to July and September. Bensulide + paclobutrazol produced equally severe phytotoxicity for CBG in July and August however was less severe in September. Bispyribac-sodium showed no differences across renovation months.

SUMMARY

Preliminary results from November of the first year of this two-year study indicate successful CBG establishment and minimizing ABG infestation during fairway renovations is influenced by interactions of multiple factors. Renovation month appears to be important to enhancing CBG establishment when relying exclusively on glyphosate-alone to eradicate the existing turf stand. Renovating in July resulted in the greatest CBG establishment, followed by August and lastly September renovation timings. Using dazomet in combination with glyphosate provided more flexibility in renovation month since no differences in CBG establishment were observed between renovation months when using the soil fumigant. Moreover, glyphosate + dazomet also reduced ABG by 8.0% compared to glyphosate-only, regardless of renovation month.

Herbicide effects on turf populations differed based on renovation month. July renovations showed bispyribac-sodium, paclobutrazol and bensulide + paclobutrazol to have the greatest reduction in ABG, and increase in CBG population compared to no herbicide. During August renovations, bispyribac-sodium and bensulide + paclobutrazol provided the greatest ABG control, although all herbicides increased CBG populations. During September renovations ethofumesate (1.1 floz.) and bispyribac-sodium where the only herbicides to reduce ABG, although all herbicides had comparable CBG populations as no herbicide.

Phytotoxicity of CBG due to post-establishment herbicide applications differed based on renovation month. Within July, only bensulide + paclobutrazol, paclobutrazol and bispyribac-sodium treated plots caused CBG phytotoxicity, albeit acceptable, at 4 WAIT. Within August, all herbicides except bensulide produced CBG phytotoxicity at 4 WAIT. Paclobutrazol and bensulide + paclobutrazol caused the most severe symptoms compared to no herbicide. Within September, all herbicide treated plots exhibited CBG phytotoxicity except for bensulide, however bispyribac-sodium resulted in the most severe CBG symptoms at this time. This study will be repeated in 2018 to confirm or refute first year results.

REFERENCES

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Gelernter, W.D., L.J., Stowell, M.E., Johnson, C.D., Brown. 2017. Documenting trends in land-use characterics and environmental stewardship programs on US golf courses. Crop, Forage and Turfgrass Management.

Table 1: Herbicides evaluated for control of annual bluegrass during fairway renovations to establish creeping bentgrass in Storrs, CT during 2017.

Active Ingredient	Formulation	Trade Name	Rate (1000 ft^2)	Interval	Manufacturer
ethofumesate	1.5 EC	Prograss	1.1 floz.	3 + 6 WASE†	Bayer, Hanover, NJ
ethofumesate	1.5 EC	Prograss	1.47 floz.	3 + 6 WASE	Bayer, Hanover, NJ
bispyribac-sodium	17.6 SG	Velocity	0.069 oz.	3 + 5 WASE	Valent, Walnut Creek, CA
bensulide	4 LF	Bensumec	5.5 floz.	2 WASE	PBI Gordon Professional, Kansas City, MO
paclobutrazol	2 SC	Trimmit	0.367 floz.	4 WASE; 14-d	Syngenta, Wilmington, DE
bensulide	4 LF	Bensumec	5.5 floz.	2 WASE	PBI Gordon Professional, Kansas City, MO
+ paclobutrazol	2 SC	+ Trimmit	0.367 floz.	4 WASE; 14-d	Syngenta, Wilmington, DE

†Weeks after seed emergence; WASE.

Figure 1: Population of creeping bentgrass influenced by eradicant and renovation month on 17 Nov. 2017 at the Plant Science Research and Education Facility in Storrs, CT. (*P*=0.0402). Means within each renovation month followed by the same lowercase letter are not statistically different. Means within each eradicant type followed by the same uppercase letter are not statistically different.

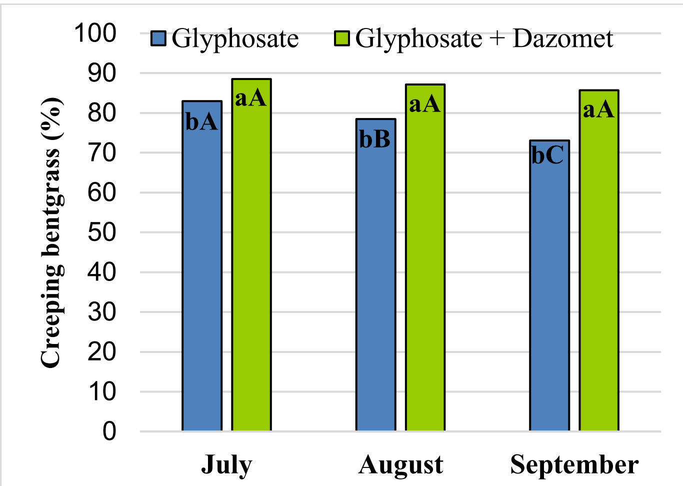

Table 2: Population of creeping bentgrass influenced by renovation month and herbicide treatment on 17 Nov. 2017 at the Plant Science Research and Education Facility in Storrs, CT. (*P*=0.0058)

Herbicide	Rate (1000 ft^2)	Interval	Renovation Month		
			July	August	September
			---------------creeping bentgrass %--------------		
No herbicide			81.41 c‡A§	75.27 dB	77.77 abAB
ethofumesate	1.1 floz.	3 + 6 WASE†	86.23 abcA	82.14 bcAB	78.27 abB
ethofumesate	1.47 floz.	3 + 6 WASE	84.23 bcA	80.41 cA	81.59 aA
bispyribac-sodium	0.069 oz.	3 + 5 WASE	90.14 aA	90.23 aA	76.59 bB
bensulide	5.5 floz.	2 WASE	81.86 cA	81.14 bcA	79.50 abA
paclobutrazol	0.367 floz.	4 WASE; 14-d	87.32 abA	84.36 bcA	82.45 aA
bensulide +paclobutrazol	5.5 floz. 0.367 floz.	2 WASE 4 WASE; 14-d	88.82 abA	85.91 bcA	79.64 abB

†Weeks after seed emergence; WASE.

‡Means followed by the same lowercase letter within each renovation timing are not statistically different based on Fisher's protected LSD (α = 0.05).

§Means followed by the same uppercase letter within each herbicide treatment are not statistically different based on Fisher's protected LSD (α = 0.05).

Figure 2. Population of annual bluegrass influenced by the eradicant main effect on 17 Nov. 2017 at the Plant Science Research and Education Facility in Storrs, CT. (*P*=0.0016). Means followed by the same lowercase letter are not statistically different.

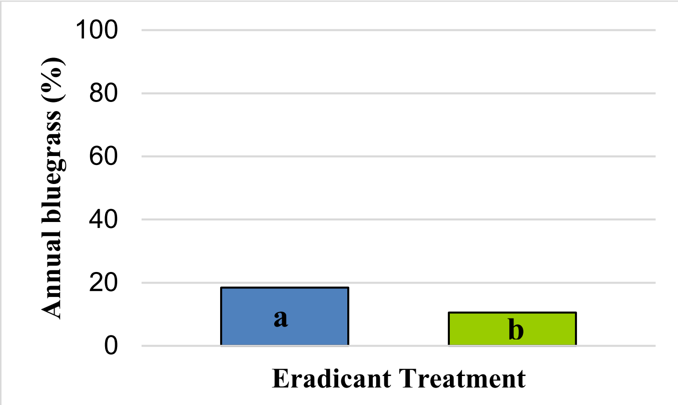

Table 3. Population of annual bluegrass influenced by renovation month and herbicide treatment on 17 Nov. 2017 at the Plant Science Research and Education Facility in Storrs, CT. (*P*=0.018).

Herbicide	Rate (1000 ft^2)	Interval	Renovation month July	August	September
			------------------ annual bluegrass %------------------		
No herbicide			16.6 a‡B§	24.91 aA	20.09 aB
ethofumesate	1.1 floz.	3 + 6 WASE†	12.5 abAB	16.41 bcA	12.05 dcB
ethofumesate	1.47 floz.	3 + 6 WASE	13.9 abB	18.73 bA	13.77 bcB
bispyribac-sodium ..	0.069 oz.	3 + 5 WASE	7.7 cA	8.32 dA	8.05 dA
bensulide	5.5 floz.	2 WASE	14.1 aB	18.45 bA	17.59 abAB
paclobutrazol	0.367 floz.	4 WASE; 14-d	9.7 bcB	15.05 bcA	17.27 abA
bensulide .... +paclobutrazol....	5.5 floz. 0.367 floz.	2 WASE 4 WASE; 14-d	9.6 bcB	12.49 cdAB	16.55 abA

†Weeks after seed emergence; WASE.

‡Means followed by the same lowercase letter within each renovation timing are not statistically different based on Fisher's protected LSD (α = 0.05).
§Means followed by the same uppercase letter within each herbicide treatment are not statistically different based on Fisher's protected LSD (α = 0.05).

Table 4: Phytotoxicity of creeping bentgrass influenced by renovation month and herbicide at four weeks after initial treatment at the Plant Science Research and Education Facility in Storrs, CT during 2017. (*P*<0.0001)

Herbicide	Rate (1000 ft^2)	Interval	Renovation Month July	August	September
			---------- phytotoxicity (1-9; 1=dead) ------------		
No herbicide			9.0 a‡A§	9.0 aA	9.0 aA
ethofumesate	1.1 floz.	3 + 6 WASE†	9.0 aA	8.1 bB	8.0 bB
ethofumesate	1.47 floz.	3 + 6 WASE	8.8 aA	7.8 cB	7.8 bB
bispyribac-sodium ...	0.069 oz	3 + 5 WASE	8.3 bA	8.3 bA	7.1 cB
bensulide	5.5 floz.	2 WASE	9.0 aA	8.9 aA	9.0 aA
paclobutrazol	0.367 floz.	4 WASE; 14-d	8.0 bA	7.3 dB	7.8 bA
bensulide .... +paclobutrazol....	5.5 floz. 0.367 floz.	2 WASE 4 WASE; 14-d	7.3 cB	7.0 dB	8.0 bA

†Weeks after seed emergence; WASE.

‡Means followed by the same lowercase letter within each renovation timing are not statistically different based on Fisher's protected LSD (α = 0.05).
§Means followed by the same uppercase letter within each herbicide treatment are not statistically different based on Fisher's protected LSD (α = 0.05).

TURFGRASS CULTURAL PRACTICES THAT MAXIMIZE SOIL CARBON SEQUESTRATION

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INTRODUCTION

Turfgrass is often overlooked as a potential sink for soil carbon (C) sequestration. Recent studies, however, have suggested that areas managed in turfgrasses may have a relatively high potential for soil C sequestration (Qian and Follett, 2002; Bandaranayake et al., 2003; Milesi et al., 2005; Huh et al., 2008; Qian et al., 2010; Morgan et al., 2010; Selhorst and Lal, 2011; Selhorst and Lal, 2013).

Too often, turfgrass is viewed negatively with respect to environmental quality. Showing that soil C sequestration can be important in turfgrass areas will be a positive attribute for advocating for, or defending, turfgrass systems from ill-informed regulations or decisions that are anti-turfgrass in principle. Secondly, turfgrass soil C sequestration may be a potential income generator for turf managers and land owners. With respect to strategies in reducing carbon dioxide (CO_2) emissions, there is a general movement globally to institute C cap-and-trading. Under this model, generators of CO_2 are given limits or goals to meet each year. If they cannot obtain those preset limits, then they can buy credits from other sources that are C sinks to meet their goals. These may be forested areas, cropland, or perennial grassland systems (i.e., prairies, savannahs, native grasslands), or other industries or land areas that are C neutral or C negative with respect to CO_2 emissions. With more information about turfgrass systems, it is not inconceivable that turfgrass areas could be used as a C-trading sink target since turfgrasses are a perennial grass system.

Climate change, and the consequences of it, is considered by many to be one of the greatest challenges humans will face this century. Soil sequestration of C, and maximizing its potential, is a goal within the environmental and scientific community, and governmental agencies as a means to lessen or delay the negative outcomes of climate change. Turfgrass areas have the potential to contribute to this goal.

The objective of this research was to determine which turfgrass cultural practices maximize soil C sequestration.

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MATERIALS & METHODS

This study was initiated in the fall of 2012. Six years prior to the start of the experiment, the existing vegetation of the area was a mixed cool-season grass sward. The experiment was set out in a split-split plot design with three replications on a Paxton fine-sandy loam soil. Main plots were species (Kentucky bluegrass [*Poa pratensis*], perennial ryegrass [*Lolium perenne*], tall fescue [*Festuca arundinacea*], and creeping red fescue [*Festuca rubra rubra*]); subplots were a combination of mowing heights (2, 3, and 4 inches) and clipping management (mulched or bagged); and subsubplots were N rates (0, 0.2, 0.4, 0.6, and 0.8 lbs N per 1000ft^2 per month, May through November).

Prior to treatment application, the experimental area was delineated into the respective plots and soil samples, to a depth of 0 to 4 inches, and 4 to 8 inches, were collected from each plot using a 18-mm dia. probe. Four samples were collected from each plot and combined into a single sample, separated by depth. After soil sample collection, plots were seeded to the species in August 2012. Full treatments commenced in May 2013, and were repeated through the 2014, 2015, and 2016 growing seasons. In November 2016, soils samples were collected from each plot at depths of 0 to 4 inches, and 4 to 8 inches as described above.

Soil samples from the 2012 and 2016 0 to 4-inch depths were analyzed for concentrations of total C using a LECO TruMac CN Macro Determinator (LECO Corp., St. Joseph, MI). (note: samples for the 4 to 8-inch depth are still being analyzed at the time of this report).

Total C concentrations were used to calculate the total mass of C (tons per acre at 0 to 4-inche depth) by using an average bulk density of 1.3 g per cm^3 for all plots. Treatment differences in C sequestration rate per year were determined by subtracting the 2012 total C mass from the 2016 total C mass for each plot, then dividing by 4 years.

Carbon sequestration rate differences were analyzed for treatment differences by using analysis of variance with Fisher's LSD for mean separation in the MIXED procedure of SAS 9.4 (SAS Institute, Cary, NC).

RESULTS & DISCUSSION

Initial mean total C mass in the experimental area prior to treatment imposition was very high: 122.4 tons/acre in the 0 to 4-inch sampling depth. Since the Paxton fine-sandy loam soil has low carbonate concentrations, the starting C contents were primarily derived from organic sources. These soils at our research farm are historically high in organic matter (5 to 8%) for a mineral soil. Since soil samples were collected from each plot prior to treatment imposition in 2012, we were able to calculate the C sequestration rate across the 4 years of the study.

Surprisingly, there were no interaction effects with the treatments, except for the 4-way Species × Mowing Height × Clipping Management × N rate effect. However, investigation of that interaction did not reveal any logical trends within the data. Therefore, only main effects will be presented.

Overall C sequestration rates at the 0 to 4-inch depth were different ($P < 0.001$) for species, with the greatest rate associated with tall fescue and the lowest rate for creeping red fescue (Fig. 1). Carbon sequestration rates at the 0 to 4-inch depth were not different between Kentucky bluegrass and perennial ryegrass.

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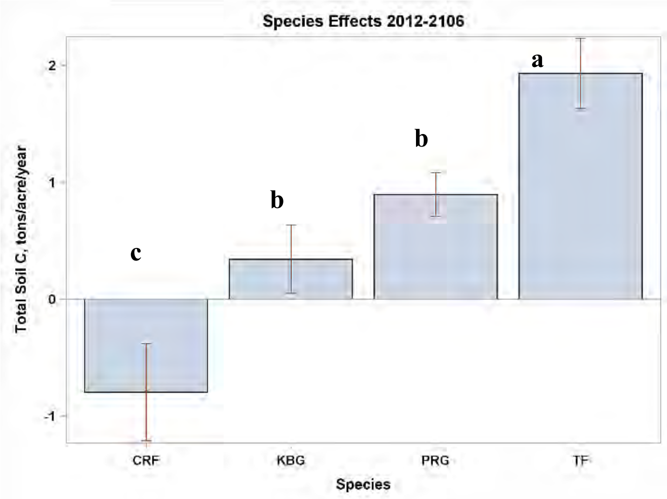

Fig. 1. Carbon sequestration rate differences among species; CRF = creeping red fescue. KBG = Kentucky bluegrass, PRG = perennial ryegrass, and TF = tall fescue. Means with the same letters are not significantly different according to Fisher's LSD. Error bars are standard errors.

Mowing height differences ($P = 0.05$) indicated that the 4-inch height of cut resulted in the greatest C sequestration rate for the 0 to 4-inch sampling depth (Fig. 2). There were no differences between the 2- and 3-inch mowing heights.

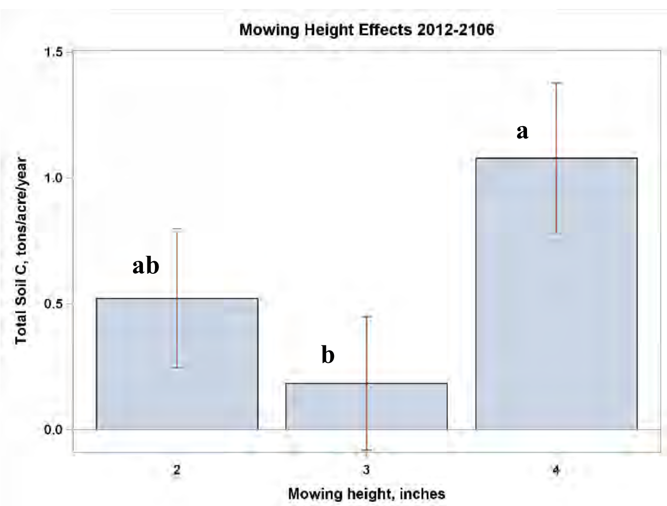

Fig. 2. Carbon sequestration rate differences among mowing heightsMeans with the same letters are not significantly different according to Fisher's LSD. Error bars are standard errors.

Clippings management had a significant ($P < 0.10$) effect on C sequestration rates in the 0 to 4-inch sampling depth. Returning clippings back to the turf surface increased soil C sequestration rates by a factor of about 1.5 (Fig. 3).

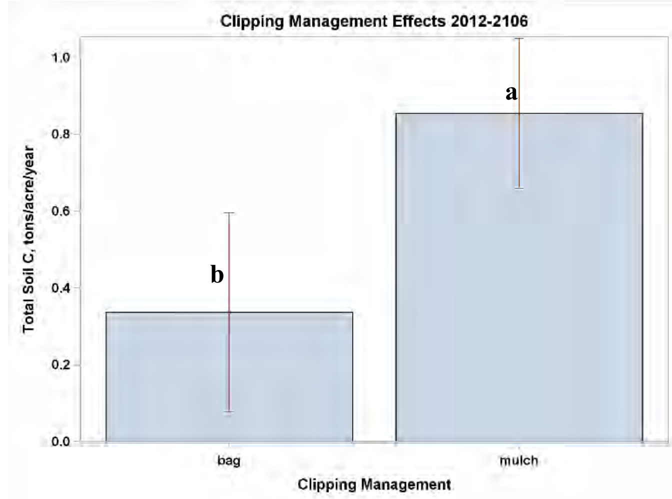

Fig. 3. Carbon sequestration rate differences between clipping management practices. Means with the same letters are not significantly different according to Fisher's LSD. Error bars are standard errors.

The most variable results were observed with N rate effects. In general, greater C sequestration rates were obtained when some N was applied (0.2 to 0.8 lbs N per 1000ft^2 per month, May through November) versus no N ($P = 0.11$) (Fig. 4).

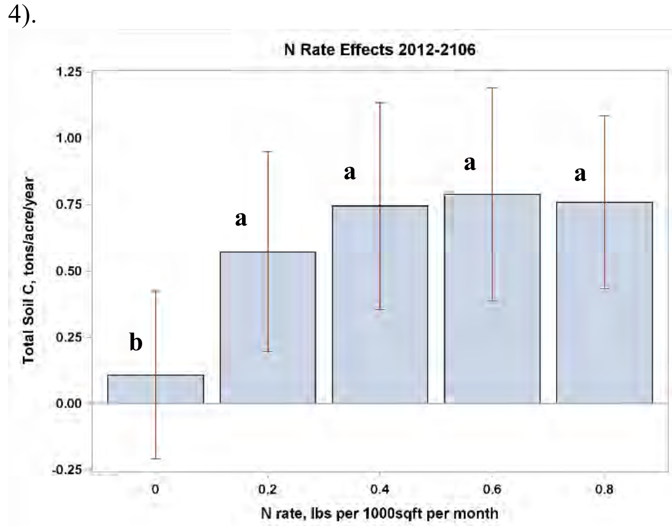

Fig. 4. Carbon sequestration rate differences among N rates. Means with the same letters are not significantly different according to Fisher's LSD. Error bars are standard errors.

SUMMARY

The results of this study indicate that turfgrass areas do have the potential to sequester C in the soil in the 0 to 4-inch sampling depth. Overall, higher potentials were obtained with tall fescue, returning clippings, higher height-of-cut, and N fertilization between 0.2 and 0.8 lbs N per 1000ft^2 per month.

We anticipate that these results may change somewhat when the 4 to 8-inch depth sample analyses for total C are completed and added to the totals from the 0 to 4-inch depth.

If Carbon Cap-and Trade policies become implemented at some future date, turfgrass areas could become a viable option as a C sink, and therefore generate revenue.

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ACKNOWLEDGEMENTS

Partial funding for this research was provided by The New England Regional Turfgrass Foundation, and the USDA National Institute of Food and Agriculture, Hatch project accession no. 226299.

CLIPPINGS SAP NITRATE-N CONCENTRATIONS AND RELATIONSHIP WITH NDVI AND DGCI – 2017

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INTRODUCTION

Annual grasses usually store N as nitrate (NO_3) in the bases of stems and shoots, and this NO_3 pool is closely related to soil N availability. Perennial turfgrasses also store N as NO_3, but this pool is dynamic throughout the growing season. In the spring and summer, rapid growth and frequent mowing lead to NO_3 being largely assimilated into leaf proteins as new leaf blades are formed. Consequently, the storage of NO_3 is generally low during this period. In autumn, however, new leaf blade formation in perennial turfgrasses declines as the onset of winter dormancy begins. During this time, N storage as NO_3 increases since the amount of N assimilated into leaf proteins is reduced because overall leaf formation declines. A measure of this NO_3 pool could be useful in the N fertilizer management of turfgrasses.

Nitrate-N concentrations in plant tissues are typically measured on a dry weight basis, which entails the drying and grinding of samples prior to extraction and analysis. The availability of field-use plant sap NO_3 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 expressed from fresh plant parts and analyzed directly for NO_3 or NO_3-N. This then serves as a guide for N fertilization based on previous calibration studies with those crops.

There are limited data that report on NO_3-N concentrations in turfgrass clippings across the growing season. Therefore, the objective of this study was to determine the relationship between clippings sap NO_3-N concentrations and Normalized Difference Vegetative Index (NDVI) and Dark Green Color Index (DCGI) of turfgrasses throughout the growing season in Connecticut. These reflectance readings serve as a measure of turfgrass color. If a relationship exists, this may be useful in guiding N fertilization.

MATERIALS & METHODS

This study was conducted during May through November 2017 on two separate cool-season turfgrass stands – Kentucky bluegrass (*Poa pratensis*) (KBG) and tall fescue (*Festuca arundinacea*) (TF) – established on a fine sandy-loam soil. The experiments were set out as randomized complete block designs with three replicates for each species. Plot size was 1.5 × 1.5 m. Stands were fertilized every month from April to November with 11 N application rates (0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50 kg N ha^{-1}), applied as a mixture of slow- and fast-release urea. Each month before mowing, NDVI of each plot was measured with a Spectrum TCM500 NDVI Turf Color Meter (Spectrum Technologies, Inc., Aurora, IL) and Spectrum FieldScout GreenIndex+ mobile app (version 2.0; Spectrum Technologies, Inc., Aurora, IL) running on an Apple iPad to determine DGCI.

Clipping samples were collected once a month (twice in October) from each plot by using a Toro Personal Pace Recycler mower with a bagger set at a mowing height of 57 mm. Fresh clipping samples were placed in a Spectrum hydraulic plant sap press (Spectrum Technologies, Inc., Aurora, IL) to expel the sap. The sap was placed into the sample well of a Spectrum LAQUA Twin Nitrate Meter (Spectrum Technologies, Inc., Aurora, IL), and measurements were made for concentrations of NO_3-N. Measurements for all dates were taken between 1030 and 1600 hr. The meter was recalibrated after each block was completed (11 samples).

Mean clippings sap NO_3-N concentrations were analyzed for treatment differences (N rates and dates) by using analysis of variance with Fisher's LSD for mean separation in the MIXED procedure of SAS 9.4 (SAS Institute, Cary, NC). The relationship between clippings sap NO_3-N concentrations and N rate was modeled with a simple linear regression using the REG procedure in SAS. Linear response-plateau (LRP) models were applied to the NDVI and DGCI data to determine a critical level for clippings sap NO_3-N concentrations by using the NLIN procedure of SAS. The critical sap NO_3-N value marks the concentration where no further change in NDVI or DCGI response is observed with increasing concentration of clippings sap NO_3-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. If the LRP model was not applicable, then a simple linear regression model was used to analyze the data.

RESULTS & DISCUSSION

Monthly Clippings Sap Nitrate-N Concentrations

Across the growing season, clippings sap NO_3-N concentrations were relatively low and stable for Kentucky bluegrass in May through August, and in May through September for tall fescue (Fig. 1). Significant ($P < 0.05$) differences among N rate treatments within each month were not observed until September in KBG and October in TF. Accumulation of NO_3 was greatest from September to November and greater for the higher N rates. Averaged across N rates, monthly sap NO_3-N concentrations were greatest in early October for Kentucky bluegrass, and mid-October through November for tall fescue (Fig. 2). The greatest rates of increase for sap NO_3-N concentrations across N rates was observed for early-October and September (in that order) for KBG, and for mid-October and November (in that order) for TF (Fig. 3 and Table 1).

The lower clippings sap NO_3-N concentrations at the beginning and middle of the growing season were probably a result of active leaf growth in late spring and summer months

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that assimilated a large amount of NO_3 within the plant. Whereas, a rapid accumulation of NO_3 at the end of the growing season in September to November was most likely attributed to a decline in leaf growth and more storage of NO_3 at the onset of winter dormancy. The sap NO_3-N concentration dynamics in the growing season could be divided into two different phases: the stable phase (May-August), and accumulation phase (September-November). Unexpectedly warmer temperatures in October and November during the 2017 growing season probably resulted in more NO_3 being assimilated into leaf proteins and lowering the clippings NO_3-N concentrations at these times compared to 2016.

Across the entire growing season for KBG and TF, clippings sap NO_3-N concentrations showed considerable variation within each N rate. However, significant ($P < 0.05$) linear increases were observed in each month as N rates increased, except in May, August, and September for TF (Fig. 3 and Table 1). Slopes of the regression model were lower in the stable phase (May-Aug.) when compared to the greater slope values in the accumulation stage (Sept.-Nov.) (Table 1).

Response of NDVI and DGCI as a Function of Clippings Sap Nitrate-N Concentrations

NDVI response significantly ($P < 0.0001$ to 0.044) fit the LRP model for Kentucky bluegrass in June, July, August, September, and mid-October (Fig. 4 and Table 1), and in June, August, early-October, mid-October, and November for TF (Fig.4 and Table 1). Critical levels across species ranged from 149 to 197 mg L^{-1} during the stable phase (May-August), and from 247 to 470 mg L^{-1} during the accumulation phase (Sept.-Nov.). Compared on a month-by-month basis, the critical levels for KBG and TF in the stable or accumulation phases were relatively close to one another, and generally agreed well.

With DGCI, the LRP model was significant (P 0.0028 to 0.0250) in only 3 of the 8 samplings for KBG, and significant ($P < 0.0001$) only in mid-October for TF (Fig. 4 and Table 1). Critical levels across species ranged from 305 to 440 mg L^{-1} during the accumulation phase (mid-Oct. to Nov.). Tall fescue showed a strong linear response for DGCI as a function of sap NO_3-N concentrations in November. There was much greater variation for DGCI than for NDVI. However, when a critical level could be established, the response between species was relatively in agreement.

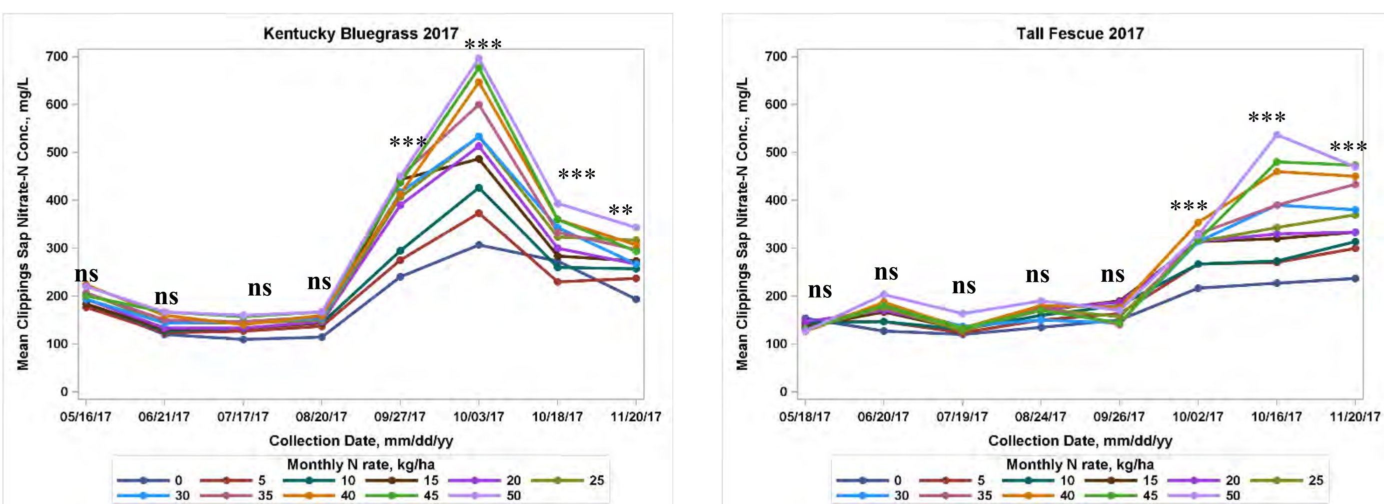

Figure 1. Responses of mean clippings sap NO_3-N concentrations for each N rate across the monthly sampling dates. Significance of the *F*-test for N rate means is shown above each date (ns, not significant; ** P <0.01; *** P <0.001).

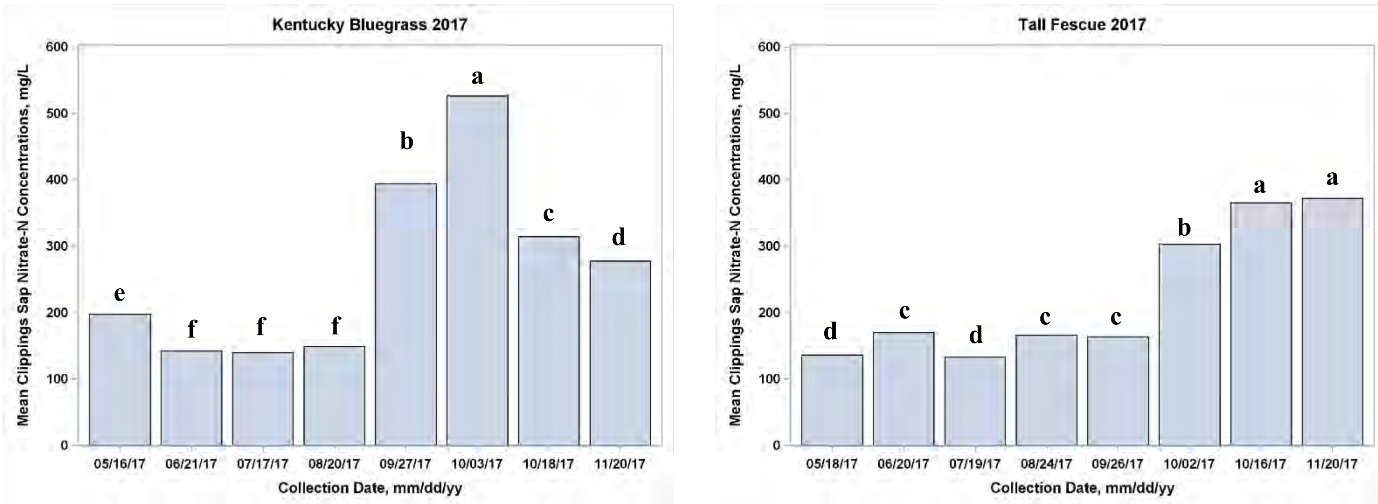

Figure 2. Responses of mean clippings sap NO_3-N concentrations for each monthly sampling date averaged across N rates. Means with the same letters are not different according to Fisher's Protected LSD (α=0.05).

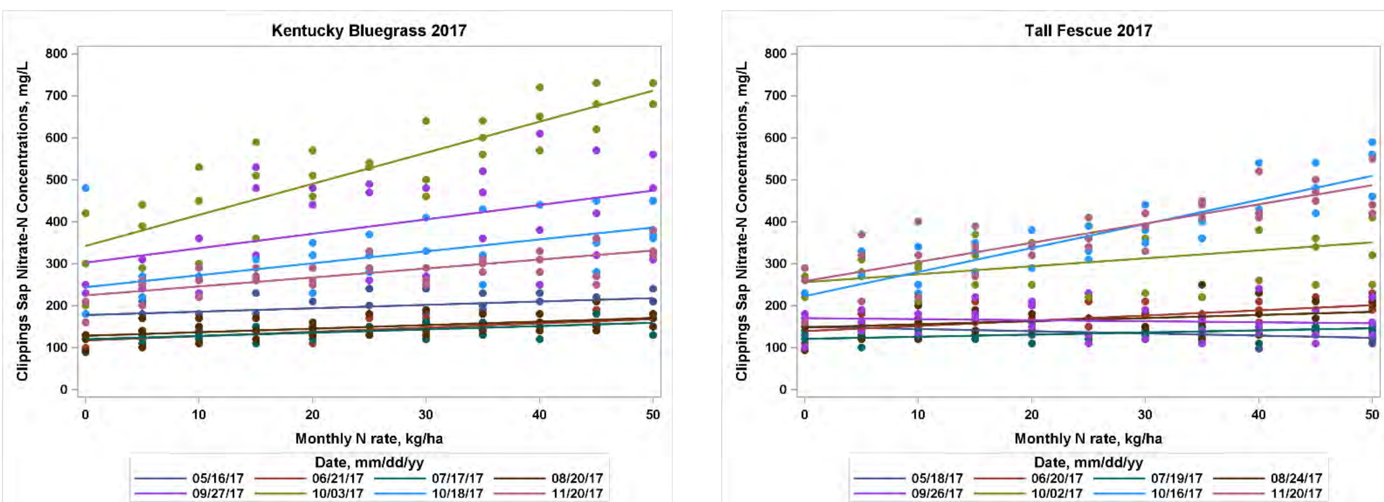

Figure 3. Linear response of clippings sap NO_3-N concentrations for each monthly sampling date across N rates. Model statistics and coefficients are presented in Table 1.

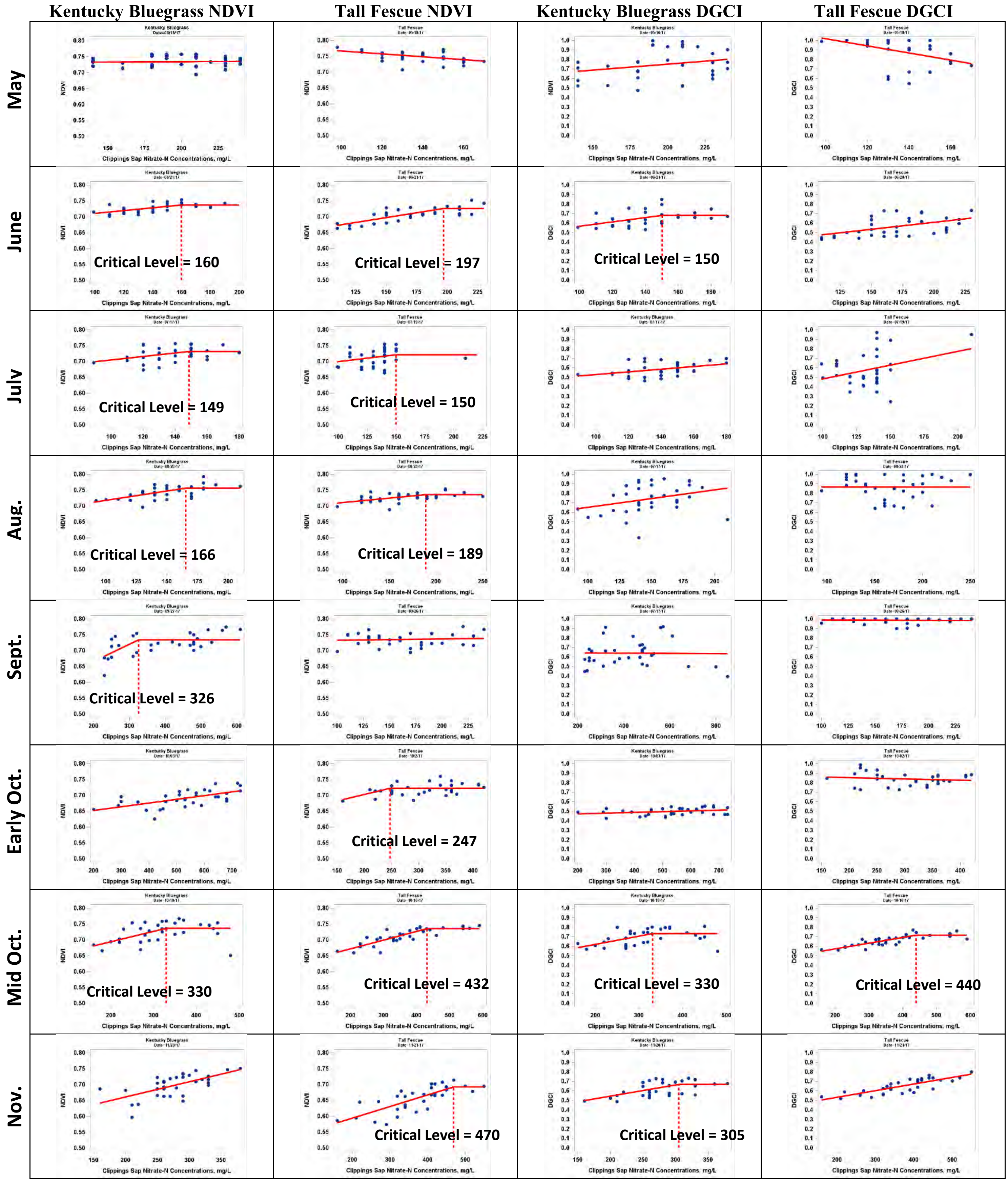

Figure 4. Response of monthly Kentucky bluegrass and tall fescue NDVI and DGCI readings as function of clippings sap nitrate-N concentrations.

Table 1. Model coefficients and statistics for Kentucky bluegrass (KBG) and tall fescue (TF) clippings sap NO_3-N concentrations as a function of N rates, and NDVI and DGCI responses to sap NO_3-N concentrations, 2017.

	Month							
	May	June	July	Aug.	Sept.	Early Oct.	Mid Oct.	Nov.
KBG Sap NO_3-N vs. N rate, Fig. 3								
Intercept	177.121	116.712	119.439	127.636	301.972	341.667	243.485	223.939
Slope	0.806	1.015	0.785	0.848	3.433	7.400	2.842	2.133
r^2	0.172	0.505	0.380	0.269	0.200	0.751	0.318	0.533
P value	0.0166	<0.0001	0.0001	0.002	0.0131	<0.0001	0.0006	<0.0001
TF Sap NO_3-N vs. N rate, Fig.3								
Intercept	149.121	138.788	120.348	147.697	169.697	255.303	222.273	257.727
Slope	-0.525	1.236	0.506	0.739	-0.242	1.897	5.727	4.576
r^2	0.243	0.357	0.166	0.104	0.010	0.198	0.786	0.686
P value	0.0035	0.0002	0.0188	0.0679	0.5877	0.0094	<0.0001	<0.0001
KBG NDVI vs. Clippings Sap NO_3-N, Fig.4								
Plateau	NA	0.737	0.731	0.756	0.734	NA	0.736	NA
Intercept	0.729	0.667	0.650	0.658	0.557	0.628	0.628	0.565
Slope	0.00002	0.00044	0.00055	0.00059	0.00054	0.00012	0.00033	0.00048
Critical Level	NA	160	149	165	326	NA	330	NA
r^2 or R^2	0.002	0.436	0.187	0.344	0.463	0.381	0.280	0.398
P value	0.8157	0.0002	0.0447	0.0018	0.0050	0.0001	0.0072	<0.0001
TF NDVI vs. Clippings Sap NO_3-N, Fig.4								
Plateau	NA	0.726	0.721	0.735	NA	0.722	0.735	0.692
Intercept	0.812	0.605	0.656	0.683	0.728	0.620	0.617	0.520
Slope	-0.00045	0.00061	0.00043	0.00028	0.00004	0.00041	0.00027	0.00037
Critical Level	NA	197	150	189	NA	247	432	470
r^2 or R^2	0.220	0.570	0.084	0.312	0.006	0.177	0.717	0.598
P value	0.0059	<0.0001	0.2693	0.0037	0.6621	0.0538	<0.0001	<0.0001
KBG DCGI vs. Clippings Sap NO_3-N, Fig.4								
Plateau	NA	0.680	NA	NA	NA	NA	0.731	0.667
Intercept	0.499	0.338	0.387	0.468	0.645	0.455	0.444	0.308
Slope	0.00125	0.00228	0.00141	0.00183	-0.00001	0.00008	0.00087	0.00118
Critical Level	NA	150	NA	NA	NA	NA	330	305
r^2 or R^2	0.063	0.218	0.182	0.098	0.000	0.084	0.288	0.324
P value	0.1590	0.0250	0.0134	0.0758	0.9266	0.1024	0.0062	0.0028
TF DCGI vs. Clippings Sap NO_3-N, Fig.4								
Plateau	NA	NA	NA	NA	NA	NA	0.715	NA
Intercept	1.389	0.313	0.192	0.866	0.989	0.879	0.450	0.391
Slope	-0.00373	0.00147	0.00290	-0.00001	-0.00003	-0.00014	0.00060	0.00070
Critical Level	NA	NA	NA	NA	NA	NA	440	NA
r^2 or R^2	0.201	0.247	0.108	0.000	0.002	0.021	0.711	0.662
P value	0.0090	0.0032	0.0617	0.9915	0.8212	0.4264	<0.0001	<0.0001

SUMMARY

The second-year results of this study suggests that clippings sap NO_3-N concentrations are relatively stable during the active leaf growing periods of the growing season (May-Aug.). However, commencing at the onset of winter dormancy preparation, clippings sap NO_3-N concentrations significantly increased from September to November.

The data also suggests that NDVI is correlated to clippings sap NO_3-N concentrations, and could potentially serve as a guide to N fertilization during the fall fertilization period. DGCI was less-well correlated to clippings sap NO_3-N concentrations than NDVI, and showed more variability than NDVI.

NATIONAL TURFGRASS EVALUATION PROGRAM (NTEP) 2014 NATIONAL FINELEAF FESCUE ANCILLARY TEST – 2017 RESULTS

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INTRODUCTION

Fineleaf fescues are fine leaf grasses that are medium to dark green in color. The leaves are narrow and "needle like". Fineleaf fescues are often utilized for turf that is grown under low input (fertility, water, etc.) conditions. A few areas/locations where they are often planted would be home lawns, parks, commercial properties, golf course roughs, and roadsides. Desirable characteristics of fineleaf fescues are that they have fine leaf texture, high leaf density, good to excellent drought resistance, low fertility needs, and they exhibit good to excellent shade tolerance. Some of the disadvantages of fineleaf fescues are that they exhibit moderate to poor wear tolerance, become thatchy, and they are slow to recuperate from injury. Fineleaf fescues are typically maintained at mowing heights between 1 to 3 inches. Fineleaf fescues include hard fescue, sheep fescue, creeping red fescue and chewings fescue. Hard, sheep, and chewings fescues are considered bunch type grasses (without rhizomes) while the creeping red fescues (both strong and slender) are both rhizomatous.

Golf course managers continue to face government restrictions and regulations regarding water and pesticide use on their golf course properties. An average eighteen hole golf course may have anywhere from 25 to 40 acres of fairways. Fairways are often irrigated and treated with pesticides. Most golf course fairways are maintained at mowing heights of one half inch or less. Typical grasses grown on fairways in northern climates are creeping bentgrass, perennial ryegrasses, and compact bluegrasses. The purpose of this study is to investigate the quality of fineleaf fescues maintained at lower mowing heights, and subjected to simulated golf cart traffic. Cultivars or species of fineleaf fescues that can be successfully grown at fairway mowing heights, and that can survive under traffic conditions may be a good alternative to the conventional grasses that have higher water and fertilizer requirements.

The National Turfgrass Evaluation Program (NTEP) is sponsored by the Beltsville Agriculture Research Center and the National Turfgrass Federation Inc. NTEP works with breeders and testing sites throughout the United States in evaluating turfgrass species and cultivars. Results from turfgrass evaluations can aid professionals in their selection of turfgrass species/cultivars that best meet their needs. Results also aid breeders in selecting new cultivars that they may put into production, as well as helping in marketing their varieties. In 2014 NTEP selected ten standard testing sites and eleven ancillary test locations for their 2014 National Fineleaf Fescue Test. The University of Connecticut, Plant Science Teaching and Research Facility in Storrs CT, was selected as an ancillary test site investigating simulated golf cart traffic tolerance of fineleaf fescue entries maintained at 0.5"mowing height. Evaluations will be made to both trafficked and non-trafficked test plots that are maintained with minimal inputs including supplemental water and fertility.

MATERIALS AND METHODS

Forty two fineleaf fescue plots were seeded on September 4, 2014 in Storrs Connecticut. Of the forty two fine fescue entries: 12 were hard fescues, 10 were strong creeping red fescues, 10 were chewings fescues, 6 were creeping red fescues, 3 were slender creeping red fescues, and 1 was a sheep fescue. A complete randomized block design with 3 replicates of each cultivar was utilized for this study. Plot size is 5' X 5'. Sponsors and entries are listed in Table 1.

For the entire 2015 growing season, simulated golf cart traffic was withheld to allow for turf to mature. Beginning in April 2016 simulated golf cart traffic treatments began on one half of each plot. As agreed upon by the cooperators of the ancillary traffic study, each plot was divided in half. One-half of each plot received simulated golf cart traffic and the other half of the plot was not subjected to traffic. The trafficked half of each plot received to two passes of simulated golf cart traffic three times per week for a total of 6 passes per week (figures 1 and 2). In 2017, traffic was intiated on plots beginning on 5/1/17 and continued throughout the season and concluded at the end of September 2017. Traffic will resume in the spring of 2017.

Management Practices

Since establishment, all plots and cultivars received the same management protocol throughout the study.

<u>Fertilizer and pesticide applications 2017</u>
4/19/17 - Pre-emergent 0.54 oz/1,000 ft^2 Prodiamine. 65 WDG
5/9/17 - 25-0-12 60% SCU at rate of 1.25 #N/1,000 sq.'
5/25/17 Acelepryn, .367 fl. Oz./1,000 ft^2

<u>Mowing</u> - Plots were maintained at a mowing height of 0.5 inches and mowed three times per week. Clippings were returned.

<u>Irrigation</u> – Irrigation was applied only to prevent severe drought stress. Supplemental irrigation was applied one time throughout the 2017 growing season.

Spring Green-up Ratings

Spring green-up ratings were taken and recorded (Table 2 non-trafficked and Table 3 trafficked) on April 11, 2017. Green-up measures the transition from winter dormancy to active spring growth. Ratings were based on a scale of 1-9, with 1 equaling brown turf and 9 equaling dark green turf.

Quality Ratings

Turfgrass quality ratings were taken on a monthly basis for overall turf quality (color / leaf texture / density) during the

2017 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. Monthly quality and mean quality ratings are provided in Table 2 for non-trafficked plots and Table 3 for trafficked plots.

Percent Living Cover

Ratings for percent living cover were taken on three separate dates; June 1st, July 31st and October 18th. The last rating for percent living cover coincided with the last seasonal traffic treatment. Perecnt living cover ratings are provided in Table 2 for non-trafficked plots and Table 3 for trafficked plots.

Disease Ratings

Ratings for percent red thread and dollarspot disease were taken on August 11th. Perecnt disease is provided in Table 2 for non-trafficked plots and Table 3 for trafficked plots.

RESULTS & DISCUSSION

In 2014 the University of Connecticut was chosen as a site for the Fineleaf Fescue Ancillary trial. Results of this ongoing study for both, simulated golf cart traffic and non-trafficked fineleaf fescue species and cultivars can be found in tables 2 and 3.

In 2017 dollar spot disease ratings were taken on August 11th. Results are recorded in tables 2 and 3. It should be pointed out that for dollarspot ratings in table 3, some plots were damaged so severly by traffic that a distinction could not be made bewtween disease and traffic injury. Those plots are denoted with a period in table.

Percent living cover ratings were taken on three separate occasions during the season. The first ratings were taken before traffic was intiated, the second rating was taken mid-season, and the third rating was when traffic concluded at the end of October. While percent cover ratings were taken for both trafficked and non-trafficked studies, the traffic effect is best noted and is discussed below. However, results for both non-trafficked and trafficked plots can be found in table 3. Of the fineleaf fescue species, the Chewings fescues appeared to perform best under traffic conditions. The top two cultivars for mean percent living cover were FRC 3057 and FRC 114 (both chewings fescue) In general, the hard fescues exhibited the least traffic tolerance. The bottom ten entries for percent living ground cover (trafficked) were all hard fescues.

Overall visual turfgrass quality ratings for both trafficked and non-trafficked plots were similar too 2016 results. Chewings, slender, and creeping red fescues exhibited higher quality ratings when compared to the hard and sheep fescues. One exception was hard fescsue DLFPS-FRC/3060 which scored in the top ten for both quality and percent density.

Results from 2017 simulated golf cart traffic trial indicate, from the mean values, that eight of the top 10 species for quality were chewings fescues. BARR VV VP3-CT a chewings fescue and C14-OS3 a strong creeping red fescue illustrated the highest ratings under simulated golf cart traffic conditions.

Lower turf quality ratings for hard fescue and sheep fescue were likely impacted by the lower mowing heights and traffic treatments. Quality for both species (hard and sheep) would most likely be higher if plots were maintained at mowing heights greater than 0.5 inches and traffic is minimal.

The results after two years of this study are promising. There were cultivars and species that exhibited high quality turf even when subjected to traffic, reduced irrigation and reduced fertilizer. Many of the entries would be acceptable for playing surfaces such as golf course fairways. In 2017 plots received supplemental irrigation on only one occasion. Irrigation was applied when all plots began to show water stress. Perhaps the biggest key for success of these species in fairway turf would be to significantly reduce irrigation. This would require the manager to be diligent in scouting and monitoring the turf for drought symptoms as well as monitoring soil moisture levels.

Table 1 – Sponsors, Entries, and Species		
SPONSOR	**ENTRY**	**SPECIES**
Landmark Turf and Native Seed	Minimus	Hard Fescue
Landmark Turf and Native Seed	Marvel	Strong Creeping Red
Brett Young Seeds Ltd	7C34	Strong Creeping Red
DLF Pickseed USA	DLFPS-FL/3066	Hard Fescue
DLF Pickseed USA	DLFPS-FRC/3060	Hard Fescue
DLF Pickseed USA	DLFPS-FL/3060	Hard Fescue
DLF Pickseed USA	DLFPS-FRR/3069	Strong Creeping Red
University of Minnesota	MNHD-14	Hard Fescue
DLF Pickseed USA	DLFPS-FRR/3068	Strong Creeping Red
Standard Entry	Quatro	Sheep
Standard Entry	Boreal	Strong Creeping Red
Columbia River Seed	TH456	Hard Fescue
John Deere Landscapes	7H7	Hard Fescue
Columbia River Seed	Sword	Hard Fescue
Standard Entry	Seabreeze GT	Slender Creeping Red
Standard Entry	Radar	Chewings
Standard Entry	Beacon	Hard Fescue
Standard Entry	Navigator II	Strong Creeping Red
Mountain View Seeds	PPG-FL 106	Hard Fescue
The Scotts Company	PPG-FRC 114	Chewings
Mountain View Seeds	PPG-FRT 101	Slender Creeping Red
Mountain View Seeds	PPG-FRR 111	Strong Creeping Red
Mountain View Seeds	PPG-FRC 113	Chewings
Columbia Seeds	Kent	Strong Creeping Red
Columbia Seeds	RAD-FC32	Chewings
Barenbrug USA	BAR FRT 5002	Slender Creeping Red
Barenbrug USA	BAR VV-VP3-CT	Chewings
Barenbrug USA	BAR 6FR126	Chewings
The Scotts Company	C14-OS3	Strong Creeping Red
Brett-Young Seed LTD	RAD-FR33R	Strong Creeping Red
Bailey Seed Company	RAD-FC44	Chewings
Bailey Seed Company	RAD-FR47	Creeping Red Fescue
Pure Seed Testing Inc.	PST-4DR4	Creeping Red Fescue
Pure Seed Testing Inc.	PST-4RUE	Creeping Red Fescue
Pure Seed Testing Inc.	PST-4BEN	Creeping Red Fescue
Pure Seed Testing Inc.	PST-4BND	Hard Fescue
Pure Seed Testing Inc.	PST-4ED4	Creeping Red Fescue
DLF Pickseed USA	DLFPS-FRC/3057	Chewings
Standard Entry	Cascade	Chewings
DLF Pickseed USA	DLF-FRC 33388	Chewings
DLF Pickseed USA	DLF-FRR 6162	Creeping Red Fescue
DLF Pickseed USA	Beudin	Hard Fescue

Figure 1 – 2014 NTEP Fineleaf fescue ancillary low cut/traffic Trials, University of Connecticut (photo- July 2017)

Figure 2 – Golf cart traffic simulator

Figure 3- FineFescue turf plots traffic and non-traffic treatments July 2017

Table 2. 2017 results for non-trafficked fine fescue turfgrass plots. Ratings are for: spring green-up (ratings 1-9, where 9 equals darker green –up), monthly turfgrass quality (rating 1-9, where 9 equals the highest turf quality), percent living ground cover on three separate dates, disease ratings for percent dollarspot. Table is listed with highest mean quality cultivars listed first.

	Spring green up	Dollar spot (% of plot)	Percent Living cover				Quality						
Entry	04/11/17	08/11/17	06/01/17	07/31/17	10/18/17	Mean	05/08/17	06/01/17	06/30/17	07/31/17	09/08/17	10/18/17	Mean
Radar	7.7	4.7	100	97.7	99.7	99.1	7.3	7.3	8.0	7.7	7.7	8.3	7.7
C14-OS3	7.0	3.0	100	96.3	96.7	97.7	8.0	7.0	7.7	7.7	7.7	8.3	7.7
DLF-FRC 3338	7.0	5.7	100	93.0	95.0	96.0	8.0	7.3	8.0	7.3	7.0	8.0	7.6
PPG-FRC-114	7.7	3.3	100	96.3	98.0	98.1	7.7	7.3	7.7	7.3	7.3	7.7	7.5
PPG-FRC 113	7.3	1.3	100	93.3	96.3	96.6	7.7	7.3	8.3	7.0	6.3	7.3	7.3
BAR VV-VP3-CT	6.7	2.7	100	96.0	99.0	98.3	7.0	7.0	7.3	8.0	7.3	7.0	7.3
DLFPS-FRC/3057	7.7	2.0	100	96.3	99.3	98.6	7.3	7.7	7.3	7.0	6.7	7.7	7.3
DLFPS-FRC/3060	7.7	3.7	100	91.7	99.3	97.0	7.0	7.0	7.7	7.0	6.7	7.0	7.1
RAD-FC32	6.7	4.7	100	93.3	96.3	96.6	8.0	7.3	6.3	7.0	6.3	6.7	6.9
RAD-FC44	6.7	4.7	100	88.3	96.0	94.8	7.3	6.0	6.3	7.0	6.7	7.3	6.8
PPG-FRT-101	6.0	2.0	98.3	91.7	96.3	95.4	7.3	7.0	6.3	5.7	5.7	7.7	6.6
BAR FRT 5002	5.3	5.3	100	88.3	91.7	93.3	6.0	6.3	5.3	5.7	5.7	6.3	5.9
7C34	5.0	38.3	95.0	73.3	91.7	86.7	5.0	5.7	6.3	5.3	6.0	6.3	5.8
BAR 6FR 126	6.7	8.3	98.3	71.7	91.7	87.2	6.7	6.0	6.0	4.7	4.3	6.7	5.7
DLFPS-FRR/3068	4.0	21.7	95.0	73.3	71.0	79.8	5.7	5.7	5.7	5.7	5.0	4.7	5.4
Cascade	6.3	3.7	95.0	86.0	86.7	89.2	5.0	5.0	5.0	5.7	5.3	5.7	5.3
PPG-FRC-111	5.0	22.7	91.7	68.3	83.3	81.1	5.3	5.3	5.0	5.3	4.7	5.7	5.2
Marvel	4.7	30.0	95.0	63.3	77.7	78.7	4.7	5.7	5.3	5.0	5.0	5.3	5.2
PST-4BEN	4.0	36.7	93.3	76.7	80.0	83.3	5.0	5.0	5.3	5.3	5.3	5.0	5.2
Beudin	5.3	20.0	93.3	75.0	81.0	83.1	5.0	5.0	5.7	5.0	4.7	5.7	5.2
DLFPS-FL/3060	4.7	3.0	93.3	76.7	80.0	83.3	5.7	5.0	4.7	5.0	5.0	5.3	5.1
Navigator II	4.7	12.3	95.0	71.7	81.7	82.8	5.7	4.7	5.0	5.3	5.0	5.0	5.1
DLF-FRR-6162	4.3	26.7	95.0	75.0	75.0	81.7	5.0	5.3	5.0	5.0	5.0	5.3	5.1
DLFPS-FL/3066	5.7	2.7	90.0	63.3	81.7	78.3	5.3	4.7	4.3	5.0	5.0	6.0	5.1

RAD-FR33R	3.7	50.0	91.7	61.7	78.3	77.2	5.0	5.0	5.3	5.0	4.7	5.3	5.1
PST-4DR4	4.3	31.0	95.0	68.3	76.0	79.8	5.0	5.0	5.0	5.3	5.0	5.0	5.1
TH456	4.7	7.5	85.0	56.7	68.3	70.0	5.7	4.7	4.3	4.3	4.7	5.7	4.9
PST-4RUE	3.7	31.7	88.3	68.3	75.0	77.2	4.7	5.3	5.0	5.0	4.7	4.7	4.9
DLFPS-FRR/3069	4.7	22.3	91.7	68.3	61.7	73.9	4.3	5.0	5.0	5.0	5.0	4.7	4.8
Kent	4.3	23.3	93.3	70.0	81.7	81.7	4.7	5.0	5.0	4.7	5.0	4.7	4.8
MNHD-14	5.7	3.5	88.3	61.7	71.0	73.7	4.7	4.7	4.7	4.7	4.3	5.7	4.8
Quatro	6.0	4.7	88.3	80.0	94.0	87.4	4.7	4.7	4.0	4.7	5.7	5.0	4.8
7H7	5.3	3.0	85.0	56.7	55.0	65.6	5.3	4.7	4.7	5.0	4.3	4.7	4.8
Seabreeze GT	6.0	23.3	90.0	71.7	76.7	79.4	4.7	4.3	5.3	5.0	4.3	5.0	4.8
RAD-FR47	5.0	28.3	93.3	65.0	73.3	77.2	5.3	4.7	5.0	4.0	5.0	4.7	4.8
PST-4ED4	4.3	51.7	90.0	56.7	76.7	74.4	5.0	5.0	5.0	4.3	4.7	4.7	4.8
Beacon	4.7	5.0	88.3	56.7	65.0	70.0	5.3	5.0	4.7	4.7	4.3	4.3	4.7
Boreal	4.3	45.0	83.3	51.7	75.0	70.0	4.7	5.0	4.7	4.0	4.3	4.7	4.6
Sword	5.0	1.5	83.3	53.3	60.0	65.6	5.0	4.7	4.7	4.0	4.3	4.7	4.6
PPG-FL-106	5.7	3.5	85.0	58.3	78.3	73.9	4.0	4.0	4.3	4.0	5.0	5.0	4.4
Minimus	4.7	2.5	80.0	40.0	53.3	57.8	4.7	3.7	3.7	3.3	3.7	4.7	3.9
PST-4BND	3.7	5.0	60.0	40.0	38.3	46.1	3.7	4.3	3.7	3.3	3.0	3.3	3.6
$LSD_{0.05}$	1.57	18.63	11.42	20.14	20.29	14.34	1.03	1.29	1.16	1.22	1.21	1.24	0.83
CV%	17.7	71.6	7.6	16.9	15.4	10.7	11.1	14.3	12.9	13.9	14.0	13.2	9.3

Table 3. 2017 results for trafficked fine fescue turfgrass plots. Ratings are for: spring green-up (ratings 1-9, where 9 equals darker green –up), monthly turfgrass quality (rating 1-9, where 9 equals the highest turf quality), percent living ground cover on three separate dates, disease rating for percent dollarspot. Table is listed with highest mean quality cultivars listed first.

	Spring green up	Dollar spot (% of plot)	Percent Living cover				Quality						
Entry	04/11/17	08/11/17	06/01/17	07/31/17	10/18/17	Mean	05/08/17	06/01/17	06/30/17	07/31/17	09/08/17	10/18/17	Mean
BAR VV-VP3-CT	6.7	10.7	100	75.0	70.0	81.7	7.0	7.0	6.3	7.0	5.7	7.7	6.8
C14-OS3	7.0	5.0	100	28.3	30.0	52.8	7.3	7.7	7.0	6.7	5.7	6.3	6.8
Radar	7.7	13.5	100	56.7	78.0	78.2	7.3	7.0	7.0	6.7	5.3	7.0	6.7
DLFPS-FRC/3057	7.7	8.7	100	86.7	87.7	91.4	7.0	7.3	6.3	6.3	5.0	6.3	6.4
PPG-FRC-114	7.7	4.7	98.3	83.3	93.0	91.6	7.3	6.7	6.0	5.7	6.0	6.0	6.3
PPG-FRC 113	7.3	3.5	100	45.0	60.0	68.3	7.7	6.7	6.3	5.3	4.7	6.3	6.2
RAD-FC32	6.7	5.5	96.7	48.3	51.7	65.6	7.3	7.3	4.7	5.7	5.3	6.3	6.1
DLF-FRC 3338	7.0	10.0	98.3	71.7	80.0	83.3	6.7	7.0	6.0	5.7	4.7	6.0	6.0
PPG-FRT-101	6.0	14.0	98.3	70.0	79.7	82.7	7.0	6.7	5.7	5.7	4.7	6.0	5.9
DLFPS-FRC/3060	7.7	33.0	98.3	51.7	46.7	65.6	6.3	6.3	6.3	5.7	4.7	6.0	5.9
RAD-FC44	6.7	4.7	93.3	81.3	88.0	87.6	5.7	6.7	5.3	4.7	4.3	5.0	5.3
7C34	5.0	4.3	96.7	65.0	78.3	80.0	5.0	6.0	5.7	4.7	4.3	5.0	5.1
Cascade	6.3	8.3	85.0	83.3	83.3	83.9	5.3	5.7	4.7	5.3	4.7	5.0	5.1
DLF-FRR-6162	4.3	.	90.0	33.3	30.0	51.1	5.0	5.7	5.3	4.7	4.3	5.0	5.0
Marvel	4.7	15.7	88.3	73.3	78.0	79.9	5.3	6.0	4.3	4.3	4.3	4.7	4.8
DLFPS-FRR/3068	4.0	13.3	88.3	63.3	53.3	68.3	4.7	6.0	5.0	4.7	4.3	4.0	4.8
Navigator II	4.7	13.0	86.7	53.3	74.3	71.4	4.7	5.3	4.7	4.7	4.3	5.0	4.8
Seabreeze GT	6.0	10.7	90.0	56.7	60.0	68.9	5.0	5.3	4.7	4.3	4.3	4.7	4.7
Quatro	6.0	27.5	83.3	41.7	53.3	59.4	4.3	4.3	4.3	5.0	4.7	5.3	4.7
RAD-FR33R	3.7	26.7	83.3	78.3	63.3	75.0	5.0	5.3	5.0	4.0	4.0	4.3	4.6
PPG-FRC-111	5.0	4.3	75.0	66.7	80.0	73.9	4.7	5.0	4.7	4.3	4.3	4.3	4.6
PST-4BEN	4.0	7.7	90.0	85.0	89.7	88.2	5.0	5.0	5.0	4.0	4.0	4.3	4.6
Kent	4.3	1.3	80.0	70.0	71.7	73.9	5.0	4.3	4.7	4.0	4.3	4.3	4.4
PST-4DR4	4.3	12.3	85.0	73.3	88.7	82.3	5.0	5.0	4.7	4.0	3.7	4.3	4.4

DLFPS-FRR/3069	4.7	26.7	86.7	56.7	55.0	66.1	4.7	5.0	4.7	3.7	4.0	4.0	4.3
BAR FRT 5002	5.3	21.0	85.0	60.0	43.3	62.8	5.0	5.7	4.0	4.0	3.7	3.7	4.3
RAD-FR47	5.0	15.0	86.7	55.0	60.0	67.2	5.0	5.0	5.0	4.0	3.3	3.7	4.3
BAR 6FR 126	6.7	45.0	80.0	68.3	76.7	75.0	5.3	5.7	4.7	3.7	2.7	3.0	4.2
Boreal	4.3	2.0	75.0	61.7	67.7	68.1	4.3	4.7	4.3	3.7	3.7	4.0	4.1
PST-4RUE	3.7	16.0	73.3	36.7	32.7	47.6	4.3	4.7	4.3	4.0	3.3	4.0	4.1
Beudin	5.3	4.7	73.3	66.7	89.3	76.4	4.3	4.7	4.7	4.0	3.0	4.0	4.1
PST-4ED4	4.3	20.0	88.3	33.3	36.0	52.6	4.7	4.7	4.0	3.3	3.3	4.0	4.0
PPG-FL-106	5.7	5.0	48.3	86.7	94.7	76.6	3.7	4.0	3.3	2.7	3.3	4.0	3.5
MNHD-14	5.7	19.7	53.3	60.0	61.7	58.3	3.7	4.0	3.0	3.0	3.0	3.7	3.4
7H7	5.3	17.3	55.0	66.7	81.7	67.8	3.3	3.3	3.3	3.0	3.7	3.7	3.4
DLFPS-FL/3060	4.7	4.7	53.3	71.7	64.7	63.2	3.7	4.0	3.0	3.0	3.0	3.3	3.3
DLFPS-FL/3066	5.7	13.0	56.7	41.7	36.7	45.0	3.7	3.7	3.3	2.3	3.0	3.3	3.2
Sword	5.0	26.7	58.3	58.3	75.0	63.9	3.7	4.0	3.0	2.3	2.7	3.3	3.2
Beacon	4.7	8.0	53.3	51.7	53.3	52.8	3.7	3.0	3.3	2.3	3.0	3.0	3.1
Minimus	4.7	5.7	41.7	65.0	73.3	60.0	3.3	2.3	3.3	2.0	2.3	2.7	2.7
TH456	4.7	6.0	41.7	71.7	67.7	60.3	3.0	2.7	2.7	2.3	2.3	2.7	2.6
PST-4BND	3.7	2.0	44.0	40.0	41.3	41.8	3.0	3.0	2.3	2.0	2.0	2.3	2.4
$LSD_{0.05}$	1.57	24.71	23.88	34.49	40.16	24.66	1.37	1.42	1.00	1.35	1.25	1.49	1.01
CV%	17.7	108.1	18.4	34.4	37.4	21.9	16.6	16.7	13.2	19.6	19.4	20.1	13.4

*. Denotes that a distinction couldn’t be made between disease and traffic injury

Acknowledgements:
This project is funded by the National Turfgrass Evaluation Program
Traffic Simulator made possible through the New England Turfgrass Research Foundation

NATIONAL TURFGRASS EVALUATION PROGRAM (NTEP)
2015 STANDARD AND ANCILLARY LOW INPUT COOL SEASON TEST – 2017 RESULTS

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INTRODUCTION

There has been increased interest to develop new plant management strategies, or to investigate new plant systems that require less input such as water, fertilizer, and pesticides. Overall quality and functionality are still desired. This trial is unique in that the maintenance of this trial, after the establishment period, will be minimal. There will be no water, fertilizer or pesticides applied after the establishment period. (Exception is the Ancillary Trial, which received one preemergent application in the first year of the study). Also unique about this trial is that it not only includes single turfgrass cultivars, it includes, blends, mixtures and mixtures with grass and non-grass species.

In 2015, the National Turfgrass Evaluation Program (NTEP) selected thirteen standard testing locations and thirteen ancillary test locations for their 2015 Low Input Cool-Season Trials. The University of Connecticut, Plant Science Teaching and Research Facility in Storrs CT, was selected for both a Standard and Ancillary site. The duration of this study is five years and will conclude in the fall of 2021.

The National Turfgrass Evaluation Program (NTEP) is sponsored by the Beltsville Agriculture Research Center and the National Turfgrass Federation Inc. NTEP works with breeders and testing sites throughout the United States in evaluating turfgrass species and cultivars. This low input study differs from conventional NTEP trials in two ways. One is that many of the entries are not single cultivars or varieties being evaluated, they contain mixtures. The second difference is that many of the entries contain non-turfgrass species. Results from this trail may aid homeowners and professionals in their selection of low input species and mixtures that best meet their needs, and those that provide a suitable ground cover that will require less water, fertility and mowing.

MATERIALS AND METHODS

Two low-input trials were seeded on September 14, 2015 in Storrs Connecticut. One trial was a "standard" test while the second trial was an "ancillary" test. Each test consisted of thirty-two entries (Table 1) containing different species, different mixtures, and different compositions. Both, the ancillary and standard trial contained the same entries and received the same maintenance regimes. The only difference between the two trials was that the ancillary trial received a preemergent application for weeds in the spring of 2016. Sponsors and entries are listed in table 1. A complete randomized block design with three replicates of each cultivar was utilized for each study. Plot size is 5' X 5'.

Establishment and Management Practices-
After seeding, plots were covered to aid in germination and to reduce any chances of seed migration. All plots for each study received the same management protocol since establishment.

Mowing (Standard and Ancillary trials) - Plots are maintained at a mowing height of 3.25" inches and mowed when no more than 1/3 of the leaf is removed.

Irrigation Regime (Standard and Ancillary trials) - No irrigation

Fertilizer and pesticide applications (2015/2016)

- Standard and Ancillary trials - Plots received a total of 1 pound of nitrogen. 4/22/16
- Standard trial – No Preemergent applied
- Ancillary Trial – Preemergent applied on 4/29/16 (Prodiamine 4L at .5oz./1000 ft^2)

Quality Ratings- Quality ratings are taken on a monthly basis throughout the growing season for overall quality (color/density). Overall quality is determined using a visual rating system of 1-9. A score of 1 illustrates the poorest quality and 9 the highest quality. (Table 2 standard test and Table 3 ancillary test).

Percent Living Ground Cover- Percent living cover ratings were taken after the growing season on October 18, 2017. (Table 2 standard test and Table 3 ancillary test).

Percent grassy and broadleaf weed encroachment Ratings – Weed encroachment ratings are taken twice per year, once in the spring and once in the fall. In 2017, ratings were done on June 30th and October 18, 2017. (Table 2 standard test and Table 3 ancillary test).

RESULTS & DISCUSSION

The University of Connecticut was chosen as a site for the National Turfgrass Program 2015 Low Input Cool-Season Trials. This trial differs from the typical NTEP trials because each plot contained different grasses and species. Evaluating the different species and grasses for visual quality was/is challenging. This was especially true when comparing broadleaf entries such as clover with straight grass entries or grass and clover mixes. Visual ratings were most influenced by plant density of the original planted species. Many of the plots had a high level of weed encroachment from non-seeded species which negatively impacted their quality ratings The purpose of this study is to investigate the use of different ground covers for low maintenance environments. For Mean quality ratings, the top entries for both the standard and ancillary studies were DLFPS TF is a tall fescue mix. DLFPS-TFAM DLFPS TFAStC, both mixtures contain high percentages of tall fescue and small percentages of micro clover and strawberry respectively, CRS Mix 3, contains hard fescue and a small percentage of Dutch white clover.Yaak (100% a western yarrow) performed well through the early part of the season but the overall quality began to deteriorate towards the end of the season. Kenblue Kentucky bluegrass and 100% Dutch White Clover had the poorest rating in both trials. Visual differences between ancillary trial plots (receiving preemergent applications) and non- ancillary plots (not receiving preemergent applications) were minimal for the 2017 season.

Density ratings indicated that many of the original species planted had died off. The percentages of Kenblue that remained in the plots at the conclusion of the 2017 growing season were estimated to be about 2.3% for the standard trail and 7% for the ancillary trial.

Perhaps the most challenging aspect of rating plots in 2017 was the fact that there was a high level of weed encroachment in many of the plots. Clover was the predominate weed. Plots that did not contain clover in the original seed mix had high populations of clover in October 2017. An example was the Kenblue plots. The predominant plant species in the planted Kenblue plots at the end of the 2017 season was clover. A complete population shift. One possible explanation for clover encroachment in many of the plots may be because plots have not received any supplemental nitrogen fertilization since establishment. Encroachment may also be occurring from neighboring plots that had clover in the original seed mix.

Figure 1- 2015 NTEP Low Input Cool Season Trials University of Connecticut
Photo taken August 2016

Table 1 Entries, Species, and Composition of the 2015 Standard and Ancillary Low Input Cool-Season Tests

PLOT	ENTRY	SPECIES/COMPOSITION	SPONSOR
1	Natural Knit® PRG Mix	50% Mensa perennial ryegrass 50% Savant perennial ryegrass	Ledeboer Seed LLC
2	Bullseye	100% Bullseye tall fescue	Standard entry
3	Bewitched	100% Bewitched Ky. Bluegrass	Standard entry
4	BGR-TF3	100% BGR-TF3 tall fescue	Berger International LLC
5	MNHD-15	100% MNHD-15 hard fescue	University of Minnesota
6	DLFPS TF-A	33% Mustang tall fescue 33% Grande 3 tall fescue 34% Fayette tall fescue	DLF/Pickseed/Seed Research of Oregon
7	DLFPS ChCrM	24% Longfellow 3 chewings fescue 24% Windward chewings fescue 24% Chantilly strong creeping red fescue 25% Ruddy strong creeping red fescue (CRF) 3% Microclover™	DLF/Pickseed/Seed Research of Oregon
8	DLFPS ShHM	32% Quatro sheep fescue 32% Spartan II hard fescue 33% Eureka II hard fescue 3% Microclover™	DLF/Pickseed/Seed Research of Oregon
9	DLFPS TFAM	33% Mustang tall fescue 33% Grande 3 tall fescue 34% Fayette tall fescue 3% Microclover™	DLF/Pickseed/Seed Research of Oregon
10	Vitality Low Maintenance Mixture	80% VNS hard fescue 20% VNS chewings fescue	Landmark Turf & Native Seed
11	Vitality Double Coverage Mixture	90% VNS tall fescue 10% VNS Kentucky bluegrass	Landmark Turf & Native Seed
12	Chantilly	100% Chantilly strong creeping red fescue (CRF)	Standard entry
13	Dutch White Clover	100% Dutch White Clover	Standard entry
14	DLFPS TFAStC	32% Mustang tall fescue 32% Grande 3 tall fescue 33% Fayette tall fescue 3% Strawberry clover	DLF/Pickseed/Seed Research of Oregon
15	DLFPS ChCrSH	14% Longfellow 3 chewings fescue 14% Windward chewings fescue 14% Chantilly strong CRF 14% Ruddy strong CRF	DLF/Pickseed/Seed Research of Oregon
16	Spartan II	100% Spartan II hard fescue	Standard entry
17	Quatro	100% Quatro sheep fescue	Standard entry
18	Ky-31E+	100% Ky-31 tall fescue w/endophyte	Standard entry
19	CRS Mix #1	55% Gladiator hard fescue 45% 4GUD hard fescue	Columbia River Seed
20	CRS Mix #2	67% Gladiator hard fescue 33% NA13-14 Kentucky bluegrass	Columbia River Seed
21	CRS Mix #3	45% Gladiator hard fescue 45% Sword hard fescue 10% Dutch White Clover	Columbia River Seed
22	DTT Tall Fescue Mix	50% DTT20 tall fescue 50% DTT43 tall fescue	Allied Seed

PLOT	ENTRY	SPECIES/COMPOSITION	SPONSOR
23	DTTHO TF/KBG Mix	45% DTT20 tall fescue 45% DTT43 tall fescue 10% Holiday lawn Ky. Bluegrass	Allied Seed
24	A-SFT	100% A-SFT tall fescue	Allied Seed
25	Kingdom	100% Kingdom tall fescue	John Deere Landscapes
26	7H7	100% 7H7 hard fescue	John Deere Landscapes
27	Northern Mixture	40% VNS perennial ryegrass 20% VNS Kentucky bluegrass 20% VNS chewings fescue 20% VNS creeping red fescue	Proseeds Marketing
28	Southern Mixture	70% VNS tall fescue 10% VNS perennial ryegrass 10% VNS Kentucky bluegrass 10% VNS chewings fescue	Proseeds Marketing
29	CS Mix	40% Castle chewings fescue 40% Sword hard fescue 10% Kent creeping red fescue 10% B-15.2415 sheep fescue	Columbia Seeds LLC
30	Yaak	100% Yaak western yarrow	Pacific NW Natives
31	Radar	100% Radar chewings fescue	Standard entry
32	Kenblue	100% Kenblue Kentucky bluegrass	Standard entry

Table 2. NTEP Low Input Standard Test results 2017 Ratings for percent establishment, Percent Living cover for fall, percent weed coverage for spring and fall, and monthly visual quality (rating 1-9, where 9 equals the highest turf quality)

	Spring green up	Percent Living cover planted species	Percent weed coverage			Quality						
Entry	04/10/17	10/18/17	06/30/17	10/18/17	Mean	05/08/17	06/01/17	06/30/17	07/31/17	09/08/17	10/18/17	Mean
DLFPS-TFAM	4.0	98.0	1.0	1.3	1.2	7.0	7.0	7.3	7.3	8.0	7.7	7.4
DLFPS TFAStC	3.7	96.3	1.0	1.0	1.0	6.7	7.3	6.3	7.0	7.7	7.7	7.1
CRS Mix #3	5.7	94.3	2.0	1.7	1.8	6.0	7.7	7.0	7.3	6.7	7.3	7.0
DLFPS TF-A	3.3	94.0	3.0	3.3	3.2	7.0	7.0	6.3	7.0	7.0	6.3	6.8
Yaak	2.0	94.7	5.3	5.0	5.2	7.0	6.0	6.7	7.3	6.7	6.3	6.7
DLFPS-ChCrM	5.7	93.3	1.0	1.3	1.2	6.0	6.7	6.7	6.3	6.3	6.0	6.3
DTT Tall Fescue Mix	3.3	79.0	16.3	14.0	15.2	6.7	7.0	5.3	5.7	6.7	6.7	6.3
CRS Mix #2	3.3	71.7	20.3	14.0	17.2	5.7	8.0	5.7	6.0	5.7	6.7	6.3
CRS Mix #1	3.7	83.7	4.7	5.0	4.8	5.3	6.3	6.0	6.0	6.3	7.0	6.2
Kingdom	2.3	78.3	22.7	17.3	20.0	6.0	7.7	5.7	6.0	5.7	6.0	6.2
Bullseye	3.0	82.3	20.0	13.0	16.5	6.3	6.3	5.3	5.7	6.7	6.0	6.1
7H7	3.7	64.0	15.7	19.0	17.3	4.7	7.3	6.0	6.3	6.0	6.0	6.1
Southern Mixture	3.7	87.7	3.0	4.3	3.7	6.3	6.7	5.7	5.7	6.3	5.7	6.1
DTTHO TF/KBG Mix	2.0	88.3	26.7	17.7	22.2	6.3	7.3	5.0	5.7	6.3	5.3	6.0
MNHD-15	4.0	82.3	12.3	10.3	11.3	5.0	7.7	5.7	5.7	5.3	6.3	5.9
BGR-TF3	3.0	89.0	17.3	6.7	12.0	5.7	6.3	5.3	4.7	6.7	6.0	5.8
Vitality Double Coverage Mix	2.7	88.3	3.7	17.0	10.3	6.0	6.3	5.7	5.7	5.3	5.7	5.8
Vitality Low Maintenance Mix	3.7	82.3	7.0	9.0	8.0	5.0	6.3	5.0	5.3	6.0	6.3	5.7
Spartan II	3.3	84.0	5.7	19.0	12.3	4.7	5.7	5.7	5.0	6.0	5.7	5.4
CS Mix	3.3	83.3	8.3	20.7	14.5	5.0	6.0	4.7	4.7	6.0	5.0	5.2
Quatro	5.0	85.0	4.3	16.0	10.2	4.7	5.0	5.7	5.3	5.3	4.3	5.1
DLFPS-ShHM	5.3	72.3	4.0	18.3	11.2	4.7	6.3	5.7	5.0	4.3	4.0	5.0
A-SFT	2.3	68.0	36.7	17.7	27.2	5.7	6.0	4.3	4.3	4.3	4.7	4.9
Ky-31 E+	3.3	97.0	1.7	6.0	3.8	4.7	4.3	4.7	6.3	4.0	3.7	4.6
Bewitched	3.0	30.0	86.7	55.0	70.8	4.7	6.3	3.3	3.3	3.7	5.3	4.4
DLFPS ChCrSH	3.7	53.3	34.3	30.3	32.3	4.7	5.3	4.3	4.0	4.0	4.3	4.4
Radar	3.7	58.3	40.0	38.3	39.2	5.7	4.7	3.7	4.0	4.0	4.7	4.4

Natural Knit®PRG Mix	5.0	21.7	18.3	36.7	27.5	5.0	6.0	3.7	4.0	3.0	4.3	4.3
Northern Mixture	4.0	35.0	16.0	50.0	33.0	5.3	5.3	4.3	3.3	3.3	3.3	4.2
Chantilly	5.3	35.0	31.7	61.7	46.7	5.0	5.3	3.3	3.7	3.3	3.3	4.0
Dutch White Clover	4.0	13.3	11.0	86.7	48.8	4.7	5.0	5.3	4.0	2.0	2.0	3.8
Kenblue	1.7	2.3	75.0	85.0	80.0	4.0	4.3	2.3	1.0	1.0	1.7	2.4
$LSD_{0.05}$	1.35	26.32	26.47	21.81	20.95	1.03	1.43	1.47	1.55	1.46	1.36	0.86
CV%	22.9	22.6	93.2	60.9	65.3	11.4	13.9	17.2	18.1	16.9	15.6	9.5

<u>Table 3.</u> NTEP Low Input Ancillary Test results 2017 Ratings for percent establishment, Percent Living cover for fall, percent weed coverage for spring and fall, and monthly visual quality (rating 1-9, where 9 equals the highest turf quality)

	Spring green up	Percent Living cover planted species	Percent weed coverage			Quality						
Entry	04/10/17	10/18/17	06/30/17	10/18/17	Mean	05/08/17	06/01/17	06/30/17	07/31/17	09/08/17	10/18/17	Mean
DLFPS-TFAM	4.7	97.7	1.3	2.7	2.0	7.0	7.3	7.7	8.0	8.0	7.0	7.5
CRS Mix #3	5.7	94.3	1.3	1.7	1.5	6.7	7.0	7.3	7.7	7.0	7.7	7.2
DLFPS TF-A	4.0	93.7	9.7	3.3	6.5	7.7	7.3	6.0	6.7	7.0	7.0	6.9
DLFPS TFAStC	4.3	95.0	1.0	2.3	1.7	6.3	6.7	6.7	7.0	6.7	7.7	6.8
Bullseye	3.7	94.3	20.7	5.0	12.8	7.0	7.3	6.0	6.3	7.0	6.3	6.7
Yaak	2.0	95.3	4.0	13.3	8.7	7.0	6.7	7.3	7.3	6.3	5.3	6.7
DLFPS-ChCrM	5.0	96.0	1.3	2.0	1.7	6.3	6.3	6.3	6.7	6.3	6.3	6.4
CRS Mix #1	5.0	76.7	21.7	12.3	17.0	6.0	7.7	6.0	6.0	6.3	6.3	6.4
CRS Mix #2	5.7	75.0	23.0	26.0	24.5	5.7	7.3	6.0	6.7	6.3	6.3	6.4
DTTHO TF/KBG Mix	3.3	71.7	36.0	5.3	20.7	6.7	7.3	6.0	5.7	6.3	6.3	6.4
MNHD-15	5.3	77.0	17.3	15.0	16.2	5.7	7.3	6.3	6.0	6.0	6.3	6.3
Vitality Double Coverage Mix	3.0	76.7	25.0	8.3	16.7	6.3	7.7	5.3	5.7	6.3	6.3	6.3
Vitality Low Maintenance Mix	5.3	88.7	5.7	10.0	7.8	5.7	6.3	6.7	6.0	6.0	6.0	6.1
Spartan II	5.0	69.7	8.7	14.3	11.5	5.7	6.3	6.7	6.0	5.3	6.0	6.0
Southern Mixture	4.0	78.0	8.7	17.0	12.8	6.3	6.0	6.3	6.3	6.3	4.7	6.0
Kingdom	3.7	70.7	33.3	10.3	21.8	6.7	6.3	5.3	5.0	6.3	6.0	5.9
CS Mix	5.3	75.3	25.3	21.0	23.2	6.7	6.7	5.0	5.7	5.7	6.0	5.9
DLFPS-ShHM	5.7	88.7	4.3	11.7	8.0	5.7	7.0	6.3	6.3	5.0	5.0	5.9
7H7	5.7	61.7	33.3	26.7	30.0	5.0	8.0	5.7	5.0	4.7	5.7	5.7
DTT Tall Fescue Mix	3.7	75.0	24.0	19.3	21.7	5.3	6.7	5.3	4.7	6.0	5.7	5.6
A-SFT	4.0	68.3	21.3	12.3	16.8	6.0	7.0	5.3	3.7	5.7	6.0	5.6
DLFPS ChCrSH	4.7	87.7	11.0	10.3	10.7	5.7	5.3	5.3	5.7	5.7	5.7	5.6
BGR-TF3	4.3	61.7	41.7	17.7	29.7	6.0	6.0	4.7	4.3	6.0	6.0	5.5
Radar	4.3	91.0	6.7	17.3	12.0	6.0	5.3	4.7	5.3	6.0	5.7	5.5
Ky-31 E+	4.0	94.0	7.7	14.3	11.0	4.7	3.7	6.0	6.3	6.0	4.3	5.2
Northern Mixture	4.0	61.7	60.0	35.0	47.5	5.0	6.0	4.7	4.3	4.7	4.7	4.9
Chantilly	5.0	80.0	16.7	28.3	22.5	5.7	5.7	4.3	4.3	4.7	4.0	4.8

Natural Knit®PRG Mix	4.7	51.7	38.3	26.7	32.5	4.7	5.7	4.3	3.3	4.7	5.3	4.7
Quatro	4.7	60.0	28.3	43.3	35.8	4.3	5.0	4.7	4.0	4.7	4.0	4.4
Bewitched	5.3	10.0	90.0	83.3	86.7	5.0	6.3	3.0	2.7	3.0	4.7	4.1
Dutch White Clover	4.7	23.3	20.0	86.7	53.3	5.0	4.0	5.3	5.7	1.7	1.7	3.9
Kenblue	4.3	7.0	90.0	88.3	89.2	6.0	5.0	3.0	2.3	1.7	2.0	3.3
$LSD_{0.05}$	1.9	27.5	30.0	18.4	21.5	1.3	1.2	1.5	1.5	1.5	1.4	0.9
CV%	25.7	22.9	79.7	52.2	58.9	13.2	11.4	16.2	17.1	16.7	15.2	9.6

Acknowledgements:
The National Turfgrass Evaluation Program funds this project

NATIONAL TURFGRASS EVALUATION PROGRAM (NTEP)
2012 NATIONAL TALL FESCUE TEST – 2017 RESULTS

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INTRODUCTION

Turf-type tall fescue has gained in popularity over the last decade. Characteristics that make turf-type tall fescue desirable are: it maintains a dense, dark green color, lower fertility requirements than conventional Kentucky bluegrass/ryegrass home lawns, and it has good traffic tolerance and shade tolerance. Turf-type tall fescue also exhibits excellent drought avoidance characteristics. When trying to reduce inputs such as fertilizer and water, turf-type tall fescue can be a good alternative.

The National Turfgrass Evaluation Program (NTEP) is sponsored by the Beltsville Agriculture Research Center and the National Turfgrass Federation Inc. NTEP works with breeders and testing sites throughout the United States in evaluating turfgrass species and cultivars. Results from turfgrass evaluations can aid professionals in their selection of turfgrass species/cultivars that best meet their needs. Results also aid breeders in selecting new cultivars that they may put into production, as well as helping in marketing their varieties. In 2012 NTEP selected fifteen standard testing sites and eleven ancillary test locations for their 2012 Turf-type Tall Fescue Test. The University of Connecticut, Plant Science Teaching and Research Facility in Storrs CT, was selected as a standard site for the 2012 Turf-type Tall Fescue Test. NTEP trials typically run for a period of five years. 2017 marked the fifth and final year of the 2012 Turf-Type Tall Fescue trial.

MATERIALS AND METHODS

One hundred and sixteen cultivars of Turf-type Tall fescue were seeded on September 11, 2012 in Storrs Connecticut. A complete randomized block design with 3 replicates of each cultivar was utilized for this study. Plot size is 5' X 5'. Sponsors and entries are listed in Table 1.

Management Practices

Since establishment, all plots and cultivars received the same management protocol throughout the study. Management practices for 2015 were as follows:

<u>Mowing</u> - Plots were maintained at a mowing height of 2.75 inches and mowed two times per week. Clippings were returned.
<u>Irrigation</u> – Water throughout this trial was applied only at times of severe drought. In 2017 supplemental water through rrigation was not needed.

<u>Fertilizer and pesticide applications for 2017</u>
4/18/17 - Pre-emergent 0.54 oz/1,000 ft^2 Prodiamine. 65 WDG,
4/29/17 - 1# N /1,000 ft^2, 25-0-12 (60% SCU).
5/25/17 – Acelepryn, .367 fl. Oz./1,000 ft^2
10/13/17 – 1# N /1,000 ft^2, 25-0-12 (60% SCU).

NTEP trials typically run for a period of five years. 2017 marked the fifth and final year of recording data for the 2012 Turf-Type Tall Fescue Trial. Ratings taken and recorded were:

Quality Ratings

Turfgrass quality ratings were taken on a monthly basis for overall turf quality (color / leaf texture / density) during the 2017 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. Monthly quality and mean quality ratings are provided in table 2.

Leaf Texture Ratings

Visual leaf texture ratings were taken in the late spring June 2, 2017) while the grass was actively growing and not under stress conditions. Texture ratings were made using a visual scale with 1 equaling coarse turf and 9 equaling fine (Table 2).

Genetic Color Ratings

Genetic color ratings (Table 2) were taken in the late spring (June 2, 2017) while the grass was actively growing and not under stress conditions. Ratings were based on visual color with 1 being light green and 9 being dark green. Areas of plots that contained browning tissue (chlorosis or necrotic) from outside factors such as disease were not considered for genetic color (Table 2).

RESULTS & DISCUSSION

Results for spring green up, genetic color, leaf texture, and monthly quality ratings, are provided in Table 2.

A few general observations noted were: mean quality values for overall quality continue to illustrate that there is little diversity between cultivars. Landmark Turf and Native Seed's Relection (U-45) had the highest mean quality ratings for the 2017 growing season. However, when comparing the mean values for overall quality, there were no significant differences between U-45 and the next 41 cultvars. Kentucky 31 exhibited the poorest overall turf quality. Throughout the five-year trial all plots exhibited excellent drought avoidance characteristics.

Table 1- Sponsors and Entries			
SPONSOR	**ENTRY**	**SPONSOR**	**ENTRY**
Semillas Fito S.A.	Terrano	DLF International Seed	IS-TF-272
Standard Entry	Ky-31	Pennington Seed	ATF 1736
Landmark Turf and Native Seed	Regenerate	Brett-Young Seeds	ATF 1754
Semillas Fito S.A	Fesnova	Burlingham Seeds	Hemi
Z Seeds	ZW 44	Burlingham Seeds	Firebird 2
Turf Merchants Inc.	W45	Standard Entry	Bullseye
Turf Merchants Inc.	U43	Pure-Seed Testing, Inc	PST-5EV2
Turf Merchants Inc.	LSD	Pure-Seed Testing, Inc	PST-5GRB
Turf Merchants Inc.	Aquaduct	Pure-Seed Testing, Inc	PST-5SALT
Standard Entry	Catalyst	Pure-Seed Testing, Inc	PST-5SDT
Ledeboer Seed LLC	Marauder	Pure-Seed Testing, Inc	PST-5DZP
Ledeboer Seed LLC	Warhawk	Pure-Seed Testing, Inc	PST-5RO5
Ledeboer Seed LLC	Annihilator	Pure-Seed Testing, Inc	PST-5BPO
Ledeboer Seed LLC	Comp.Res. SST	Pure-Seed Testing, Inc	PST-5BRK
Ledeboer Seed LLC	204 Res.Blk4	John Deere Landscapes	DB1
Jacklin Seed by Simplot	JS 819	John Deere Landscapes	RZ2
Jacklin Seed by Simplot	JS 818	Columbia Seeds LLC	TD1
Jacklin Seed by Simplot	JS 809	Columbia Seeds LLC	DZ1
Jacklin Seed by Simplot	JS 916	Landmark Turf and Native Seed	T31
Jacklin Seed by Simplot	JS 825	Pickseed West Inc.	PSG-GSD
The Scotts Company	MET 1	Pickseed West Inc.	PSG-8BP2
The Scotts Company	F711	Pickseed West Inc.	PSG-TT4
DLF International Seed	IS-TF 291	Standard Entry	Faith
DLF International Seed	IS-TF 276 M2	The Scotts Company	K12-13
DLF International Seed	IS-TF 305 SEL	The Scotts Company	K12-05
DLF International Seed	IS-TF 269 SEL	Peak Plant Genetics	PPG-TF-156

Table 1 (continued) - Sponsors and Entries			
SPONSOR	**ENTRY**	**SPONSOR**	**ENTRY**
DLF International Seed	IS-TF 282 M2	Columbia Seeds LLC	PPG-TF-157
DLF International Seed	IS-TF 284 M2	Columbia Seeds LLC	PPG-TF-169
Great Basin Seed	OR-21	Columbia Seeds LLC	PPG-TF-170
Great Basin Seed	TY 10	Lewis Seed Company	PPG-TF-137
Great Basin Seed	EXP TF-09	Ampac Seed Company	PPG-TF-135
Seed Research Oregon	SRX-TPC	Lewis seed Company	PPG-TF-115
Pickseed West Inc.	PSG-WEI	Lewis seed Company	PPG-TF-105
Pickseed West Inc.	Pick-W43	Peak Plant Genetics	PPG-TF-172
Pickseed West Inc.	Grade 3	Grassland Oregon	PPG-TF-151
Pickseed West Inc.	PSG-PO1	Peak Plant Genetics	PPG-TF-152
Landmark Turf and Native Seed	U45	Peak Plant Genetics	PPG-TF-148
Pennington Seed	B23	Columbia Seeds	PPG-TF-150
Pennington Seed	ATF 1612	Semillas Fito S.A.	Bizem
Peennington Seed	ATF 1704	Proseeds Marketing	CCR2
Burlingham Seed	Burl TF-2	Proseeds Marketing	Met-3
Burlingham Seed	Burl TF-136	The Scotts Company	W41
Lebanon Turf Products	LTP-FSD	Peak Plant Genetics	PPG-TF-145
Lebanon Turf Products	LTP-TWUU	.Ampac Seed Company	PPG-TF-138
Lebanon Turf Products	LTP-F5DPDR	Landmark Turf and Native Seed	PPG-TF-139
DLF International Seed	IS-TF-289	Landmark Turf and Native Seed	PPG-TF-142
DLF International Seed	MET 6 SEL	Columbia Seeds LLC	RAD-TF-89
Columbia Seeds LLC	IS-TF-330	Radix Reasearch	RAD-TF-92
Columbia Seeds LLC	TF-287	Grasslands Oregon	GO-DFR
Columbia Seeds LLC	IS-TF-307 SEL	The Scotts Company	K12-MCD
Columbia Seeds LLC	IS-TF 308 SEL	Pure-Seed Testing Inc.	PST-5EX2
Brett-Young Seeds	IS-TF-311	Pure-Seed Testing Inc.	PST-5MVD
Brett-Young Seeds	IS-TF-285	Oak Park Farms	RAD-TF-83
Brett-Young Seeds	IS-TLF 310 SEL	Grassland Oregon	RAD-TF 88
Barenbrug USA	BAR Fa 120878	Pure-Seed testing Inc.	PST-R5NW
Barenbrug USA	BAR Fa 121089	Burlingham Seeds	Burl TF 69
Barenbrug USA	BAR Fa 121091	Standard Entry	Falcon IV
Barenbrug USA	BAR Fa 121095	Standard Entry	Falcon V

Figure 1 – 2012Turf-Type Tall Fescue NTEP Trial, University of Connecticut (photo- July 2016)

Table 2. Tall Fescue NTEP results 2017 for genetic color (ratings 1-9, where 9 equals darker green), leaf texture (rating 1-9, where 9 equals the finest texture leaf blade), turfgrass quality (rating 1-9, where 9 equals the highest turf quality). Table is listed with highest mean quality cultivars listed first.

	Spring Greenup	Genetic color	Texture	Quality						
Entry	4/11/2017	06/02/17	06/02/17	05/08/15	06/01/17	07/01/17	07/31/17	09/01/17	10/18/17	mean
U45	6.0	7.0	6.3	7.3	7.0	7.7	8.0	8.0	7.3	7.6
MET 1	6.3	5.3	7.0	7.7	6.7	8.0	7.3	7.7	7.3	7.4
PSG-PO1	6.0	7.0	6.7	6.7	7.3	8.0	7.7	7.3	7.7	7.4
Pick-W43	5.3	7.7	6.0	6.7	7.7	7.7	6.0	8.0	8.3	7.4
PPG-TF-105	5.7	7.7	6.0	7.7	7.0	7.3	7.0	7.7	7.3	7.3
PPG-TF-157	6.3	8.3	6.3	6.7	7.7	8.0	6.7	7.3	7.7	7.3
IS-TF 310 SEL	5.7	7.7	6.7	6.3	7.7	8.0	6.7	7.7	7.0	7.2
LTP-F5DPDR	6.7	7.0	5.7	7.3	7.0	7.0	6.7	7.3	8.0	7.2
PPG-TF-172	4.7	7.0	5.7	7.3	7.3	7.7	6.7	7.0	7.3	7.2
Regenerate	5.7	7.0	7.0	7.0	7.0	6.7	7.7	7.7	7.3	7.2
U43	5.7	7.0	7.0	7.0	6.3	7.7	7.7	7.3	7.3	7.2
PPG-TF-135	6.0	6.0	7.3	7.0	6.7	6.7	7.7	8.0	7.0	7.2
Bullseye	5.7	7.0	5.3	7.0	7.0	7.0	6.7	7.7	7.0	7.1
PPG-TF-150	6.0	6.7	6.0	7.0	6.7	7.0	6.7	7.0	8.0	7.1
PPG-TF-151	5.0	7.0	6.3	6.7	7.3	7.3	6.7	6.7	7.7	7.1
Bizem	5.3	6.0	6.7	6.0	6.3	7.7	7.3	7.0	7.7	7.0
PPG-TF-138	5.3	7.3	5.7	7.0	6.7	7.0	6.3	7.3	7.7	7.0
PPG-TF-170	5.3	6.3	6.0	7.0	7.0	6.7	7.3	7.0	7.0	7.0
PSG-WE1	5.0	7.0	6.0	7.3	7.0	7.0	6.7	7.0	7.0	7.0
SRX-TPC	4.3	7.0	6.0	7.0	7.3	6.7	7.0	6.7	7.0	6.9
CCR2	5.7	6.7	6.7	6.7	6.3	6.7	6.7	7.7	7.3	6.9
IS-TF 311	5.3	7.3	5.7	6.7	7.0	7.0	6.7	7.0	7.0	6.9
LTP-FSD	4.3	6.0	5.7	7.0	7.0	7.0	6.7	6.7	7.0	6.9
LTP-TWUU	5.7	7.0	6.7	7.0	6.7	7.3	6.3	6.3	7.7	6.9
PPG-TF-115	5.0	8.0	6.0	7.7	7.0	6.3	6.3	6.7	7.3	6.9
PPG-TF-152	5.3	7.0	6.7	7.0	7.0	7.0	6.7	7.0	6.7	6.9
W45	5.0	6.3	6.3	7.3	7.3	6.7	6.3	7.0	6.7	6.9
F711	6.3	5.3	6.0	7.0	6.7	6.3	7.0	7.0	7.0	6.8
Faith	6.3	6.7	5.3	6.7	6.7	7.3	6.0	7.3	7.0	6.8
Hemi	4.7	6.3	6.3	7.0	6.3	7.3	6.7	6.7	7.0	6.8
IS-TF 284 M2	5.0	8.7	5.7	8.0	7.7	8.0	5.7	5.7	6.0	6.8
IS-TF 291	6.0	8.0	6.7	6.7	7.0	6.7	6.3	8.0	6.3	6.8
T31	5.0	6.7	6.0	7.3	7.0	6.7	6.7	6.3	7.0	6.8
W41	5.3	6.7	6.3	7.0	6.7	7.0	6.0	7.0	7.3	6.8
B23	5.3	7.3	5.7	6.0	6.7	7.0	7.0	6.7	7.3	6.8
Burl TF-136	5.7	5.7	6.0	7.0	6.0	7.0	6.3	7.3	7.0	6.8
Catalyst	5.3	6.0	5.7	7.0	7.0	6.3	6.3	6.7	7.3	6.8
Falcon IV	5.7	7.3	4.7	7.0	7.7	6.7	6.0	6.3	7.0	6.8
LSD	4.0	6.7	6.3	6.3	6.3	7.3	7.0	6.7	7.0	6.8

MET 6 SEL	5.3	5.3	6.0	7.0	7.0	6.3	6.3	7.0	7.0	6.8
PSG-GSD	5.0	6.3	5.0	7.3	6.7	7.3	6.0	6.3	7.0	6.8
IS-TF 330	4.3	9.0	6.7	6.7	6.7	6.7	6.3	7.0	7.0	6.7
PST-5EV2	5.7	5.7	5.3	6.0	6.7	6.7	7.0	7.0	7.0	6.7
TF-287	5.7	6.3	6.0	6.7	6.3	7.3	6.3	7.3	6.3	6.7
ZW44	5.0	6.7	6.3	7.0	6.7	7.0	6.7	6.7	6.3	6.7
ATF 1612	6.0	6.7	6.3	6.3	6.7	7.3	6.7	6.7	6.3	6.7
Burl TF-2	6.3	6.3	6.3	6.3	6.7	7.0	6.0	7.3	6.7	6.7
IS-TF 308 SEL	5.3	7.3	6.0	6.3	7.0	7.0	6.3	6.7	6.7	6.7
PPG-TF-148	5.7	6.3	6.0	6.3	6.7	7.0	6.7	6.7	6.7	6.7
TD1	5.0	7.7	6.7	7.0	7.7	7.7	4.7	7.0	6.0	6.7
Fesnova	5.3	7.0	5.7	6.3	6.7	6.7	6.0	6.7	7.3	6.6
Firebird 4	4.7	6.7	5.3	6.0	6.3	7.0	6.7	6.7	7.0	6.6
IS-TF 305 SEL	5.7	7.7	7.0	7.0	7.3	5.7	6.0	6.7	7.0	6.6
PPG-TF-156	5.7	6.7	7.0	6.3	6.0	6.7	6.7	7.0	7.0	6.6
RZ2	5.3	5.7	6.7	6.3	6.7	6.7	6.0	6.7	7.3	6.6
IS-TF 307 SEL	5.0	7.7	5.3	6.0	7.0	7.0	6.0	6.7	6.7	6.6
MET-3	5.7	5.3	6.3	6.3	6.7	6.3	5.7	7.3	7.0	6.6
PPG-TF-139	4.3	7.3	6.0	6.0	6.7	7.3	6.3	6.3	6.7	6.6
ATF 1736	6.0	5.7	5.0	7.0	6.3	6.3	6.0	6.3	7.0	6.5
IS-TF 269 SEL	5.0	8.3	5.7	6.7	7.3	6.3	5.3	6.3	7.0	6.5
IS-TF 272	3.7	8.7	6.3	6.0	6.3	6.0	6.0	7.7	7.0	6.5
IS-TF 276 M2	4.7	8.0	5.7	6.0	6.3	6.7	6.3	6.7	7.0	6.5
IS-TF 282 M2	5.0	8.3	6.7	6.7	7.0	7.0	5.7	6.7	6.0	6.5
IS-TF 289	4.3	8.7	5.7	6.7	6.3	6.7	6.3	6.3	6.7	6.5
K12-MCD	5.7	6.7	6.3	6.3	6.3	7.3	6.0	6.3	6.7	6.5
PST-5BPO	5.0	6.3	5.3	6.7	6.3	6.7	6.3	6.0	7.0	6.5
PST-5BRK	6.7	5.7	5.3	7.0	6.3	6.7	6.0	6.3	6.7	6.5
PST-5MVD	5.7	7.3	4.7	5.3	7.0	6.3	7.0	6.7	6.7	6.5
IS-TF 285	4.3	7.7	6.0	6.3	6.7	6.0	6.0	6.7	7.0	6.4
PPG-TF-137	5.3	6.3	6.0	6.0	6.3	6.3	6.0	7.0	7.0	6.4
RAD-TF-88	3.0	6.3	7.7	5.7	6.7	6.7	5.3	7.3	7.0	6.4
Burl TF-69	4.7	7.7	6.3	5.3	6.0	6.7	6.3	7.0	7.0	6.4
DB1	4.0	8.7	6.3	6.7	7.0	6.0	5.3	7.3	6.0	6.4
Terrano	4.3	7.7	5.3	6.7	6.7	7.0	5.3	6.3	6.3	6.4
Falcon V	6.3	5.7	6.0	6.0	6.0	6.0	6.7	6.3	7.0	6.3
JS818	3.7	8.7	5.0	7.0	6.7	6.7	4.7	7.0	6.0	6.3
PPG-TF-169	6.3	6.0	4.7	6.0	5.7	6.7	6.0	7.0	6.7	6.3
PSG-8BP2	4.3	7.3	5.0	6.7	6.7	6.3	6.0	6.3	6.0	6.3
PSG-TT4	5.7	6.7	5.3	7.0	6.0	7.0	5.3	6.0	6.7	6.3
ATF 1704	5.0	5.3	5.7	6.0	6.0	6.3	6.0	6.7	6.7	6.3
DZ1	5.7	7.0	6.0	6.3	6.7	6.3	5.7	6.0	6.7	6.3
Grade 3	7.0	6.3	4.7	6.0	5.7	6.0	6.3	7.0	6.7	6.3
K12-05	5.3	9.0	7.3	6.7	7.0	6.0	5.0	6.7	6.3	6.3

PPG-TF-142	4.3	9.0	6.3	6.3	6.7	5.7	5.0	6.7	7.3	6.3
PPG-TF-145	3.7	7.7	5.3	6.7	7.3	6.0	5.0	6.3	6.3	6.3
PST-5R05	4.7	6.0	5.3	6.0	6.3	6.3	6.7	6.3	6.0	6.3
RAD-TF-89	3.7	6.3	6.3	5.7	6.3	6.0	5.7	7.0	7.0	6.3
JS916	4.3	7.0	5.7	6.0	6.3	6.0	5.7	6.7	6.3	6.2
GO-DFR	4.3	8.0	5.7	6.0	7.0	6.7	5.0	6.7	5.3	6.1
PST-5SALT	4.0	6.3	5.0	6.0	5.7	6.0	6.0	6.0	7.0	6.1
JS809	4.0	8.0	5.3	6.3	7.0	6.7	4.7	6.3	5.3	6.1
PST-5EX2	5.7	5.3	4.0	5.7	5.3	6.3	6.3	6.0	6.7	6.1
TY 10	5.3	7.7	5.3	6.3	6.3	5.7	5.0	6.7	6.3	6.1
JS819	4.3	8.0	5.7	6.0	7.3	6.3	4.7	6.0	5.7	6.0
PST-5DZP	4.3	7.3	5.0	5.7	6.3	6.0	5.7	6.0	6.3	6.0
RAD-TF-83	5.3	6.3	6.0	6.3	6.3	5.7	4.7	6.3	6.0	5.9
Exp TF-09	5.3	9.0	5.7	6.3	6.0	6.7	4.7	6.3	5.0	5.8
PST-R5NW	5.0	7.3	4.3	6.0	6.3	5.7	5.3	6.0	5.7	5.8
RAD-TF-92	3.7	7.0	6.0	5.3	6.0	6.0	5.0	6.7	5.7	5.8
ATF 1754	4.7	5.0	5.3	5.0	5.7	5.7	6.0	5.7	6.3	5.7
PST-57DT	5.3	5.0	5.3	6.0	5.7	6.0	5.3	6.0	5.3	5.7
BAR Fa 121089	4.0	6.3	5.0	5.3	6.7	5.7	5.0	5.7	5.7	5.7
BAR Fa 121095	3.3	7.7	6.0	6.0	6.7	5.7	4.7	6.0	5.0	5.7
PST-5GRB	5.0	5.7	7.0	6.0	5.7	5.7	5.0	6.0	5.7	5.7
OR-21	4.7	9.0	6.0	5.7	6.0	5.3	5.0	6.3	5.3	5.6
BAR Fa 121091	4.7	8.0	4.7	6.0	6.0	6.0	4.3	5.7	5.3	5.6
Annihilator	5.3	6.0	6.0	5.3	6.0	6.0	5.0	5.3	5.3	5.5
JS825	3.3	7.7	5.3	5.3	6.7	5.7	4.7	5.7	5.0	5.5
Aquaduct	3.7	7.0	4.3	5.0	6.3	5.7	5.0	5.0	5.3	5.4
K12-13	4.0	8.3	6.3	6.0	5.7	5.7	4.0	6.0	5.0	5.4
204 Res. Blk4	5.7	5.0	7.3	5.0	6.3	4.7	4.7	5.7	5.0	5.2
Comp. Res. SST	5.0	6.3	6.7	4.7	5.0	5.0	4.7	6.0	5.0	5.1
Marauder	4.3	5.7	6.3	4.7	5.7	5.0	4.0	5.7	5.3	5.1
Warhawk	3.7	6.3	5.3	5.0	5.3	5.0	4.3	5.7	5.0	5.1
BAR Fa 120878	4.3	5.7	3.3	4.3	5.3	4.7	5.3	4.7	5.3	4.9
Ky-31	5.0	2.0	2.0	3.0	3.0	3.0	3.7	4.0	3.7	3.4
$LSD_{0.05}$	1.44	1.54	1.36	1.38	1.38	1.67	1.20	1.18	1.16	0.82
CV%	17.6	13.9	14.5	13.5	13.1	15.9	12.4	11.1	11.0	8.0

Acknowledgements: This project is funded by the National Turfgrass Evaluation Program

2017 Alliance for Low Input Sustainable Turfgrasses (ALIST) – Perennial Ryegrass

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INTRODUCTION

The Alliance for Low Input Sustainable Turf (ALIST) is a non-profit organization that seeks to develop guidelines for sustainable turfgrass growth. The variety evaluation trial program was initiated by turfgrass breeders of independent commercial seed companies to support evaluation of both experimental and commercial cultivars, both of high turf quality and low-input performance. The following companies contributed germplasm for evaluation: Mountain View Seeds, Seed Research of Oregon, Lebanon Turf, Landmark Turf and Native Seed, and DLF Pickseed. The University of Connecticut is one of eight universities that serves as an ALIST Cooperator. The 2016 Perennial Ryegrass Trial has 8 locations. Site cooperators collect data on visual turf quality and digital image analysis. Cultivars are evaluated for two years from the date of establishment.

MATERIALS AND METHODS

Twenty-four cultivars of perennial ryegrass were established on September 26, 2016 at the Plant Science Research and Education Facility in Storrs, CT. A complete randomized block design with four replicates of each cultivar was utilized for this study. Plot size was 3' X 5'. Cultivars, species, and sponsors are listed in Table 1.

All cultivars received the same management protocol during establishment and during the first year of evaluation. Plots were seeded on 9/26/2016 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 Remay turf cover until germination was evident. Plots were seeded at a rate of 7 lb. seed per 1,000 ft^2. 'Karma' perennial ryegrass was seeded around the perimeter of the trial.

Plots were managed under a low maintenance regime that consisted of a mowing height of 2.5 inches, mown once a week with clippings returned. The plots were fertilized on May 9, 2017 and received 1#N/1,000 ft^2 of a 50% slow 30-0-6, applied in 2 directions. Mesotrione was applied in two applications (5/12/2017 and 6/23/17) at a rate of 1.5 fl. oz./A. No supplemental irrigation was applied during establishment or in 2017.

All tests were visually rated each month throughout the growing season (April-October) on a scale of 1-9, where a score of 1 represented the poorest quality and 9 represented the most desirable turf quality. A subjective visual rating for turf quality included observations on overall turf performance, turf density, texture, color, as well as any impacts of weed, disease and insect pressure. The monthly quality and mean quality ratings are provided in Tables 2 and 3.

Additionally, digital image analysis (DIA) was captured 4 times during the growing season (7/21/2017, 8/15/2017, 9/18/2017, 10/16/2017) and used to quantify dark green color and percent green cover (Karcher and Richardson, 2005). The digital images were scanned by Sigma Scan software (Cranes Software International Ltd. Chicago, IL. 1991).

RESULTS & DISCUSSION

Overall data for turfgrass quality ratings and percent green color are presented in Tables 2 and 3. Turfgrass quality ratings were impacted by drought stress, disease and broadleaf weed pressure that increased as the summer season progressed. Turf quality means for 2016 perennial ryegrass ALIST test ranged from 6.0 – 4.1 with LSD of .40.

Little diversity in turf quality was evident between the cultivars of the top statistical group, which included DLFPS 3538, DLFPS 3548, DLFPS 3556, PPG-PR-339, PPG-PR-343, PPG-PR-367, PPG-PR-329, PPG-PR-385, DLFPS 3540, DLFPS 3542, DLFPS 3543, PPG-PR-419, DLFPS-3541, Karma, and Grand Slam GLD. Linn exhibited the poorest turf quality.

The top statistical group of cultivars with the highest mean of percent green cover included DLFPS-3556, LTP-FCB, Man O' War, PPG-PR-329, PPG-PR-419, Pharaoh, PPG-PR-339, DLFPS-3543, SR-4650, PPG-PR-367, Seabiscuit, DLFPS-3541. Linn exhibited the poorest mean for percent green cover.

Table 1. Perennial Rye Grass, Cultivars and Sponsors

PLOT	CULTIVAR	SPONSOR
101	Stellar 3GL	MVS
102	Linn	Standard
103	PPG-PR-343	PPG
104	PPG-PR-385	PPG
105	LTP-FCB	LTP
106	DLFPS-3538	DLF
107	DLFPS-3542	DLF
108	Tetradark	DLF
109	DLFPS-3540	DLF
110	DLFPS-3541	DLF
111	DLFPS-3556	DLF
112	DLFPS-3548	DLF
113	DLFPS-3543	DLF
114	SR-4650	SRO
115	PPG-PR-419	PPG
116	Pharoah	LTP
117	LTP-DF	LTP
118	Grand Slam GLD	MVS
119	PPG-PR-329	PPG
120	Karma	Pick
121	PPG-PR-339	PPG
122	Seabiscuit	LTP
123	PPG-PR-367	PPG
124	Man O' War	LTP

Table 2. ALIST Results 2017: Sorted by Highest Mean Quality

		Quality							Green Cover, %				
Entry no.	Entry	05/31/17	06/17/17	07/20/17	08/11/17	09/18/17	10/16/17	**Mean**	7/21/17	8/15/17	9/18/17	10/16/17	Mean
1	DLFPS-3538	6.8	6.8	6.3	5.8	5.5	5.3	**6.0**	51.7	60.7	73.2	85.9	67.9
6	DLFPS-3548	7.3	6.8	5.8	5.5	5.0	5.3	**5.9**	46.9	59.1	73.1	84.5	65.9
7	DLFPS-3556	6.3	6.0	6.3	5.5	5.5	5.5	**5.8**	58.8	69.4	80.5	90.3	74.8
16	PPG-PR-339	6.8	6.5	6.5	5.3	5.0	5.0	**5.8**	56.9	61.7	75.7	84.7	69.7
17	PPG-PR-343	6.5	6.8	6.0	5.3	5.0	5.0	**5.8**	49.3	59.6	75.3	85.0	67.3
18	PPG-PR-367	6.5	7.0	5.8	5.3	5.3	4.8	**5.8**	43.8	62.8	80.2	87.9	68.7
15	PPG-PR-329	6.3	6.3	6.5	5.0	5.0	5.3	**5.7**	55.0	64.6	74.9	85.5	70.0
19	PPG-PR-385	6.0	6.3	6.3	5.8	5.0	5.0	**5.7**	49.4	55.1	70.0	80.3	63.7
2	DLFPS-3540	6.3	6.5	5.8	5.8	4.8	5.0	**5.7**	40.2	53.7	70.5	79.7	61.0
4	DLFPS-3542	6.8	6.5	5.8	5.0	5.0	5.0	**5.7**	43.9	53.8	73.5	90.2	65.3
5	DLFPS-3543	6.3	6.3	6.0	5.3	5.0	5.3	**5.7**	53.0	63.5	77.0	85.2	69.7
9	Karma	6.3	6.3	6.0	5.3	5.0	5.3	**5.7**	45.7	59.8	75.4	84.7	66.4
8	Grand Slam GLD	6.8	6.8	5.8	5.0	4.5	5.0	**5.6**	40.3	60.4	75.3	85.2	65.3
20	PPG-PR-419	6.0	6.0	6.3	5.0	5.3	5.3	**5.6**	51.7	62.4	78.9	86.6	69.9
3	DLFPS-3541	6.3	6.0	6.0	5.3	5.0	5.0	**5.6**	49.6	63.8	75.8	84.9	68.5
11	LTP-DF	6.5	5.8	5.8	5.3	5.3	5.0	**5.6**	41.5	61.5	77.2	84.0	66.0
12	LTP-FCB	7.3	6.5	5.3	5.0	4.5	4.8	**5.5**	51.2	64.7	78.2	91.2	71.3
22	SR-4650	6.0	6.0	6.0	5.0	5.0	5.0	**5.5**	47.5	65.8	81.3	82.3	69.2
14	Pharoah	6.3	5.8	5.8	5.3	4.8	5.0	**5.5**	53.0	63.7	77.9	85.0	69.9
23	Stellar 3GL	6.3	5.5	5.8	5.0	5.0	5.0	**5.4**	50.2	59.8	75.5	83.8	67.3
13	Man O' War	6.0	5.8	5.5	5.0	5.0	5.0	**5.4**	50.4	63.1	80.8	89.3	70.9
21	Seabiscuit	6.0	6.0	5.8	5.0	4.8	4.8	**5.4**	53.3	61.4	75.6	83.9	68.5
24	Tetradark	5.3	5.3	5.0	4.3	4.5	4.3	**4.8**	43.9	53.0	73.9	79.0	62.4
10	Linn	4.0	4.0	4.0	4.0	4.5	4.3	**4.1**	32.4	51.8	72.1	72.8	57.3
	$LSD_{0.05}$	0.65	0.76	0.89	0.58	0.67	0.55	**0.40**	10.71	10.69	6.94	5.21	6.36
	CV%	7.3	8.8	10.8	8.0	9.6	7.7	**5.1**	15.7	12.5	6.5	4.4	6.7

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Table 3. ALIST Results 2017: Sorted by Highest Mean Cover

		Quality							Green Cover, %				
Entry no.	Entry	05/31/17	06/17/17	07/20/17	08/11/17	09/18/17	10/16/17	Mean	7/21/17	8/15/17	9/18/17	10/16/17	**Mean**
7	DLFPS-3556	6.3	6.0	6.3	5.5	5.5	5.5	5.8	58.8	69.4	80.5	90.3	**74.8**
12	LTP-FCB	7.3	6.5	5.3	5.0	4.5	4.8	5.5	51.2	64.7	78.2	91.2	**71.3**
13	Man O' War	6.0	5.8	5.5	5.0	5.0	5.0	5.4	50.4	63.1	80.8	89.3	**70.9**
15	PPG-PR-329	6.3	6.3	6.5	5.0	5.0	5.3	5.7	55.0	64.6	74.9	85.5	**70.0**
20	PPG-PR-419	6.0	6.0	6.3	5.0	5.3	5.3	5.6	51.7	62.4	78.9	86.6	**69.9**
14	Pharoah	6.3	5.8	5.8	5.3	4.8	5.0	5.5	53.0	63.7	77.9	85.0	**69.9**
16	PPG-PR-339	6.8	6.5	6.5	5.3	5.0	5.0	5.8	56.9	61.7	75.7	84.7	**69.7**
5	DLFPS-3543	6.3	6.3	6.0	5.3	5.0	5.3	5.7	53.0	63.5	77.0	85.2	**69.7**
22	SR-4650	6.0	6.0	6.0	5.0	5.0	5.0	5.5	47.5	65.8	81.3	82.3	**69.2**
18	PPG-PR-367	6.5	7.0	5.8	5.3	5.3	4.8	5.8	43.8	62.8	80.2	87.9	**68.7**
21	Seabiscuit	6.0	6.0	5.8	5.0	4.8	4.8	5.4	53.3	61.4	75.6	83.9	**68.5**
3	DLFPS-3541	6.3	6.0	6.0	5.3	5.0	5.0	5.6	49.6	63.8	75.8	84.9	**68.5**
1	DLFPS-3538	6.8	6.8	6.3	5.8	5.5	5.3	6.0	51.7	60.7	73.2	85.9	**67.9**
23	Stellar 3GL	6.3	5.5	5.8	5.0	5.0	5.0	5.4	50.2	59.8	75.5	83.8	**67.3**
17	PPG-PR-343	6.5	6.8	6.0	5.3	5.0	5.0	5.8	49.3	59.6	75.3	85.0	**67.3**
9	Karma	6.3	6.3	6.0	5.3	5.0	5.3	5.7	45.7	59.8	75.4	84.7	**66.4**
11	LTP-DF	6.5	5.8	5.8	5.3	5.3	5.0	5.6	41.5	61.5	77.2	84.0	**66.0**
6	DLFPS-3548	7.3	6.8	5.8	5.5	5.0	5.3	5.9	46.9	59.1	73.1	84.5	**65.9**
4	DLFPS-3542	6.8	6.5	5.8	5.0	5.0	5.0	5.7	43.9	53.8	73.5	90.2	**65.3**
8	Grand Slam GLD	6.8	6.8	5.8	5.0	4.5	5.0	5.6	40.3	60.4	75.3	85.2	**65.3**
19	PPG-PR-385	6.0	6.3	6.3	5.8	5.0	5.0	5.7	49.4	55.1	70.0	80.3	**63.7**
24	Tetradark	5.3	5.3	5.0	4.3	4.5	4.3	4.8	43.9	53.0	73.9	79.0	**62.4**
2	DLFPS-3540	6.3	6.5	5.8	5.8	4.8	5.0	5.7	40.2	53.7	70.5	79.7	**61.0**
10	Linn	4.0	4.0	4.0	4.0	4.5	4.3	4.1	32.4	51.8	72.1	72.8	**57.3**
	$LSD_{0.05}$	0.65	0.76	0.89	0.58	0.67	0.55	0.40	10.71	10.69	6.94	5.21	**6.36**
	CV%	7.3	8.8	10.8	8.0	9.6	7.7	5.1	15.7	12.5	6.5	4.4	**6.7**

Acknowledgements: This project is funded by The Alliance for Low Input Sustainable Turf (ALIST)

ELEVATED JASMONATE LEVELS INDUCE SHADE TOLERANCE IN PERENNIAL RYEGRASS.

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ABSTRACT

Perennial ryegrass (*Lolium perenne*, L.) is an important cool-season turfgrass species which is widely grown around the world. While it has many desirable traits, perennial ryegrass is sensitive to shade stress, which may limit its applications. The phytohormone jasmonate (JA) has been shown to reduce plant height, an important symptom of the shade avoidance response (SAR) in perennial ryegrass, and is known to be involved in plant light perception. In this report, we manipulated JA levels in perennial ryegrass through exogenous applications of jasmonate and the jasmonate-biosynthesis inhibitor phenidone. We found that increasing jasmonate levels in the plant was sufficient to induce shade tolerance, while reducing jasmonate levels led to an accelerated shade avoidance response. We believe that these finding might have an impact on turf breeding strategies aimed at producing shade-tolerant cultivars.

INTRODUCTION

Perennial ryegrass (*Lolium perenne*, L.) is an important cool-season turfgrass species that is used globally and is included in many commercial seed mixtures due to its fast germination and fast establishment (Pearson *et al*., 2011). However, perennial ryegrass is very susceptible to abiotic stresses, notable shade stress (Stier, 1999). Under shade stress perennial ryegrass undergoes the shade avoidance response (SAR), which includes rapid leaf elongation and chlorosis (Mc Millen & Mc Clendon, 2011).

Jasmonates (JAs) are a family of phytohormones that play a vital role in controlling plant growth and development. Previous studies have demonstrated that JA levels are increased in response to abiotic stress and JA has been shown to act downstream of phytochromes in plant light response (Yan *et al*.,2013). There is also evidence that JA levels are reduced under low-light conditions (Kazan & Manners, 2011). Additionally, Arabidopsis JA-deficient mutants showed an exaggerated SAR under low-light conditions (Robson *et al*., 2010).

In this report, we demonstrate that elevated JA levels can suppress SAR in perennial ryegrass, which could help to direct breeding efforts to produce shade-tolerant turf plants.

MATERIALS AND METHODS

Plant material and shade environment

'Fiesta 4' (DLF Pickseed USA, Tangent, OR, USA) wild-type plants and *shadow-1* mutant plants were vegetatively propagated. Plant roots and shoots were first cut to a 2.5 cm length, and six groups of two tillers each were evenly spread within each pot. Plants were maintained at a five cm height in full light for six weeks. Plants that were selected for shade-stress treatment were placed in a 95% shade environment (~200-300 µmol/m^2/s PAR on a sunny day) in the greenhouse, which was created using black polyfiber cloth. Plants that were selected for full-sunlight treatment were left out in the open in the greenhouse (~2000 µmol/m^2/s PAR on a sunny day). After growing for an additional two weeks under either full sunlight or 95% shade photos were taken.

Application of Methyl-jasmonate (MeJA) and Phenidone

Wild-type plants were vegetatively propagated in 50-plug trays as described above. Plants were maintained for six weeks after which they were cut to a height of five centimeters. The plants were then separated into five groups, each containing six plugs. The plants were foliar sprayed with a MeJA solution (Sigma-Aldrich, St. Louis, MO, USA), with different concentrations for each group (50, 100, 200 and 300 µM, and water control) every three days. Plants were allowed to grow in the greenhouse under full light for two weeks, after which pictures were taken.

For MeJA application under shade, two wild-type groups and one of shadow-1 group, of six plants each were vegetatively propagated in similar way as described above. The first group of wild-type plants was treated with a 200 µM MeJA solution (Sigma-Aldrich). The second group consisted of wild-type plants treated with water, as a negative control for shade tolerance. The shadow-1 group was treated with water, as a positive control for shade tolerance. One week after MeJA application, plants were cut to five centimeters and placed in a 95% shade environment within the greenhouse. After two weeks, with continued MeJA application where appropriate, photographs were taken.

For phenidone application, wild-type plants were vegetatively propagated in 50-plug trays as described above. After 6 weeks, plants were cut to a height of five centimeters. Plants were divided into two groups, each consisting of six plugs. One group was treated with a 2µM phenidone solution (Sigma-Aldrich) every 3 days until the end of the experiment. The other group was treated with water as a control. Plants were allowed to grow under full light in the greenhouse for one week, then were recut to five cm and moved to 95% shade environment for two weeks, after which pictures were taken.

Quantification of JA Content

Wild-type and *shadow-1* plants were vegetatively propagated in 50-plug trays as described above and kept in the greenhouse. Plants were allowed to grow for 6 weeks before the experiment was initiated. Leaf sampling and hormone quantification were done in the same manner as described by Li *et al*. (2016). Leaf samples were collected from wild type and *shadow-1* plants kept under either full light or 95% shade for two weeks. Leaf samples from 10 plants were pooled for each biological replicate. Two biological replicates were analyzed for each genotype and treatment. About 200 mg of frozen leaf samples were ground to a fine powder in liquid nitrogen using a mortar and pestle. Prior to extraction, 100 nmol of deuterium-labeled JA was added as an internal standard. JA content analysis was carried out using an ultra-high-performance LC-tandem mass spectrometer (UPLC/MS/MS) (Quattro Premier XE ACQUITY Tandem Quadrupole; Waters, Milford, MA, USA). Data were reported as a mean of two biological replicates. Analysis of variance was performed on JA content data collected from wild-type and shadow-1 plants under both full light and 95% shade using IBM SPSS 19.0 (IBM Corp., Somers, NY, USA). When sufficient differences ($P < 0.05$) were observed, Fisher's protected least significant difference test ($P = 0.05$) was performed to calculate differences between groups.

RESULTS

Exogenous jasmonate application reduces canopy height in perennial ryegrass in a dose-dependent manner

One of the major symptoms of the shade avoidance response (SAR) in turfgrasses is rapid leaf elongation under low-light conditions. In an effort to determine the role that jasmonate (JA) plays in the growth of perennial ryegrass, we treated plants with various concentrations of exogenous methyl-Jasmonate (MeJA), one of the bioactive forms of jasmonate. MeJA is a highly volatile compound, and could also have trouble penetrating the waxy surface of leaves following foliar spraying, therefore we tested various concentrations to determine which concentrations were physiologically relevant (Fig. 1). We found that a 50 µM dose had no discernable impact on canopy height, while doses of 100 µM and 200 µM decreased canopy height proportional to the concentration without negatively impacting the color of the leaves. A 300 µM dose had no additional impact on canopy height or color, compared to a 200 µM dose, and doses above 300 µM had no additional impact on canopy height but had a lethal effect on plants (data not shown). We chose a 200 µM dose going forward for our exogenous MeJA applications.

Shade stress reduces endogenous jasmonate levels in perennial ryegrass

Two of the key elements of SAR are the rapid elongation of leaves in conjunction with chlorosis. Due to our previous results, namely a reduction in leaf elongation following exogenous jasmonate application, we explored the possibility shade stress reduces endogenous jasmonate levels as a part of SAR. Hormone content analysis of both light-grown and shade-treated perennial ryegrass revealed a steep decline in jasmonate levels following exposure to severe shade stress (Fig. 2).

Manipulation of jasmonate levels can control SAR in perennial ryegrass

Following our discovery of decreased endogenous jasmonate in shade-stressed plants, we hypothesized that exogenous application of jasmonate could mitigate SAR in perennial ryegrass. Continuous applications of MeJA prior to, and during shade treatment was sufficient to suppress SAR (Fig. 3). A previously-identified shade-tolerant mutant, *shadow-1*, was used as a positive control for shade tolerance. Continued shade treatment past two weeks had no additional impact on canopy heights compared to *shadow-1* control plants (data not shown).

To further confirm the role of jasmonate in SAR, we applied a jasmonate biosynthesis inhibitor (phenidone), to plants undergoing shade treatment. We found that blocking JA biosynthesis had an accelerating effect on SAR, increasing the speed of both leaf elongation and chlorosis for shade treated plants, ultimately leading to plant death (Fig. 4). Interestingly, we found no increased severity of SAR for phenidone-treated plants, as they experienced increased canopy height and chlorosis to the same degree as untreated plants. Instead, the timeframe of these symptoms was accelerated for plants treated with the inhibitor, ultimately causing them to die earlier than non-treated plants (data not shown).

DISCUSSION

In this report, we demonstrated that exogenous application of jasmonate (JA) can reduce canopy heights of perennial ryegrass under light conditions. We also examined JA levels before and after exposure to shade stress and found that endogenous JA levels dropped significantly under low-light conditions. We were able to induce shade tolerance in wild type perennial ryegrass, mimicking the shade tolerant phenotype of the *shadow-1* mutant line, through the exogenous application of JA. Interestingly, while we expected that application of the JA-biosynthesis inhibitor phenidone would induce an exaggerated shade avoidance response (SAR), instead we discovered that it merely accelerated the onset of SAR. This finding is puzzling because previous reports demonstrated that JA-biosynthesis mutants in Arabidopsis had an exaggerated SAR (Robson *et al*., 2010). This discrepancy could be explained by the fact that phenidone acts early in the JA biosynthesis pathway and is not specific to JA biosynthesis. It is possible that phenidone-induced suppression of some other pathway reduced the severity of SAR in our experiment. Alternatively, JA-deficiency may manifest differently in monocots, like perennial ryegrass, compared to dicots, like Arabidopsis. The generation of a JA-deficient perennial ryegrass mutant would help to elucidate the cause of these conflicting results.

Taken together, these results demonstrate that elevated JA levels promote shade tolerance in perennial ryegrass. We believe that these findings could help direct turf breeders to develop new shade-tolerant cultivars, however more work needs to be done to establish the impact of JA-deficiency in turfgrass.

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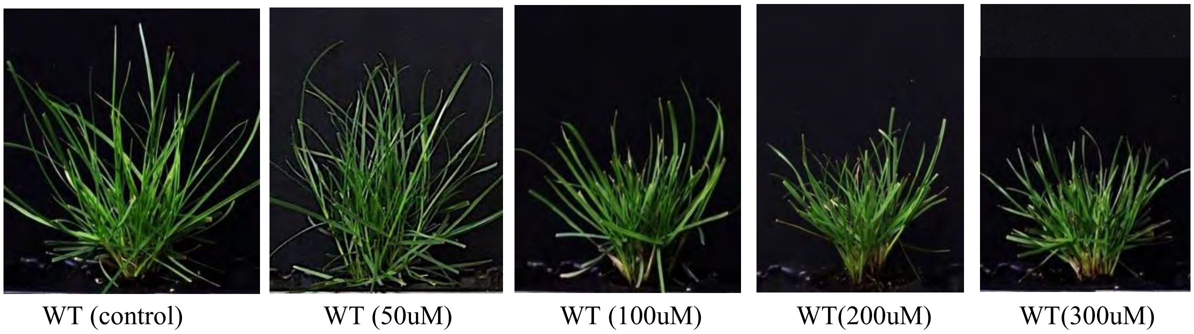


Figure 1: Application of methyl-jasmonate (MeJA)to wild-type plants reduced plant height with no visual change in plant color. Photographs of a representative plant were taken 2 weeks after the initial MeJA application. Plants were sprayed with MeJA solution every 3 days. Each treatment had six replicates. Plants were grown in greenhouse under full-light condition.

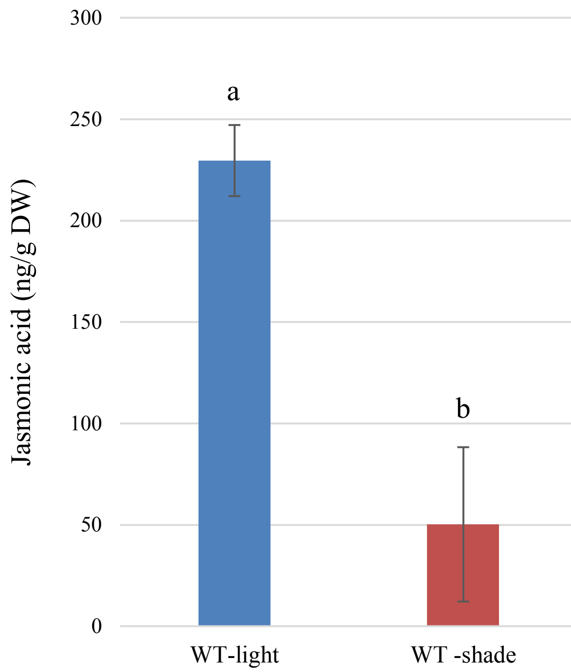
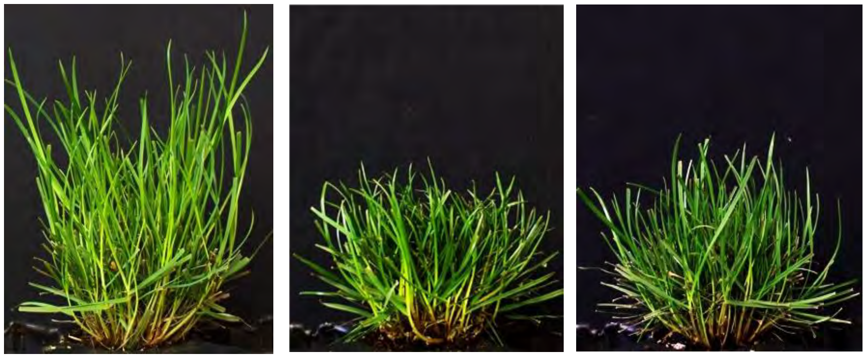


Figure 2: High JA content in wild-type plants grown under light compared to those under 95% shade conditions. Data represent the average of two biological replicates under each treatment. Each replicate consisted of the pooled leaf samples from 10 plants. Bars represent the standard error. Bars with the same letter above them are not significantly different from each other according to Fisher's least significant difference (P=0.05).



WT (control) *shadow-1* (control) WT(200uM)

Figure 3: Application of methyl-jasmonate (MeJA) to wild-type plants eliminated shade-induced etiolation. Comparison between untreated WT, untreated *shadow-I* and treated WT after 2 weeks of shade stress (95%). Plants were sprayed with either a MeJA solution or water every 3 days and were transferred to shade 6 days following the first MeJA application. Each treatment had six replicates. Photographs of a representative plant were taken for each treatment.

WT (control) WT(2mM) WT (control) WT(2mM) WT (control) WT(2mM)

Figure 4: Application of jasmonate biosynthesis inhibitor (Phenidone) accelerated shade-induced etiolation in wild-type plants. Comparison in the appearance of untreated WT to treated WT after (a) 7, (b) 14 and (c) 21 days of shade stress (95%). Plants were allowed to grow in light for 1 week after phenidone application and were then placed in shade. Photographs of a representative plant were taken for each treatment. Plants were sprayed with a phenidone solution, or water, every 3 days.

NORMALIZED DIFFERENCE VEGETATIVE INDEX RESPONSE OF NON-IRRIGATED KENTUCKY BLUEGRASS AND TALL FESCUE LAWN TURF RECEIVING SEASWEED EXTRACTS

Guillard, K. and J.C. Inguagiato. 2017. Normalized difference vegetative index response of nonirrigated Kentucky bluegrass and tall Fescue lawn turf receiving seaweed extracts. HortScience 52: 1615 – 1620 doi: 10.21273/HORTSCI12090-17

ABSTRACT

Turf managers are continually seeking improved grasses, management practices, and products that enhance heat and drought tolerance and reduce supplemental irrigation needs. To this end, products like seaweed extract (SWE) have been extensively studied on short-cut (≤12 mm) golf turf and seedlings of various turfgrass species exposed to stress conditions. Few studies, however, have reported SWE effects on mature, higher cut (≥38 mm) cool-season turfgrass swards. A 3-year field study (2013–15) was conducted in Connecticut to determine the effect of various SWE treatments on the normalized difference vegetative index (NDVI) response of nonirrigated kentucky bluegrass (*Poa pratensis* L.) and tall fescue (*Festuca arundinacea* Schreb.) turf managed as a lawn and cut at 76.2 mm. Separate experiments for each species were set out as randomized complete block designs with three replicates. Throughout the growing season in each year, various liquid SWEs were applied at a concentration of 9.55 $L·ha^{-1}$ weekly or 19.1 $L·ha^{-1}$ biweekly. A nontreated control was included. The study lacked extreme heat stress conditions during the yearly growing seasons, but periodic moisture deficits below normal were present. Within each year, there were no significant SWE effects on the NDVI of either species. The results suggest that there is no improvement in the NDVI by applying SWEs to mature, higher cut cool-season turfgrass lawns under less than extreme heat-stress conditions, water-stress conditions, or both. Because this study was conducted only at one site without extreme stress, further research of SWE applications to established, higher cut cool-season turfgrass lawns should be conducted across different locations and soils to determine the effects of applying SWE to these stands under extreme heat-stress conditions, water-stress conditions, or both.

BIOREMEDIATION AND PHYTOREMEDIATION OF TOTAL PETROLEUM HYDROCARBONS (TPH) UNDER VARIOUS CONDITIONS

McIntosh, P., C.P. Schulthess, Y.A. Kuzovkina, and K. Guillard. 2017. Bioremediation and phytoremediation of total petroleum hydrocarbons (TPH) under various conditions. Int. J. Phytoremediation 19:755-764
doi.org/10.1080/15226514.2017.1284753

ABSTRACT

Turf managers are continually seeking improved grasses, management practices, and products that enhance heat and drought tolerance and reduce supplemental irrigation needs. To this end, products like seaweed extract (SWE) have been extensively studied on short-cut (≤12 mm) golf turf and seedlings of various turfgrass species exposed to stress conditions. Few studies, however, have reported SWE effects on mature, higher cut (≥38 mm) cool-season turfgrass swards. A 3-year field study (2013–15) was conducted in Connecticut to determine the effect of various SWE treatments on the normalized difference vegetative index (NDVI) response of nonirrigated kentucky bluegrass (*Poa pratensis* L.) and tall fescue (*Festuca arundinacea* Schreb.) turf managed as a lawn and cut at 76.2 mm. Separate experiments for each species were set out as randomized complete block designs with three replicates. Throughout the growing season in each year, various liquid SWEs were applied at a concentration of 9.55 $L \cdot ha^{-1}$ weekly or 19.1 $L \cdot ha^{-1}$ biweekly. A nontreated control was included. The study lacked extreme heat stress conditions during the yearly growing seasons, but periodic moisture deficits below normal were present. Within each year, there were no significant SWE effects on the NDVI of either species. The results suggest that there is no improvement in the NDVI by applying SWEs to mature, higher cut cool-season turfgrass lawns under less than extreme heat-stress conditions, water-stress conditions, or both. Because this study was conducted only at one site without extreme stress, further research of SWE applications to established, higher cut cool-season turfgrass lawns should be conducted across different locations and soils to determine the effects of applying SWE to these stands under extreme heat-stress conditions, water-stress conditions, or both.

GLYPHOSATE EFFICACY AS INFLUENCED BY CULTIVATION PRACTICES ON A CREEPING BENTGRASS FAIRWAY TURF

Miele, K.M., J.J. Henderson, and J.C. Inguagiato. 2017. Glyphosate efficacy as influenced by cultivation practices on a creeping bentgrass fairway turf. HortScience 52: 1621-1626 doi: 10.21273/HORTSCI12221-17

ABSTRACT

Glyphosate is routinely used to eradicate existing turf in golf course fairway renovations. However, current label recommendations suggest delaying cultivation of glyphosate treated areas for 7 days. A 2-year field study was conducted to assess how various seedbed preparation techniques (i.e., verticutting, core-cultivation, or verticutting + core-cultivation) influence glyphosate efficacy on creeping bentgrass fairway turf when completed at various intervals shortly after application [0–7 days before cultivation (DBC)]. Percent green cover declined from initial values of ≈90% to ≤0.2% at the end of the study after glyphosate application at all timings, regardless of cultivation during both years. All cultivated plots had 37.9% to 72.3%, or 5.9% to 62.1% less green cover compared with noncultivated plots when glyphosate was applied ≤3 days before cultivation in 2014 and 2015, respectively. Generally, the number of days until green cover reached 1% (GC_1) ranged from 6.6 to 11.1 in 2014 and 5.2 to 6.9 in 2015. Within glyphosate application timings, no differences in GC_1 were observed between cultivated and noncultivated treatments in 2014, except at 0 DBC. The GC_1 for verticutting was 5.1 days longer than noncultivated plots; however, all other cultivation treatments were equivalent to noncultivated plots when glyphosate was applied 0 DBC. All cultivation treatments reduced GC_1 1.7 to 2.5 days compared with the no cultivation treatment, regardless of glyphosate application timing in 2015. Results from this study indicate that cultivation of creeping bentgrass fairway turf within 7 days of glyphosate application is not detrimental to long-term herbicide efficacy, and in some cases may actually enhance the rate of decline of glyphosate treated creeping bentgrass.

TRANSCRIPTOME ANALYSIS REVEALS DIFFERNTIAL GENE EXPRESSION AND A POSSIBLE ROLE OF GIBBERELLINS IN A SHADE-TOLERANT MUTANT OF PERENNIAL RYEGRASS

Li, W., L. Katin-Grazzini, X. Gu, X. Wang , R. El -Tanbouly, H. Yer, C. Thammina, J. Inguagiato, K. Guillard, R.J. McAvoy, J. Wegrzyn, T. Gu, and Y. Li. 2017. Transcriptome analysis reveals differential gene expression and a possible role of gibberellins in a shade-tolerant mutant of perennial ryegrass. Front. Plant Sci. 8:868. doi.org/10.3389/fpls.2017.00868

ABSTRACT

The molecular basis behind shade tolerance in plants is not fully understood. Previously, we have shown that a connection may exist between shade tolerance and dwarfism, however, the mechanism connecting these phenotypes is not well understood. In order to clarify this connection, we analyzed the transcriptome of a previously identified shade-tolerant mutant of perennial ryegrass (Lolium perenne L.) called shadow-1. shadow-1 mutant plants are dwarf, and are significantly tolerant to shade in a number of environments compared to wild-type controls. In this study, we treated shadow-1 and wild-type plants with 95% shade for 2 weeks and compared the transcriptomes of these shade-treated individuals with both genotypes exposed to full light. We identified 2,200 differentially expressed genes (DEGs) (1,096 up-regulated and 1,104 down-regulated) in shadow-1 mutants, compared to wild type, following exposure to shade stress. Of these DEGs, 329 were unique to shadow-1 plants kept under shade and were not found in any other comparisons that we made. We found 2,245 DEGs (1,153 up-regulated and 1,092 down-regulated) in shadow-1 plants, compared to wild-type, under light, with 485 DEGs unique to shadow-1 plants under light. We examined the expression of gibberellin (GA) biosynthesis genes and found that they were down-regulated in shadow-1 plants compared to wild type, notably gibberellin 20 oxidase (GA20ox), which was down-regulated to 3.3% (96.7% reduction) of the wild-type expression level under shade conditions. One GA response gene, lipid transfer protein 3 (LTP3), was also down-regulated to 41.5% in shadow-1 plants under shade conditions when compared to the expression level in the wild type. These data provide valuable insight into a role that GA plays in dwarfism and shade tolerance, as exemplified by shadow-1 plants, and could serve as a guide for plant breeders interested in developing new cultivars with either of these traits.