K-STATE TURFGRASS RESEARCH 2011

REPORT OF PROGRESS 1053

K·STATE Research and Extension

KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

K-STATE TURFGRASS RESEARCH 2011

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2011

Foreword

Turfgrass Research 2011 contains results of projects conducted by Kansas State University faculty and graduate students. Some of these results will be presented at the Kansas Turfgrass Field Day, August 4, 2011, at the John C. Pair Horticultural Research Center in Olathe, Kan. Articles included in this Report of Progress present summaries of research projects that were completed recently or will be completed in the next year or two. Specifically, this year's report presents summaries of research on turf and the environment, pest control, and turf evaluations.

What questions can we answer for you? The K-State turfgrass research team strives to be responsive to the needs of the industry. If you have problems that you feel need to be addressed, please let one of us know. You can access this report, reports from previous years, and all K-State Research and Extension publications relating to turfgrass online at:

www.ksuturf.com and ***www.ksu.edu/library/***

Personnel Associated with the K-State Turfgrass Program

Faculty

Bob Bauernfeind	Extension Entomologist 133A Waters Hall, KSU, Manhattan, KS 66506 Phone: (785) 532-4752; Fax: (785) 532-6258; *rbauernf@ksu.edu*
Dale Bremer	Associate Professor, Turfgrass, Division of Horticulture 2021 Throckmorton Hall, KSU, Manhattan, KS 66506 Phone: (785) 532-1420; Fax: (785) 532-6949; *bremer@ksu.edu*
Ray Cloyd	Associate Professor, Entomology Department 235 Waters Hall, KSU, Manhattan, KS 66506 Phone: (785) 532-4750; Fax: (785) 532-6258; *rcloyd@ksu.edu*
Jack Fry	Professor, Turfgrass Research and Teaching Division of Horticulture 2021 Throckmorton Hall, KSU, Manhattan, KS 66506 Phone: (785) 532-1430; Fax: (785) 532-6949; *jfry@ksu.edu*
Jason Griffin	Associate Professor, Director of the John C. Pair Horticultural Center 1901 E. 95th St. South, Haysville, KS 67060 Phone: (316) 788-0492; Fax: (316) 788-3844; *jgriffin@ksu.edu*
Rodney St. John	Assistant Professor, Extension Turfgrass Specialist K-Sate Research & Extension Center 35125 W. 135th S., Olathe, KS 66061 Phone: (913) 856-2335, Ext. 110; Fax: (913) 856-2350; *rstjohn@ksu.edu*
Steve Keeley	Associate Professor, Turfgrass Teaching and Research Division of Horticulture 2021 Throckmorton Hall, KSU, Manhattan, KS 66506 Phone: (785) 532-1420; Fax: (785) 532-6949; *skeeley@ksu.edu*
Larry Leuthold	Professor Emeritus, Horticulture
Megan Kennelly	Assistant Professor, Extension Plant Pathologist Plant Pathology Department 4063 Throckmorton Hall, KSU, Manhattan, KS 66506 Phone: (785) 532-1387; Fax: (913) 532-5692; *kennelly@ksu.edu*

Stu Warren — Professor and Head, Department of Horticulture
Forestry and Recreation Resources
2021 Throckmorton Hall, KSU, Manhattan, KS 66506
Phone: (785) 532-3365; Fax: (785) 532-6949; *slwarren@ksu.edu*

Bob Wolf — Associate Professor, Application Technology
Biological & Agricultural Engineering
145 Seaton Hall, KSU, Manhattan, KS 66506
Phone: (785) 532-2935; Fax: (785) 532-6944; *rewolf@ksu.edu*

Support Staff

Kira Arnold — Research Assistant, Division of Horticulture
2748 Throckmorton, KSU, Manhattan, KS 66506
Phone: (785) 532-1421; *arnoldk@ksu.edu*

Christy Dipman — Extension Horticulture Secretary, Division of Horticulture
2021 Throckmorton, KSU, Manhattan, KS 66506
Phone: (785) 532-6173; Fax: (785) 532-5780; *cdipman@ksu.edu*

Robin Dresma — Research Assistant, K-Sate Research & Extension Center
35125 W. 135th S., Olathe, KS 66061
Phone: (913) 856-2335

Anthony Goldsby — Research Technician, Manager of the Rocky Ford Turfgrass Research Center
2021 Throckmorton Hall, KSU, Manhattan, KS 66506
Phone: (785) 539-9133; Fax: (785) 532-6949; *alg8787@ksu.edu*

Linda Parsons — Research Assistant, John C. Pair Horticultural Center, Wichita
1901 E. 95th St. S., Haysville, KS 67060
Phone: (316) 788-0492; Fax: (316) 788-3844; *hollysocam@aol.com*

Mike Shelton — Field Maintenance Supervisor, John C. Pair Horticultural Center, Wichita
1901 E. 95th St., S., Haysville, KS 67060
Phone: (316) 788-0492; Fax: (316) 788-3844; *mshelton@ksu.edu*

Ward Upham — Extension Associate, Horticulture
2021 Throckmorton Hall, KSU, Manhattan, KS 66506
Phone: (785) 532-1438; Fax: (785) 532-5780; *wupham@ksu.edu*

Graduate Students

Cody Domenghini	Ph.D. Student, Horticulture
Anthony Goldsby	Ph.D. Student, Horticulture
Ken Obasa	Ph.D. Student, Plant Pathology
Jesse Ostrander	M.S. Student, Plant Pathology
Kenton Peterson	Ph.D. Student, Horticulture
Zane Raudenbush	M.S. Student, Horticulture
Cole Thompson	Ph.D. Student, Horticulture

2009 Corn Gluten Meal/Fertilizer Trial

Objective: Evaluate corn gluten meal as a weed control and fertilizer product compared to synthetic and organic fertilizer sources.

Investigators: Rodney St. John and Robin Dremsa

Introduction

Corn gluten meal (CGM) is a by-product of the corn wet-milling process and a component of many livestock, poultry, fish, and dog foods. Research at Iowa State University has shown that CGM can stop root formation in various weeds, including dandelions, pigweed, crabgrass, plantain, lambs quarters, and curly dock. CGM comprises about 60% corn protein, which contains 9 to 10% nitrogen (N) in the finished product. CGM has great potential to be a natural "weed-and-feed" product.

Several long-term, ongoing studies at Iowa State University are demonstrating CGM's weed-and-feed characteristics, but Kansas has a longer growing season than Iowa, and most of Kansas is 2 to 3 heat zones away from where the research is being conducted. Therefore, a CGM study was started in Olathe to determine if CGM would be a viable weed-and-feed product for Kansas.

The study was designed around the general recommendation to apply 20 lb of CGM product/1,000 ft^2. Three different rates were chosen: 10 lb CGM in the spring and 10 lb CGM in the fall, 20 lb CGM in the spring and 20 lb CGM in the fall, or 40 lb CGM in the spring (Table 1).

Because CGM contains N, we wanted to determine if any weed control we observed was from the herbicidal properties of CGM or from the improved density and competiveness of the fertilized turf. Therefore, six more treatments were added using urea or Milogranite as the N source, replicating the timing and amount of N applied in the CGM plots (Table 1).

The overall objectives were to determine if CGM would perform well as a weed-and-feed product in Kansas, and if any observed weed control was caused by the CGM or side benefit of fertilized turf.

Methods

The research plots were set up in a randomized complete block design with three replications. Each plot was 5 ft × 10 ft. Each of the three products, Corn Gluten Meal, Milorganite, and urea, were applied at three different rates and timings (Table 1). The CGM used in this study was WOW! from Gardens Alive! (Lawrenceburg, IN). The CGM had 9% N, of which 0.64% was water-soluble and 8.36% was water-insoluble. The Milorganite was the Classic formulation from Milorganite (Milwaukee, WI), which had an analysis of 6-2-0 with 0.75% water-soluble N and 5.25% water-insoluble N. The Milorganite also contained 1.2% calcium, 4.0% iron, and up to 1% chlorine. The urea 46-0-0 was Greenskeeper's Secret Professional Nitrogen from T&N Inc. (Foristell, MO). All products were weighed and applied by hand using shaker cups.

The trial was initiated in the spring of 2009. The entire trial was duplicated on two areas with different grass types. One was a Kentucky bluegrass area that was established from seed in the fall of 2006 using Bluemaster KBG Blend (containing 19.84% 'Goldrush,' 19.90% 'Abbey,' 19.77% 'Envicta,' 19.73% 'Raven,' 9.89% 'Midnight,' and 9.95% 'Sapphire'). The second area was a tall fescue area that was seeded with '2nd Millennium' in the fall of 2008. Both areas are irrigated to prevent dormancy.

Monthly quality ratings were made on a scale of 1 to 9: 1 = brown and dead turf, 6 = minimally acceptable turf, and 9 = optimum turf. Dandelions were individually counted in each of the plots and crabgrass content was determined by estimating the percentage of crabgrass concentration in each plot.

Results

Quality

The mean turfgrass quality for the Kentucky bluegrass and tall fescue from the 2010 growing season is presented in Tables 2 and 3. All rates and application timings produced better-performing turf than the untreated control. All applications of 3.6 lb N/1,000 ft^2 per year created better-performing turf plots than the ones that received only 1.8 lb N/1,000 ft^2 per year. The 3.6 lb N/1,000 ft^2 per year that was split into an equal spring and fall application provided better-performing Kentucky bluegrass and tall fescue plots.

Dandelions

The average dandelion counts found in the Kentucky bluegrass area are presented in Table 4. Like the quality results, the higher annual rates of lb of N/1,000 ft^2 had lower dandelion counts. No correlation appears to exist between dandelion control and CGM. Although we found trends in the numbers of dandelions found in the treated plots, statistical differences did not occur among the treated plots. The only differences occurred between the control and the treated plots. No dandelions grew in the tall fescue plots. The tall fescue area was recently established from seed (2008), and the plots are still very dense and do not have a very high weed presence.

Crabgrass

The single 3.6 lb N/1,000 ft^2 per year applied in the spring from urea or Milorganite controlled crabgrass better than the other treatments in the Kentucky bluegrass plots (Tables 5 and 6). CGM doesn't appear to control crabgrass in the Kentucky bluegrass plots any better than well-fertilized, thick, dense turf (Table 5). Although the single 40 lb CGM/1,000 ft^2 applied all in the spring to tall fescue plots appeared to control crabgrass better than all the other treatments, it was not statistically different than most of the treatments. The Kentucky bluegrass area is two years older than the tall fescue area; therefore, the Kentucky bluegrass area is not as dense and has much more weed pressure than the tall fescue area. Perhaps the less dense Kentucky bluegrass and higher crabgrass pressure is too much for the herbicidal effects of the CGM.

Conclusions

This research clearly indicates that properly fertilized turf is a great defense against weeds. Many recommendations for CGM discuss the need to apply CGM yearly for a number of years to build up a certain level of CGM to prevent weed seed germination. The crabgrass weed pressure in the Kentucky bluegrass plots seems to be too much for the CGM compared to the thicker, denser tall fescue area.

Table 1. Treatments, rates, and application timing

Treatment	Product	Amount of product (lb/1,000 ft^2)	lb N/1,000 ft^2 per application	Timing	Total lb N/1,000 ft^2 per year
1	CGM	10	0.9	Spring and fall	1.8
2	CGM	20	1.8	Spring and fall	3.6
3	CGM	40	3.6	Spring	3.6
4	Urea	2.0	0.9	Spring and fall	1.8
5	Urea	3.9	1.8	Spring and fall	3.6
6	Urea	7.8	3.6	Spring	3.6
7	Milorganite	15	0.9	Spring and fall	1.8
8	Milorganite	30	1.8	Spring and fall	3.6
9	Milorganite	60	3.6	Spring	3.6
10	Control		0		0

Table 2. Average Kentucky bluegrass quality[1] in the 2010 growing season

Treatment	Product	lb N/1,000 ft^2 per year	Timing	March	April	May	June	July	August	October	Average
2	CGM	3.6	Spring and fall	7.3	7.7	8.0	8.7	8.3	5.3	6.7	7.4
5	Urea	3.6	Spring and fall	7.3	8.0	8.3	8.7	8.0	5.0	6.3	7.4
9	Milorganite	3.6	Spring	6	6.0	8.3	9.0	8.7	6.0	8.0	7.4
6	Urea	3.6	Spring	6	6.0	8.3	9.0	8.3	6.7	7.7	7.4
8	Milorganite	3.6	Spring and fall	7.3	7.7	8.0	8.0	7.7	5.0	6.3	7.1
3	CGM	3.6	Spring	6	6.3	9.0	9.0	8.0	5.0	6.3	7.1
1	CGM	1.8	Spring and fall	6.7	7.0	7.0	7.0	7.0	4.7	5.7	6.4
4	Urea	1.8	Spring and fall	7	7.0	7.7	7.7	6.7	4.0	5.0	6.4
7	Milorganite	1.8	Spring and fall	6.7	6.7	7.0	6.7	6.0	3.7	5.0	6.0
10	Control	0		6	6.0	5.0	4.3	5.3	3.3	4.0	4.9

[1] Visual ratings based on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum).

Table 3. Average tall fescue quality[1] in the 2010 growing season

Treatment	Product	lb N/1,000 ft^2 per year	Timing	March	April	May	June	July	August	October	Average
5	Urea	3.6	Spring and fall	7.3	8.0	8.3	8.3	9	7.7	8	8.1
2	CGM	3.6	Spring and fall	7	7.7	8.7	8.7	8.7	7.7	8	8.1
3	CGM	3.6	Spring	6	7.0	9	9	7.7	8	9	8.0
8	Milorganite	3.6	Spring and fall	7.3	8.0	8.7	7.7	8.3	7.3	7.3	7.8
6	Urea	3.6	Spring	6	6.0	8.7	9	8.7	7.7	8.3	7.8
9	Milorganite	3.6	Spring	6	6.0	9	9	8.7	7.7	8	7.8
4	Urea	1.8	Spring and fall	7	7.0	8	7.3	8.3	7.3	8	7.6
1	CGM	1.8	Spring and fall	6.3	7.0	8	7.7	8	7	7.3	7.3
7	Milorganite	1.8	Spring and fall	6.3	7.0	7.7	7.3	7.7	6.7	7.3	7.1
10	Control	0		5.7	6.0	6.7	6.7	6.7	6	6.7	6.4

[1] Visual ratings based on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum).

Table 4. Average dandelion counts[1] in Kentucky bluegrass plots

Treatment	Product	lb N/1,000 ft² per year	Timing	June	July	October	Average
6	Urea	3.6	Spring	8	6	22	12
9	Milorganite	3.6	Spring	8	6	37	17
5	Urea	3.6	Spring and fall	13	9	30	18
8	Milorganite	3.6	Spring and fall	17	12	37	22
3	CGM	3.6	Spring	23	11	39	24
2	CGM	3.6	Spring and fall	23	21	47	30
4	Urea	1.8	Spring and fall	25	12	76	38
1	CGM	1.8	Spring and fall	40	18	56	38
7	Milorganite	1.8	Spring and fall	36	20	77	44
10	Control	0		24	63	251	113
	LSD[2]			ns	23	73	38

[1] Dandelions were individually counted.
[2] To determine statistical differences among entries, subtract one entry's mean from another's. If the result is larger than the corresponding LSD value, the two are statistically different.

Table 5. Average percentage crabgrass cover[1] in Kentucky bluegrass plots

Treatment	Product	lb N/1,000 ft² per year	Timing	July	August	Average
6	Urea	3.6	Spring	5.0	11.7	8.3
9	Milorganite	3.6	Spring	6.7	11.7	9.2
2	CGM	3.6	Spring and fall	15.0	28.3	21.7
3	CGM	3.6	Spring	31.7	28.3	30.0
5	Urea	3.6	Spring and fall	30.0	40.0	35.0
8	Milorganite	3.6	Spring and fall	28.3	45.0	36.7
4	Urea	1.8	Spring and fall	46.7	66.7	56.7
1	CGM	1.8	Spring and fall	58.3	60.0	59.2
7	Milorganite	1.8	Spring and fall	48.3	71.7	60.0
10	Control	0		65.0	73.3	69.2
	LSD[2]			42.7	38.0	38.4

[1] Determined by estimating the percentage crabgrass cover in each plot.
[2] To determine statistical differences among entries, subtract one entry's mean from another's. If the result is larger than the corresponding LSD value, the two are statistically different.

Table 6. Average percentage crabgrass cover[1] in tall fescue plots

Treatment	Product	lb N/1,000 ft^2 per year	Timing	July	August	Average
3	CGM	3.6	Spring	5.0	5.0	5.0
2	CGM	3.6	Spring and fall	20.0	7.0	13.5
5	Urea	3.6	Spring and fall	18.3	10.0	14.2
4	Urea	1.8	Spring and fall	16.7	12.0	14.3
6	Urea	3.6	Spring	13.3	20.0	16.7
1	CGM	1.8	Spring and fall	21.7	20.0	20.8
9	Milorganite	3.6	Spring	26.7	22.0	24.3
8	Milorganite	3.6	Spring and fall	40.0	29.0	34.5
7	Milorganite	0.9	Spring and fall	55.0	48.0	51.5
10	Control	0		66.7	72.0	69.3
	LSD[2]			28.6	32.7	29.8

[1] Determined by estimating the percentage crabgrass cover in each plot.
[2] To determine statistical differences among entries, subtract one entry's mean from another's. If the result is larger than the corresponding LSD value, the two are statistically different.

Efficacy and Volatility of Spring- and Fall-Applied Broadleaf Weed Herbicides

Objective: To evaluate efficacy and volatility of postemergence of broadleaf herbicides.

Investigators: Zane Raudenbush and Steve Keeley

Sponsor: Kansas Turfgrass Foundation

Introduction

Fall is considered the best time for herbicidal control of cool-season perennial broadleaf weeds in turfgrass. Herbicidal control in fall is thought to be effective because perennial weeds are moving carbohydrate reserves to underground storage structures, which aids in the movement of herbicides to their site of action; however, turfgrass managers may need herbicidal options for spring weed control to meet the needs of their clients. New products marketed as "low-volatile" esters are now available and may give improved springtime dandelion control, but little research has been published concerning the effect of timing on their efficacy or their potential to harm surrounding desirable plants through volatility. This research has two main objectives: The first is to determine the efficacy of seven herbicides (Trimec Classic, Speedzone, Escalade II, Surge, Confront, 4 Speed XT, and Cool-Power) applied at various spring and fall application timings for control of common dandelion (*Taraxacum officinale*) growing in a tall fescue (*Festuca arundinacea*) stand. The second objective is to compare the volatility of the seven herbicides when applied to tall fescue turf.

Methods

Herbicide Timing Study

Seven herbicides (Table 1) were applied at the low label rate for dandelion control on six different dates in 2010. Spring timings coincided with dandelion emergence (April 4), peak bloom (April 20), and post-bloom (May 27). Fall timings were September 11 and October 6, and a combination spring and fall timing was included (April 4 and October 6). Applications were made to 4 ft × 6 ft plots with a CO_2-powered sprayer using XR8002VS nozzles. For each application timing, percentage control was determined 30 days after treatment (DAT), at the end of the growing season (November 2010), and the following spring (April 2011) by comparing treated and untreated plots.

Volatility Study

Seven herbicides, plus 2,4-D butyl ester (highly volatile standard) and a water control were applied in a spray chamber to tall fescue turf (Table 1). All herbicides were applied at the high label rate for dandelion control. Tomatoes (*Lycopersicon lycopersicum*) were used as indicator plants to detect volatility. Two tomato plants were placed on the herbicide-treated tall fescue and enclosed in sterilite containers in the laboratory at 72°F for 24 hours (Figures 1 and 2). The tomatoes were removed from the containers and grown in the greenhouse for 18 days while data was collected. Visual ratings of tomato quality, epinasty, and callus formation were recorded daily (Figures 3–7). After 18 days, shoots were harvested, dried, and dry weight was recorded.

Results

Herbicide Timing Study

30 DAT: Speedzone, 4 Speed XT, Surge, and Escalade II provided good control when applied at dandelion emergence (April 4) and peak bloom (April 20) (Table 2). All herbicides provided good control when applied post-bloom (May 27 and September 11). For the combination spring and fall treatment, all herbicides provided 100% control. Some herbicides, such as Confront and Trimec Classic, had lesser control 30 DAT when applied on April 4, April 20, and October 6, possibly due to slower metabolism in the plant.

End of season (November 2010): At the end of the season, no treatment differences were noticeable among herbicides at the six application timings (Table 3), despite the fact that treatment differences were measurable at 30 DAT for the April-applied herbicides. By November, all herbicides provided >88% control when applied on April 4, April 20, May 27, September 11, and April and October. Apparently some herbicides, such as Trimec Classic, Confront, and Cool Power simply took longer to work. The October 6 application date showed lower control for Confront, but Confront is a slower-acting herbicide, and at the time of this rating it had been applied only one month earlier.

Following spring (April 2011): All herbicides provided greater than 92% control the following spring when applied at dandelion emergence (April 4), post-bloom (May 27), in September, and April and September, with the exception of Speedzone in September (Table 4). When applied at peak bloom (April 20), control levels were slightly lower for some herbicides but differences were not significant. When applied in early October, Speedzone gave significantly poorer control than most of the other herbicides. Notably, Speedzone gave >93% control when applied in spring, but only 73.8 to 81.3% control when applied in September or October. Some dandelion re-growth occurred with Speedzone at these timings, because the previous fall control was excellent (Table 3).

Volatility

Tomato plant quality: Confront and Surge did not cause a decline in tomato plant quality, indicating these herbicides were not volatile (Table 5). Tomato quality remained above minimal acceptable quality (6) at all rating dates for Escalade II and Trimec Classic. Speedzone, 4 Speed XT, Cool Power, and 2,4-D butyl ester caused a significant reduction in tomato plant quality at all rating dates, indicating that volatility could be a concern with these herbicides.

Tomato plant dry weight: No statistical differences were measured in tomato plant dry weight between Escalade II, Surge, Trimec Classic, and the untreated water control (Table 6). 4 Speed XT, Cool power, and 2,4-D butyl ester significantly reduced tomato plant dry weight, again suggesting these herbicides may cause volatility damage to surrounding plants

Conclusions

- The best control 30 DAT occurred after peak bloom, on the May 27 and Sept 11 application dates, or with the April and October treatment (Table 2).
- Slower-acting herbicides such as Confront and Trimec Classic gave excellent control by the end of the season when applied more than 30 days before the rating date (Table 3).
- Almost all herbicides gave excellent control by the following spring when applied at all application timings. Speedzone applied in October was a notable exception (Table 4).
- Overall, herbicide performance was as good in the spring as it was in the fall.
- Herbicides causing the most volatility damage to tomato plants were Speedzone, 4-Speed XT, Cool-Power, and 2,4-D butyl ester (Figures 3 and 4; Tables 5 and 6). All contained ester formulations of the synthetic auxins (Table 1).
- Trimec Classic, Surge, and Confront are all amine formulations and had minimal volatility (Figures 5 and 6; Tables 5 and 6).
- The volatile herbicides affected tomato growth (Table 5), but callus formation (Figure 8) may have caused a gain in dry biomass for tomatoes exposed to Speedzone, 4-Speed XT, and Cool-Power.
- Although Speedzone and 4-Speed XT gave excellent spring dandelion control, they also caused significant volatility damage to tomatoes.
- Surge gave good to excellent spring dandelion control with no volatility damage to tomatoes. This herbicide appears to be a good choice for spring dandelion control when volatility to surrounding plants is a concern.
- Good dandelion control is possible earlier in the spring, before or at peak bloom, but ester formulations should be avoided when volatility is a concern.

Table 1. Herbicide active ingredients and percentages

Trimec Classic	
2,4-D, dimethylamine salt	25.93%
MCPP, dimethylamine salt	6.93%
Dicamba, dimethylamine salt	2.76%
Speedzone	
Carfentrazone-ethyl	0.62%
2,4-D, 2-ethylhexyl ester	28.57%
MCPP acid	5.88%
Dicamba acid	1.71%
Escalade II	
2,4-D, dimethylamine salt	39.53%
Fluroxypr, 1-methylheptyl ester	5.90%
Dicamba acid	4.10%
Surge	
Sulfentrazone	0.67%
2,4-D, dimethylamine salt	18.79%
MCPP, dimethylamine salt	6.80%
Dicamba, dimethylamine salt	3.02%
Confront	
Triclopyr, triethylamine salt	33.0%
Clopyralid, triethylamine salt	12.1%
4-Speed XT	
2,4-D, isooctyl ester	41.92%
Triclopyr, butoxyethyl ester	4.81%
Dicamba acid	3.46%
Pyraflufen ethyl	0.067%
Cool-Power	
MCPA, isooctyl Ester	56.14%
Triclopyr, butoxyethyl ester	5.00%
Dicamba acid	3.60%

Table 2. Percentage dandelion control 30 days after treatment (DAT) when seven broadleaf herbicides were applied at various spring and fall application timings

	Dandelion control 30 DAT, %					
	Application date					
Herbicide	April 4	April 20	May 27	September 11	October 6	April and October
Speedzone	94.4 a[1]	94.5 a	100	97.1 b	100	100
4 Speed XT	93.1 a	96.3 a	99.1	100 a	98.7	100
Escalade II	88.5 ab	89.0 abc	100	100 a	91.8	100
Surge	88.0 ab	91.8 ab	99.3	98.5 a	91.8	100
Cool Power	82.0 b	65.5 d	100	100 a	91.3	100
Confront	82.0 b	80.6 bcd	97.7	96.6 b	69.3	100
Trimec Classic	80.5 b	75.7 cd	100	100 a	86.1	100
P-value[2]	0.0005	0.004	NS[3]	0.037	NS	NS

[1] Means followed by the same letter in a column are not statistically different ($P \leq 0.05$) by Fisher's Protected LSD.
[2] P-value associated with the F-test statistic for treatment differences.
[3] NS = no significant differences among treatments ($P \leq 0.05$).

Table 3. Percentage dandelion control at end of season (November 2010) when seven broadleaf herbicides were applied at various spring and fall application timings

	End-of-season dandelion control, %					
Herbicide	April 4	April 20	May 27	September 11	October 6	April and October
Speedzone	93.9	93.5	97	99.1	100	100
4 Speed XT	98.7	100	90.5	99.5	98.7	100
Escalade II	100	97	98.7	100	91.8	100
Surge	100	98.2	97.8	99.1	91.8	100
Cool Power	99.1	88.7	96.5	100	91.3	100
Confront	100	95.7	99.1	100	69.3	100
Trimec Classic	99.5	98.2	98.7	100	86.1	100
P-value[1]	NS[2]	NS	NS	NS	NS	NS

[1] P-value associated with the F-test statistic for treatment differences.
[2] NS = no significant differences among treatments ($P \leq 0.05$) by Fisher's Protected LSD.

Table 4. Percentage dandelion control the following spring (April 2011) when seven broadleaf herbicides were applied at various spring and fall application timings

	Following spring dandelion control, %					
Herbicide	April 4	April 20	May 27	September 11	October 6	April and October
Speedzone	95.2 c[1]	93.7	95.2	81.3	73.8 c	100
4 Speed XT	99.0 ab	100	96.7	97.1	99.1 a	100
Escalade II	99.0 ab	89.8	97	98	96.8 ab	100
Surge	99.5 ab	98.7	95.4	94	81.6 bc	99.5
Cool Power	97.6 bc	84.7	95.5	92.7	97.6 ab	100
Confront	100 a	92.9	98.1	94.7	89.8 abc	100
Trimec Classic	98.6 ab	79.8	98	97.5	90.8 ab	100
P-value[2]	0.015	NS[3]	NS	NS	0.047	NS

[1] Means followed by the same letter in a column are not statistically different ($P \leq 0.05$) by Fisher's Protected LSD.
[2] P-value associated with the F-test statistic for treatment differences.
[3] NS = no significant differences among treatments ($P \leq 0.05$) by Fisher's Protected LSD.

Table 5. Broadleaf herbicide effect on tomato plant visual quality following exposure to herbicide-treated turf in an enclosed chamber

	Visual quality (1 to 9; 9 = best)			
Herbicide	1 DAT[1]	7 DAT	13 DAT	18 DAT
Water control	8.6 a[2]	8.6 a	9.0 a	9.0 a
Confront	9.0 a	8.6 a	8.6 ab	9.0 a
Surge	8.3 a	8.3 a	9.0 a	8.6 a
Trimec Classic	8.3 a	8.6 a	7.6 c	7.6 b
Escalade II	8.0 a	7.6 a	8.0 bc	7.3 b
Speedzone	3.0 b	4.6 b	5.0 d	5.0 c
4 Speed XT	2.3 bc	4.6 b	4.3 de	4.6 cd
Cool Power	2.0 bc	4.3 b	4.0 e	4.0 d
2,4-D butyl ester	1.3 c	3.0 c	2.0 f	1.3 e

[1] Days after treatment
[2] Means followed by the same letter in a column are not statistically different ($P \leq 0.05$) by Fisher's Protected LSD.

Table 6. Broadleaf herbicide effect on tomato plant dry weight following exposure to herbicide-treated turf in an enclosed chamber

Herbicide	Dry weight (g)
Escalade II	1.91 a[1]
Surge	1.77 ab
Untreated	1.76 ab
Trimec Classic	1.69 ab
Confront	1.52 c
Speedzone	1.33 c
4 Speed XT	0.89 d
Cool Power	0.87 d
2,4-D butyl ester	0.32 e

[1] Means followed by the same letter are not statistically different ($P \leq 0.05$) by Fisher's Protected LSD.

Figure 1. Spray chamber and turf placement.

Figure 2. Tomato placement on treated turf.

Figure 3. Effect of water control and Speedzone on tomatoes 16 days after treatment.

Figure 4. Effect of water control and 2,4-D butyl ester on tomatoes 16 days after treatment.

Figure 5. Effect of water control and Surge on tomatoes 16 days after treatment.

Figure 6. Effect of water control and Trimec Classic on tomatoes 16 days after treatment.

Figure 7. Callusing of tomato exposed to 4 Speed XT 16 days after treatment.

Evaluation of Fungicides and Fungicide Programs for Dollar Spot Control

Objective: To compare fungicide programs for efficacy in dollar spot control on a creeping bentgrass putting green.

Investigators: Megan Kennelly, Cole Thompson, and Zane Raudenbush

Sponsors: Kansas Turfgrass Foundation, Bayer

Introduction

Dollar spot is caused by the fungus *Sclerotinia homoeocarpa*. It is a common disease that appears on golf course putting greens nearly every year. It can develop throughout the growing season but is most common in spring through early summer and again in late summer through early fall. In putting green-height turf, the disease appears as sunken patches of tan or brown turf up to about 2 in. in diameter. In severe cases, the infection spots coalesce to form larger blighted areas. This test was done to evaluate several season-long fungicide programs, reflecting real-world selections superintendents might make. In addition, several individual fungicides were applied repeatedly and evaluated on an individual basis.

Methods

Fungicides were evaluated on an established stand of 'A4' creeping bentgrass on a sand-based putting green at the Rocky Ford Turf Research Center in Manhattan, Kan. The turf was mowed to a height of 0.156 in. and irrigated daily for 15 min. The area was fertilized biweekly with 0.25 lb nitrogen (N)/1,000 ft^2 from March through June and 0.16 lb N/1,000 ft^2 from July through November. Fungicide applications were made at 14- to 21-day intervals beginning May 21, with the exception of the two Bayer Program treatments, which included early season applications on April 20. The final application for all treatments was on August 24 with the exception of the 21-day treatments, which had final applications on August 31. Fungicides were applied with a CO_2-powered boom sprayer equipped with two XR Tee Jet 8004VS nozzles at 30 psi in water equivalent to 2.0 gal/1,000 ft^2. Plots were 4 ft × 5 ft and arranged in a randomized complete block design with four replications. Disease was assessed periodically by visually estimating the percentage of each plot affected by dollar spot symptoms.

Results

Full results are presented in Table 1. Dollar spot reached about 10% severity in the non-treated plots in mid- to late August. Except for low levels of symptoms (≤ 1.0% severity) in early June, the products and programs reduced dollar spot significantly compared to the non-treated control and resulted in complete suppression of symptoms. On August 13, the Kansas State University program plots displayed a slight blue-gray color, which is typical of the phytotoxic effects caused by the application of demethylation inhibitor fungicides to greens-height bentgrass under stressful environmental conditions.

Table 1. Effect of fungicide programs and individual fungicides on dollar spot development

Treatment and rate/1,000 ft[2]	Spray date or interval (days)[1]	Dollar spot severity[2] June 17	July 15	August 2	August 17	September 9
Non-treated control	--	5.3 a	7.5 a	8.5 a	10.0 a	7.3 a
Bayer Program 1						
Bayleton Flo 4SC 1.0 fl oz	April 20					
Tartan 2.4SC 2.0 fl oz	May 21					
Chipco Signature 80WG 4 oz + Interface 2.27SC 4.0 fl oz	June 2					
Reserve 4.8SC 3.6 fl oz	June 15					
Chipco Signature 80WG 4 oz + Insignia 20WG 0.9 oz	June 29					
Chipco Signature 80WG 4 oz + Daconil Ultrex 82.5WDG 3.2 oz	July 13					
Chipco Signature 80WG 4 oz + Reserve 4.8SC 3.6 fl oz	July 27					
Chipco Signature 80WG 4 oz + Insignia 20WG 0.9 oz	August 10					
Tartan 2.4SC 2.0 fl oz	August 24	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Bayer Program 2						
Bayleton Flo 4SC 1.0 fl oz	April 20					
Chipco Signature 80WG 4 oz + Triton Flo 3SC 0.5 fl oz	May 21					
Chipco Signature 80WG 4 oz + Interface 2.27SC 4.0 fl oz	June 2					
Reserve 4.8SC 3.2 fl oz + Honor 28WG 0.83 oz	June 15					
Chipco Signature 80WG 4.0 oz + Daconil Ultrex 82.5WDG 3.2 oz	June 29					
Chipco Signature 80WG 4.0 oz + Honor 28WG 0.3 oz	July 13					
Chipco Signature 80WG 4.0 oz + Daconil Ultrex 82.5WDG 3.2 oz	July 27					
Chipco Signature 80WG 4.0 oz + Interface 2.27SC 4.0 fl oz	August 10					
Reserve 4.8SC 3.6 fl oz	August 24	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b

continued

Table 1. Effect of fungicide programs and individual fungicides on dollar spot development

Treatment and rate/1,000 ft²	Spray date or interval (days)[1]	Dollar spot severity[2] June 17	July 15	August 2	August 17	September 9
KSU Program 1						
Emerald 70WG 0.13 oz	May 21					
Banner MAXX 1.3ME 1.0 fl oz + Daconil Ultrex 82.5WDG 3.2 oz	June 2					
26GT 2SC 4.0 fl oz	June 15					
Bayleton 50 WDG 0.5 oz	June 29					
Emerald 70WG 0.13 oz + Daconil Ultrex 82.5WDG 3.2 oz	July 13					
Reserve 4.8SC 3.2 fl oz	July 27					
26 GT 2SC 4.0 fl oz	August 10					
Emerald 70WG 0.13 oz	August 24	1.0 b	0.0 b	0.0 b	0.0 b	0.0 b
KSU Program 2						
Bayleton 50WDG 0.5 oz	May 21					
Emerald 70WG 0.13 oz + Daconil Ultrex 82.5WDG 3.2 oz	June 2					
Spectro 90WDG 4.0 oz	June 15					
Banner MAXX 1.3ME 1.0 fl oz + Insignia 20WG 0.7 oz	June 29					
26/36 3.8SC 3.0 fl oz	July 13					
26GT 2SC 4.0 fl oz + Daconil Ultrex 82.5WDG 3.2 oz	July 27					
Emerald 70WG 0.13 oz	August 10					
Banner MAXX 1.0 fl oz	August 24	0.8 b	0.0 b	0.0 b	0.0 b	0.0 b

continued

Table 1. Effect of fungicide programs and individual fungicides on dollar spot development

		Dollar spot severity[2]				
Treatment and rate/1,000 ft^2	Spray date or interval (days)[1]	June 17	July 15	August 2	August 17	September 9
Honor 28WG 0.55 oz	14	0.3 b	0.0 b	0.0 b	0.0 b	0.0 b
Honor 28WG 0.83 oz	21	0.3 b	0.0 b	0.0 b	0.0 b	0.0 b
Insignia SC 0.54 fl oz	21	0.5 b	0.0 b	0.0 b	0.0 b	0.0 b
Insignia SC 0.7 fl oz	14	0.3 b	0.0 b	0.0 b	0.0 b	0.0 b
Emerald 70WG 0.13 oz	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Emerald 70WG 0.18 oz	21	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Honor 28WG 0.83 oz	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Honor 28WG 1.1 oz	21	0.5 b	0.0 b	0.0 b	0.0 b	0.0 b

[1] The 14-day treatments received applications on May 21; June 2, 15 and 29; July 13 and 27; and August 10 and 24. The 21-day treatments were applied on May 21, June 8 and 29, July 20, and August 10 and 31.

[2] Values represent the average percentage of plot area blighted by dollar spot symptoms. Means within columns followed by the same letter are not significantly different according to Tukey's pairwise comparisons (family error rate P = 0.05). Values were square-root-transformed for analysis and back-transformed for presentation.

Preventative Fungicide Applications for Control of Dollar Spot on Creeping Bentgrass

Objective: To compare fungicides and their application rates for efficacy in dollar spot control.

Investigators: Megan Kennelly, Zane Raudenbush, Cole Thompson

Sponsors: Kansas Turfgrass Foundation, DuPont, Bayer, Syngenta

Introduction

Dollar spot is caused by the fungus *Sclerotinia homoeocarpa*. It is a common disease that appears on golf course putting greens nearly every year. It can develop throughout the growing season, but is most common in spring through early summer and again in late summer through early fall. In putting green-height turf, the disease appears as sunken patches of tan/brown turf up to about 2 in. in diameter. In severe cases, the infection spots coalesce to form larger blighted areas. Many fungicides are labeled for dollar spot and brown patch suppression in golf courses. This test was done to evaluate several fungicides, separately and in rotations, for dollar spot and brown patch control.

Methods

Fungicides were evaluated on an established stand of a 'Cato' plus 'Crenshaw' blend of creeping bentgrass on a sand-based putting green at the Rocky Ford Turf Research Center in Manhattan, Kan. The turf was mowed to a height of 0.156 in. and irrigated daily for 15 min. The area was fertilized biweekly with 0.25 lb nitrogen (N)/1,000 ft^2 from March through June and 0.16 lb N/1,000 ft^2 from July through November. Fungicide applications were made at variable intervals beginning May 24 using a CO_2-powered boom sprayer equipped with two XR Tee Jet 8004VS nozzles at 30 psi in water equivalent to 2.0 gal/1,000 ft^2. Plots were 4 ft × 5 ft and arranged in a randomized complete block design with four replications. Plots were assessed periodically by visually estimating the percentage of each plot affected by dollar spot infection centers.

Results

See Table 1 for full results. Dollar spot was present on several rating dates and did not exceed 10% severity in the untreated controls during the course of the experiment. All fungicides reduced dollar spot symptoms to <2.5% severity, and most treatments reduced disease compared to the untreated control. No significant differences occurred among treatments. Phytotoxicity, evident as slight thinning and suboptimal color, was observed in the Concert treatments on 3 rating dates, which is typical of repeated applications of demethylation inhibitor fungicides in turfgrass. Concert contains the demethylation inhibitor (DMI) fungicide propiconazole. No phytotoxic effects were observed in Reserve treatments, which contain the DMI fungicide triticonazole.

Table 1: Effect of fungicides on dollar spot severity

		Dollar spot severity[2]				
Treatment and rate per 1,000 ft²	Application timing[1] (days)	June 9	June 17	July 7	July 15	August 2
Untreated control	Not applicable	2.0 a	9.0 a	2.8 a	4.8 a	9.0 a
Reserve 4.8SC 2.5 fl oz	0, 16, 29, 35, 43, 51, 57	0.8 a	1.0 ab	0.0 a	2.0 ab	0.0 b
Reserve 4.8SC 3.2 fl oz	0, 16, 29, 35, 51	1.8 a	0.8 ab	0.0 a	0.0 b	0.0 b
Reserve 4.8SC 3.5 fl oz	0, 16, 29, 35, 51	0.8 a	0.0 b	0.0 a	0.0 b	0.0 b
Concert 4.3SE 5.5 fl oz	0, 16, 29, 35, 51	0.5 a	0.5 b	0.0 a	0.0 b	0.0 b
Interface 2.27SC 3.0 fl oz	0, 16, 29, 35, 51	0.3 a	2.3 ab	0.0 a	0.0 b	0.0 b
Interface 2.27SC 4.0 fl oz	0, 16, 29, 35, 51	0.0 a	0.0 b	0.0 a	0.0 b	0.0 b
Interface 2.27SC 5.0 fl oz	0, 16, 29, 35, 51	0.0 a	0.0 b	0.0 a	0.0 b	0.0 b
Iprodione Pro 2SE 4.0 fl oz	0, 16, 29, 35, 51	0.3 a	0.0 b	0.0 a	0.0 b	0.0 b
Emerald 70WG 0.13 oz	0, 16, 29, 35, 51	0.0 a	0.0 b	0.0 a	0.0 b	0.0 b
Honor 28WG 0.83 oz alternate Iprodione Pro 2SE 4 fl oz	0, 16, 36, 51 29	0.3 a	0.3 b	0.3 a	0.0 b	0.0 b
Velista 50WDG 0.3 oz	0, 16, 29, 43, 57	1.8 a	2.0 b	0.3 a	0.0 b	0.0 b
Velista 50WDG 0.5 oz	0, 16, 29, 43, 57	0.5 a	0.3 b	0.3 a	0.0 b	0.0 b
Renown 5.16SC 4.5 fl oz	0, 16, 29, 43, 57	0.8 a	1.5 b	0.0 a	0.0 b	0.0 b
Heritage TL 0.8ME 2 fl oz + Daconil Weatherstik 6F 3.6 fl oz	0, 16, 29, 43, 57	0.5 a	0.5 b	0.0 a	0.0 b	0.0 b

[1] The first application date was May 24 (day 0); values reflect date of application relative to the first application.
[2] Values represent the average percentage of plot area blighted by dollar spot infection centers. Means within columns followed by the same letter are not significantly different according to Tukey's pairwise comparisons (family error rate P = 0.05). Values were square-root-transformed for analysis, but actual percentage values are displayed.

Susceptibility of Creeping Bentgrass Cultivars to Dollar Spot Under Fairway and Putting Green Management

Objective: Determine the susceptibility of several creeping bentgrass cultivars to dollar spot when the timing of fungicide application is based on thresholds in a highly resistant cultivar.

Investigators: Cole Thompson, Megan Kennelly, and Jack Fry

Introduction

Dollar spot, cased by the pathogen *Sclerotinia homoeocarpa*, is one of the most important diseases of creeping bentgrass (*Agrostis stolonifera*). Increasing fungicide resistance, as well as increasing regulations on chemical use, require alternative methods of controlling the disease. Integrated pest management (IPM) strategies allow pesticide applications only when damage from pests has reached a predetermined threshold value. Creeping bentgrass cultivars should be evaluated for dollar spot resistance within the context of an IPM strategy.

Methods

Separate fairway and putting green studies are being conducted at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. Similar studies are being conducted at other universities throughout the north central region of the United States. Fifteen creeping bentgrass cultivars were established on a native soil fairway and a putting green constructed to United States Golf Association specifications. The cultivars evaluated were ‘L-93,’ ‘T-1,’ ‘Alpha,’ ‘Kingpin,’ ‘Crenshaw,’ ‘Penncross,’ ‘A4,’ ‘Crystal Bluelinks,’ ‘007,’ ‘Mackenzie,’ ‘Memorial,’ ‘Independence,’ ‘Declaration,’ ‘LS-44,’ and ‘Bengal.’ Each cultivar was seeded in September 2008 at 49 kg/ha in 3 1.2 × 3.0 m plots.

The fairway and the putting green were mowed with a triplex reel mower at 13 and 3 mm, respectively. The fairway was mowed 3 days per week and the putting green was mowed 6 days per week. Urea (46-0-0 N-P-K) was used to provide N at 25 kg/ha per month to the fairway and at 49 kg/ha per month to the putting green during establishment from September to November in the fall of 2008 and in May and June in the spring of 2009. When fungicide applications began in 2009, urea fertilization ceased and a polymer-coated methylene urea N source (Professional Fertilizer, 18-2-20 N-P-K, Spring Valley, Jackson, WI) was applied once monthly from July to November to provide N at 25 kg/ha to the fairway and at 49 kg N/ha to the putting green. In 2010, Professional Fertilizer was applied from May to November at 25 kg N/ha biweekly to the putting green and once monthly to the fairway. The fairway was irrigated at 75% of reference evapotranspiration (ET) 3 days/week and the putting green was irrigated daily at 100% ET. Evapotranspiration was estimated using an on-site weather station and the FAO-56 Penman-Monteith equation. Core aerification was performed on the putting green study, leaving approximately 388 holes/m^2 on May 19, 2009, and on the putting green and fairway studies on October 21, 2009. Aerification holes were 1.6 cm in diameter and 3.8 cm deep. The putting green was sand-topdressed to fill aerification holes. The putting green study was vertically mown to a depth of 1 cm on May 12, 2009, and putting green and fairway studies were vertically mown to the same depth on October 27, 2010. The putting green was sand-topdressed to fill slits following vertical mowing. Additionally, the putting green was sand-topdressed to a depth of 2 mm biweekly from May to November in 2009 and 2010.

Dylox (trichlorfon) was applied at 6 kg ai/ha on six dates in 2009 (June 29, July 6 and 15, August 8, and September 2 and 25) to control black cutworms (*Agrotis ipsilon)*. In 2010, Dylox was applied once (May 25) and Acelepryn (chlorantraniliprole) was applied at 0.06 kg ai/ha on June 28 and August 25 for black cutworm control.

A tank-mix of Emerald (boscalid, BASF Corporation, Durham, NC) at 0.4 kg ai/ha and Daconil Ultrex (chlorothalonil, Syngenta Group Company, Greensboro, NC) at 8 kg ai/ha was applied preventatively to the fungicide-treated subplot within each cultivar at the first appearance of dollar spot infection centers in three replicate plots of 'Crenshaw,' a highly susceptible cultivar. Subsequent curative fungicide applications were to follow when 2 of 3 replicate subplots of fungicide-treated Declaration, a less susceptible cultivar, had >10% dollar spot coverage in the fairway study. In the putting green study, curative fungicide applications were to be made when 2 of 3 replicate subplots of fungicide-treated Declaration plots had at least 5% dollar spot coverage. For treatment thresholds, plots were assessed weekly by visually estimating the percentage of each plot blighted by dollar spot symptoms. Preventative fungicide applications were made on July 7, 2009, and May 25, 2010. Curative fungicide applications were not required in either 2009 or 2010 in either the putting green or the fairway study because thresholds were not reached.

Data Collection

Study areas were rated biweekly for turfgrass quality in 2009 and 2010. Quality data were taken considering turfgrass color, texture, density, and uniformity and followed a 1 to 9 scale (1 = poorest quality, 6 = minimum acceptable quality, and 9 = optimum color, texture, density, and uniformity, including dollar spot damage).

Dollar spot severity was rated weekly, when disease was present, by counting the number of dollar spot infection centers (DSIC) in each research plot. A 1-m square was arbitrarily placed three times in each plot and infection centers occurring within the square were counted and an average taken. Area under the disease progress curve (AUDPC) analysis was performed on dollar spot data to give a cumulative, season-long indication of disease pressure. Area under the disease progress curve was calculated as AUDPC = $\sum^{ni-1}_{i=1} ([y_i + y_{(i+1)}] / 2) (t_{(i+1)} - t_i)$, where i is the order index for the times and n_i is the number of times.

An outbreak of foliar Pythium blight (*Pythium spp.*) occurred in the fairway study in 2009. Brown patch, caused by *Rhizoctonia solani*, infected the putting green in 2009 and 2010. Both diseases were rated, when present, as the percentage of blighted turf in each plot.

Results

Differences in dollar spot and brown patch susceptibility and creeping bentgrass quality were observed at the cultivar (main plot) and fungicide (subplot) levels in 2009 and 2010 in the green and fairway studies. Cultivars varied in dollar spot susceptibility and generally experienced less dollar spot injury and higher creeping bentgrass quality in subplots that received fungicide application (data not shown). No significant cultivar × fungicide interaction occurred; as such, cultivar means represent an average of fungicide-treated and nontreated plots.

Cultivar Performance at Fairway Height

Dollar Spot Susceptibility

Dollar spot data were collected throughout the 2009 growing season, but in 2010, dollar spot data were collected only from May 24 to July 22 because of low turf quality due to heat stress and scalping. 'Declaration' had the least amount of dollar spot in both 2009 (AUPDC of 117) and 2010 (AUDPC of 149) (Table 1). With AUDPC values ranging from 262 to 400 in 2009 and from 227 to 333 in 2010, 'L-93,' 'Kingpin,' and 'Memorial' were not significantly different from 'Declaration' in either year, indicating that 'Declaration,' 'L-93,' 'Kingpin,' and 'Memorial' were the least susceptible to dollar spot infection under fairway management. 'Crenshaw,' 'Independence,' and 'Bengal' had the most dollar spot in both years (AUDPC values ranging from 545 to 1,406 in 2009 and 441 to 1,124 in 2010) and were the most susceptible to dollar spot. 'Crystal Bluelinks' and '007' were not different from 'Declaration' in 2009, but had more dollar spot than 'Declaration' and less than 'Crenshaw' in 2010 (AUDPC values of 409 and 365, respectively) and were moderately susceptible to dollar spot infection in this study. With AUDPC values ranging from 351 to 486, 'T-1,' 'Alpha,' 'Penncross,' 'A4,' 'Mackenzie,' and 'LS-44' were more resistant than 'Crenshaw' in 2009, but similar in susceptibility in 2010 (AUDPC of 431 to 703), indicating that the cultivars are quite susceptible to dollar spot infection.

Creeping Bentgrass Quality

In 2009, mean quality of all cultivars was acceptable (Table 2). 'Crenshaw' and 'Declaration' were acceptable on 92% of rating dates, and all other cultivars were acceptable on 100% of rating dates. 'Memorial' had the highest creeping bentgrass quality (8.1) and 'L-93,' 'Kingpin,' 'Penncross,' '007,' 'Mackenzie,' 'LS-44,' and 'Bengal' were not significantly different from 'Memorial.' 'Declaration' had the lowest mean quality (7.3) and was not different from 'Crenshaw' or 'Independence.'

No significant differences were measured in season-long creeping bentgrass quality in 2010. Quality ratings at fairway height were greatly affected by scalping of the research area. 'Crenshaw,' 'Memorial,' and 'LS-44' had acceptable creeping bentgrass quality on 58% of rating dates, 'A4' and 'Declaration' were acceptable on 50% of rating dates, and all other cultivars were acceptable on 42% of rating dates in 2010.

Cultivar Performance at Putting Green Height

Dollar Spot Susceptibility

'Memorial,' 'Declaration,' 'L-93,' 'Kingpin,' 'Penncross,' 'Crystal Bluelinks,' and 'LS-44' had the least amount of dollar spot in 2009 (AUDPC values ranging from 2 to 22) and 2010 (AUDPC values ranging from 9 to 240) (Table 1). 'Crenshaw' and 'Independence' experienced the most dollar spot both years (AUDPC values of 707 and 244, respectively, in 2009, and 1,209 and 634, respectively, in 2010). 'T-1,' 'Alpha,' 'A4,' '007,' 'Mackenzie,' and 'Bengal' had less dollar spot than 'Crenshaw' (2009 AUDPC values from 109 to 191 and 2010 AUDPC values from 156 to 456 in 2010).

'Kingpin,' 'Memorial,' 'Declaration,' 'L-93,' 'Penncross,' 'Crystal Bluelinks,' and 'LS-44' were the least susceptible to dollar spot infection under putting green management. 'T-1,' 'Alpha,' 'A4,' '007,' 'Mackenzie,' and 'Bengal' were moderately susceptible, and 'Crenshaw' and 'Independence' were highly susceptible to dollar spot infection.

Brown Patch Susceptibility

Cultivars differed in brown patch on three rating dates (August 28, 2009, and July 8 and 16, 2010) (Table 3). 'L-93,' 'Kingpin,' 'A-4,' 'Crystal Bluelinks,' and 'Memorial' had the most blight from brown patch infection, and '007,' 'T-1,' 'Alpha,' 'Penncross,' 'Independence,' 'Declaration,' and 'LS-44' experienced the least amount of brown patch. All other cultivars were more variable in response to the pathogen.

Creeping Bentgrass Quality

In 2009, all cultivars had acceptable mean creeping bentgrass quality, and were acceptable on 92% of rating dates (Table 2). 'Declaration' had the highest creeping bengrass quality (8.0), and only 'L-93,' 'Crenshaw,' '007,' and 'Mackenzie' (7.4 to 7.5) were significantly different. In 2010, mean quality of all cultivars was higher than minimally acceptable. 'T-1' and 'Penncross' were acceptable on 92% of rating dates. 'Independence' and 'Crenshaw' were acceptable on 75% and 58% of rating dates, respectively. All other cultivars were acceptable on 100% of rating dates in 2010. 'Declaration' had better quality (8.5) than any other cultivar. 'Memorial,' 'Kingpin,' 'Crystal Bluelinks,' and 'LS-44' were slightly lower in quality. 'Crenshaw' had significantly lower quality than any other cultivar.

Creeping bentgrass quality was consistently higher in blocks that received a fungicide application each year (data not shown). The cultivars 'Declaration,' 'Memorial,' 'Crystal Bluelinks,' 'Kingpin,' and 'LS-44' consistently maintained higher mean quality than others, particularly when disease pressure was highest. 'Crenshaw,' 'T-1,' 'Alpha,' 'Penncross,' 'A4,' 'Independence,' and 'Bengal' were among the lowest in quality. With the exception of 'Penncross,' the lower quality of these cultivars can be attributed to excessive dollar spot injury.

Conclusions

Several cultivars performed well in this study. 'Declaration,' 'Memorial,' 'L-93,' and 'Kingpin' were the least susceptible to dollar spot infection under both fairway and putting green management. The four cultivars also maintained high quality at putting green height, and with the exception of 'Declaration,' at fairway height. Cultivars resistant to dollar spot exhibited high quality when disease pressure was elevated even without fungicide application. These results indicate that establishing a resistant cultivar such as 'Declaration,' 'Memorial,' or 'Kingpin' would aid in the implementation of an IPM strategy for dollar spot management. Regular, preventive fungicide applications would not be required to maintain acceptable quality, and golf courses could save money and possibly delay or prevent the onset of fungicide resistance.

Table 1. Area under the disease progress curve (AUDPC) for dollar spot in cultivars maintained at fairway and putting green height in 2009 and 2010

	AUDPC[1]			
	Fairway		Putting green	
Cultivar	2009	2010	2009	2010
007	160 de[2,3]	365 bcd	116 bcde	194 cde
A4	480 bcd	683 abc	109 bcde	169 cde
Alpha	450 bcd	703 ab	114 bcd	156 cde
Bengal	545 abc	887 a	244 bcde	240 cde
Crenshaw	1406 a	1124 a	707 a	1209 a
Crystal Bluelinks	296 bcde	409 bcd	17 def	50 e
Declaration	117 e	149 e	9 ef	11 e
Independence	565 ab	441 abcd	244 ab	634 ab
Kingpin	234 cde	238 de	3 f	33 e
L-93	400 bcde	333 cde	22 def	53 e
LS-44	486 bcd	459 abcd	77 cdef	144 de
Mackenzie	351 bcde	431 abcd	117 bcde	379 bcd
Memorial	262 bcde	227 de	2 f	9 e
Penncross	388 bcde	510 abcd	16 def	80 de
T-1	456 bcd	602 abc	191 bc	456 bc

[1] Area under the disease progress curve (AUDPC) summarizes all rating dates in 2009 and 2010 (AUDPC = $\sum^{ni-1}_{i=1}$ ([y_i + $y_{(i+1)}$] / 2) ($t_{(i+1)}$ - t_i), where i is the order index for the times, and n_i is the number of times). Within a column, means with the same letter are not significantly different ($P \leq 0.05$) by Fisher's Protected LSD.

[2] Cultivar means were determined from six observations: three fungicide-treated subplots and three nontreated subplots.

[3] Data were subject to the $\log_{10}(y+1)$ transformation to normalize prior to analysis, and means were back-transformed for presentation.

Table 2. Quality of creeping bentgrass maintained at fairway and putting green height in 2009 and 2010

	Fairway[1]				Putting green			
	Mean[2]		% dates acceptable[3]		Mean		% dates acceptable	
Cultivar	2009	2010	2009	2010	2009	2010	2009	2010
007	7.8 abc[4]	5.3	100	42	7.4 c	7.6 cd	92	100
A4	7.6 cde	5.4	100	50	7.8 ab	7.4 def	92	100
Alpha	7.6 cde	5.5	100	42	7.7 abc	7.3 ef	92	100
Bengal	7.9 abc	5.6	100	42	7.6 abc	7.3 ef	92	100
Crenshaw	7.5 def	5.0	92	58	7.5 bc	6.3 g	92	58
Crystal Bluelinks	7.7 bc	5.4	100	42	7.7 abc	7.8 bc	92	100
Declaration	7.3 f	5.2	92	50	8.0 a	8.5 a	92	100
Independence	7.4 ef	5.4	100	42	7.6 abc	7.1 f	92	75
Kingpin	7.9 abc	5.3	100	42	7.9 a	7.8 bc	92	100
L-93	7.9 abc	5.4	100	42	7.5 bc	7.4 de	92	100
LS-44	7.9 abc	5.0	100	58	7.9 a	7.9 bc	92	100
Mackenzie	7.8 abc	5.5	100	42	7.5 bc	7.4 de	92	100
Memorial	8.1 a	5.8	100	58	7.7 abc	7.9 b	92	100
Penncross	8.0 ab	5.7	100	42	7.7 abc	7.2 ef	92	92
T-1	7.7 bcd	5.7	100	42	7.9 a	7.2 ef	92	92

[1] Turf was rated on a 1 to 9 scale (1 = lowest possible quality, 6 = minimum acceptable quality, and 9 = optimum color, texture, density, and uniformity). Within a column, means with the same letter are not significantly different ($P \leq 0.05$) by Fisher's Protected LSD.
[2] The season-long mean summarizes all rating dates in 2009 and 2010.
[3] Percentage of rating dates at or above minimum acceptable quality in 2009 and 2010.
[4] Cultivar means were determined from six observations: three fungicide-treated subplots and three nontreated subplots.

Table 3. Brown patch in creeping bentgrass at putting green height in 2009 and 2010

	Brown patch (%)[1]		
	2009	2010	
Cultivar	August 28	July 8	July 16
007	1.2 e[2,3]	0.4 e	0.8 d
A4	16.4 a	14.3 a	11.5 a
Alpha	4.8 bcde	0.5 de	1.5 cd
Bengal	5.2 bcd	4.3 abcd	1.0 d
Crenshaw	10.8 ab	3.6 abcde	1.1 cd
Crystal Bluelinks	12.6 ab	4.6 abc	6.1 abc
Declaration	7.5 abc	0.4 e	0.5 d
Independence	1.6 de	2.7 bcde	2.7 abcd
Kingpin	9.1 abc	4.8 abc	2.7 abcd
L-93	8.8 abc	10.0 ab	8.7 ab
LS-44	7.3 abc	1.7 cde	0.4 cd
Mackenzie	5.7 abcd	3.4 abcde	2.0 bcd
Memorial	9.4 abc	9.6 ab	10.6 a
Penncross	3.3 cde	1.0 cde	0.5 d
T-1	2.9 cde	2.3 bcde	3.0 abcd

[1] Rated visually as the percentage of plot area with brown patch. Within a column, means with the same letter are not significantly different ($P \leq 0.05$) by Fisher's Protected LSD.
[2] Cultivar means were determined from six observations: three fungicide-treated subplots and three nontreated subplots.
[3] Data were subject to the $\log_{10}(y + 1)$ transformation to normalize prior to analysis, and means were back-transformed for presentation.

Alternative Chemical Controls for Silvery-Thread Moss in Creeping Bentgrass Putting Greens

Objective: Evaluate traditional and alternative moss control products by using different rates and application methods.

Investigators: Cole Thompson, Megan Kennelly, and Jack Fry

Sponsor: Kansas Turfgrass Foundation

Introduction

Mosses are nonvascular plants that commonly occur on creeping bentgrass (*Agrostis stolonifera*) putting greens. Although many species of moss occur, silvery-thread moss (*Bryum argenteum*) is most commonly found on putting greens. The current state of moss as an invasive weed is a result of ultra-low mowing heights, deficient nitrogen fertility, and the absence of mercury-based fungicides in today's pesticide programs. Carfentrazone-ethyl (Quicksilver) is an herbicide commonly used by golf course superintendents to control moss. Alternative products such as sodium bicarbonate (baking soda) also may be used to control moss and are worth investigating.

Methods

This study was conducted in 2009 and 2010 at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. In 2009, research plots were established on a 'Pennlinks' creeping bentgrass putting green constructed to United States Golf Association specifications. The putting green had a soil pH of 8.1. In 2010, the study was repeated on a push-up 'Penncross' creeping bentgrass putting green that had a pH of 8.0. The putting green had been topdressed for years and a 30.5-cm sand cap was present on the surface. Both study sites had a natural infestation of silvery-thread moss.

Treatments consisted of an untreated control and 11 spot or broadcast applications: sodium bicarbonate (SB, baking soda, Arm and Hammer, Church and Dwight Co., Inc., Princeton, NJ) applied as a spot spray at 22.5 and 45 g ai/L or as a broadcast at 55 and 110 kg ai/ha; potassium bicarbonate (PB, Armicarb, Helena Chemical Company, Collierville, TN), a labeled fungicide for turf, applied as spot-spray at 22.5 or 45 g ai/L or as broadcast treatment at labeled rate and specifications for disease control (4.8 kg ai/ha) or at labeled rate with increased water carrier (11.4 kg ai/ha), a rate similar to the highest SB rate tested (93.5 kg ai/ha); ready-to-use essential oil (Moss Buster, 1% essential oil of oregano, Moss Buster LLC, Mason City, IA) applied as a spot spray following label instructions; and CE (Quicksilver, FMC Corporation, Philadelphia, PA) broadcast at 0.09 kg ai/ha.

Spot spray treatments were applied to individual colonies with a handheld trigger-spray bottle until moss colonies were visibly wet. Broadcast sprays were applied using a handheld CO_2-powered sprayer equipped with a single TeeJet 8008EVS Even Flat Spray

Nozzle at 207 kPa. Sodium bicarbonate (55 and 110 kg ai/ha) and PB (11.4 and 93.5 kg ai/ha) were applied in a water carrier rate equal to 2,447 L/ha, and PB (4.8 kg ai/ha) and CE (0.09 kg ai/ha) were applied following label specifications at water carrier rates equal to 1,019 L/ha and 816 L/ha, respectively. In 2009, treatments were applied on May 21, June 4, and September 11 and 24. In the second experiment in 2010, treatments were applied on May 14 and 26 and September 8 and 23.

The putting green was mowed at 3.2 mm 6 days each week with a triplex reel mower and was irrigated at 100% ET replacement. Evapotranspiration was estimated using an onsite weather station and the FAO-56 Penman-Monteith equation. The putting green was fertilized with 245 kg N/ha from May through September each year. Urea (46-0-0 N-P-K) was applied at 49 kg N/ha per month in 2009. In 2010, a polymer-coated methylene urea N source (Professional Fertilizer, 18-2-20 N-P-K, Spring Valley, Jackson, WI) was applied biweekly at 24 kg N/ha. Dylox (trichlorfon) was applied at 6 kg ai/ha on six dates in 2009 (June 29, July 6 and 15, August 8, and September 2 and 25) to control black cutworms (*Agrotis ipsilon*). In 2010, Dylox was applied once (May 25) and Acelepryn (chlorantraniliprole) was applied at 0.06 kg ai/ha on two dates (June 28 and August 25) for black cutworm control.

Data Collection

Plots were rated every 2 weeks in 2009 and 2010 for moss severity and creeping bentgrass color. Creeping bentgrass color data also were collected 1 and 7 days after treatment. Moss severity was rated visually by estimating the percentage of each plot infested by silvery-thread moss. Moss severity differed among plots at the beginning of the study in each year. For this reason, moss severity was considered to be 100% at the time of the initial rating and percentage moss coverage for later rating dates was scaled accordingly (moss severity in each plot = [% moss on rating date/% moss on first rating date] × 100). Area under the curve (AUC) analysis was conducted on moss severity data to give a cumulative, season-long indication of moss severity. Area under the curve was calculated as $AUC = \sum^{ni-1}_{i=1} ([y_i + y_{(i+1)}] / 2)(t_{(i+1)} - t_i)$, where i is the order index for sampling dates, n_i is the number of sampling dates, y is moss severity, and t is time. Creeping bentgrass color was rated using a 1 to 9 scale where 1 = totally brown, 6 = minimum acceptable color, and 9 = optimum green color.

Effect of Treatments on Silvery-Thread Moss Severity

No treatment completely eliminated silvery-thread moss. According to AUC analysis in 2009, spot application with SB (45 g ai/L), PB (45 g ai/L), or essential oil, as well as broadcast applications of CE, reduced moss severity 39% to 55% compared to untreated plots, and were not different from each other (Figure 1). Applying CE to moss temporarily turned it black, whereas moss treated with SB, PB, or essential oil changed from green to reddish brown (Figures 2 through 4).

With the exception of PB (45 g ai/L), essential oil-treated plots had significantly lower moss severity than all other treatments on the final rating date in 2009 (October 20), and had moss severity reduced to 8.4 from the starting point of 100 (Figure 1). Sodium bicarbonate (45 g ai/L) had significantly higher moss severity on this date than essential oil, with a moss severity rating of 25.3. All other treatments were not significantly different from untreated plots, which had a moss severity rating of 82.7 compared to the starting point of 100.

Spot treatments of SB or PB (22.5 g ai/L) were not effective in suppressing moss, and broadcast applications of SB or PB were not effective at any rate tested. In 2010, no treatment reduced silvery-thread moss compared to untreated plots according to AUC analysis (data not shown). Absolute moss levels in untreated plots at the beginning of the study in 2010 ranged from 10 to 40%, and colonies receded through the summer. The reason for general moss decline in the 2010 study is not known.

Influence of Effective Moss Treatments on Creeping Bentgrass Color

Of the treatments that were effective in suppressing moss in 2009, CE was the only one that caused no visible phytotoxicity in either 2009 on 'Pennlinks' or 2010 on 'Penncross' creeping bentgrass (Table 1, Figure 2). Spot treatments of essential oil, SB, and PB were phytotoxic to creeping bentgrass and affected the turf bordering silvery-thread moss colonies (Figures 3 and 4). Spot treatments of essential oil were most phytotoxic to creeping bentgrass, resulting in color ratings below 4 within 1 day after application and requiring up to 18 days to return to an acceptable level (data not shown). Season-long average creeping bentgrass color in essential oil-treated plots was 6.7 in 2009 and 6.0 in 2010 (Table 1). In 2009, creeping bentgrass color in essential oil-treated plots was acceptable on 71% of rating dates, and in 2010 on 41.2% of rating dates.

Creeping bentgrass color after treating moss with spot applications of SB (45 g ai/L) was variable. In 2009, the season-long average creeping bentgrass color in SB-treated plots was 6.8, and acceptable on 76% of rating dates (Table 1). Recovery time following creeping bentgrass injury with SB ranged from 1 to 7 days. In 2010, no adverse effects of applying SB were observed. Creeping bentgrass injury following treatment with SB has been variable in previous studies as well.

Creeping bentgrass phytotoxicity was observed after treating moss with PB (45 g ai/L) in 2009 and 2010 (Table 1). Average creeping bentgrass color in plots spot-treated with PB at this rate was 7.1 in 2009 and 7.3 in 2010. Creeping bentgrass color was acceptable on 82.4% of rating dates in both years. Recovery time following creeping bentgrass injury associated with PB ranged from 1 to 8 days.

Spot treatment with SB or PB at reduced concentration (22 g ai/L) was not phytotoxic to creeping bentgrass, and neither were broadcast treatments with SB (55 kg ai/HA) or PB at lower rates (4.8 or 11.4 kg ai/ha) (Table 1); however, variable phytotoxicity to creeping bentgrass was observed after broadcast treatment with SB (110 kg ai/ha) or PB at high rates (93.5 kg ai/ha).

Conclusions

Two spring and two fall applications (four total) with spot treatments of SB (45 g ai/L), PB (45 g ai/L), or essential oil, as well as broadcast applications of CE, can reduce moss severity. Spot treatments of bicarbonate and essential oil products are potential alternatives for moss control and can suppress moss colonies at a level similar to CE; however, at least some phytotoxicity can be expected when using SB or PB. Severe phytotoxicity is possible when using the essential oil product examined in this study, because even spot-sprays led to damage to turfgrass bordering moss colonies. Carfentrazone-ethyl was not phytotoxic to 'Pennlinks' or 'Penncross' creeping bentgrass when applied at 0.09 kg ai/ha.

Table 1. Effect of treatments on creeping bentgrass color in 2009 and 2010

	Color[1]			
	Mean[2]		Dates acceptable (%)[3]	
Treatment[4]	2009[5]	2010[6]	2009	2010
Untreated control	8.3 a	8.6 a	100	100
Sodium bicarbonate (45 g ai/L)[7]	6.8 cd	8.1 bc	76	100
Sodium bicarbonate (22.5 g ai/L)[7]	7.8 b	8.5 ab	100	100
Potassium bicarbonate (45 g ai/L)[7]	7.1 c	7.3 d	82	82
Potassium bicarbonate (22.5 g ai/L)[7]	7.8 b	8.3 abc	100	94
Essential oil (Ready-to-use)[7]	6.7 d	6.0 e	71	41
Sodium bicarbonate (110 kg ai/ha)[8]	7.0 cd	8.5 ab	82	100
Sodium bicarbonate (55 kg ai/ha)[8]	7.8 b	8.6 a	94	100
Potassium bicarbonate (4.8 kg ai/ha)[8]	8.1 ab	8.6 a	100	100
Potassium bicarbonate (11.4 kg ai/ha)[8]	8.1 ab	8.7 a	100	100
Potassium bicarbonate (93.5 kg ai/ha)[8]	7.0 cd	8.0 c	76	94
Carfentrazone-ethyl (0.09 kg ai/ha)[8]	8.1 ab	8.4 abc	100	100

[1] Creeping bentgrass color was rated on a 1 to 9 scale (1 = totally brown, 6 = minimum acceptable color, and 9 = optimum green color). Means with the same letter are not significantly different ($P \leq 0.05$) according to Fisher's Protected LSD.

[2] Season-long means for 2009 and 2010 summarize 17 rating dates from May 22 to October 20, 2009, and 17 rating dates from May 15 to October 13, 2010.

[3] Color was rated on 17 dates in 2009 and on 17 dates in 2010; the percentage of dates acceptable represents the rating dates on which color was ≥6.

[4] Treatments included sodium bicarbonate (baking soda, Arm and Hammer, Church and Dwight Co., Inc., Princeton, NJ); potassium bicarbonate (Armicarb, Helena Chemical Company, Collierville, TN); essential oil (Moss Buster, 1% essential oil of oregano, Moss Buster LLC, Mason City, IA); and carfentrazone-ethyl (Quicksilver, FMC Corporation, Philadelphia, PA).

[5] Application dates were May 21, June 4, and September 11 and 24, 2009.

[6] Application dates were May 14 and 26, and September 8 and 23, 2010.

[7] Spot-spray treatments: SB and PB were added to 1 L of water (essential oil was premixed) and applied with a handheld trigger-spray bottle until moss colonies were visibly wet.

[8] Broadcast treatments were applied using a handheld CO_2-powered sprayer equipped with a single TeeJet 8008EVS Even Flat Spray Nozzle at 207 kPa. Sodium bicarbonate (55 and 110 kg ai/ha) and potassium bicarbonate (11.4 and 93.5 kg ai/ha) were applied in a water carrier rate equal to 2,447 L/ha, and potassium bicarbonate (4.8 kg ai/ha) and carfentrazone-ethyl (0.09 kg ai/ha) were applied following label specifications at a water carrier rate equal to 1,019 L/ha and 816 L/ha, respectively.

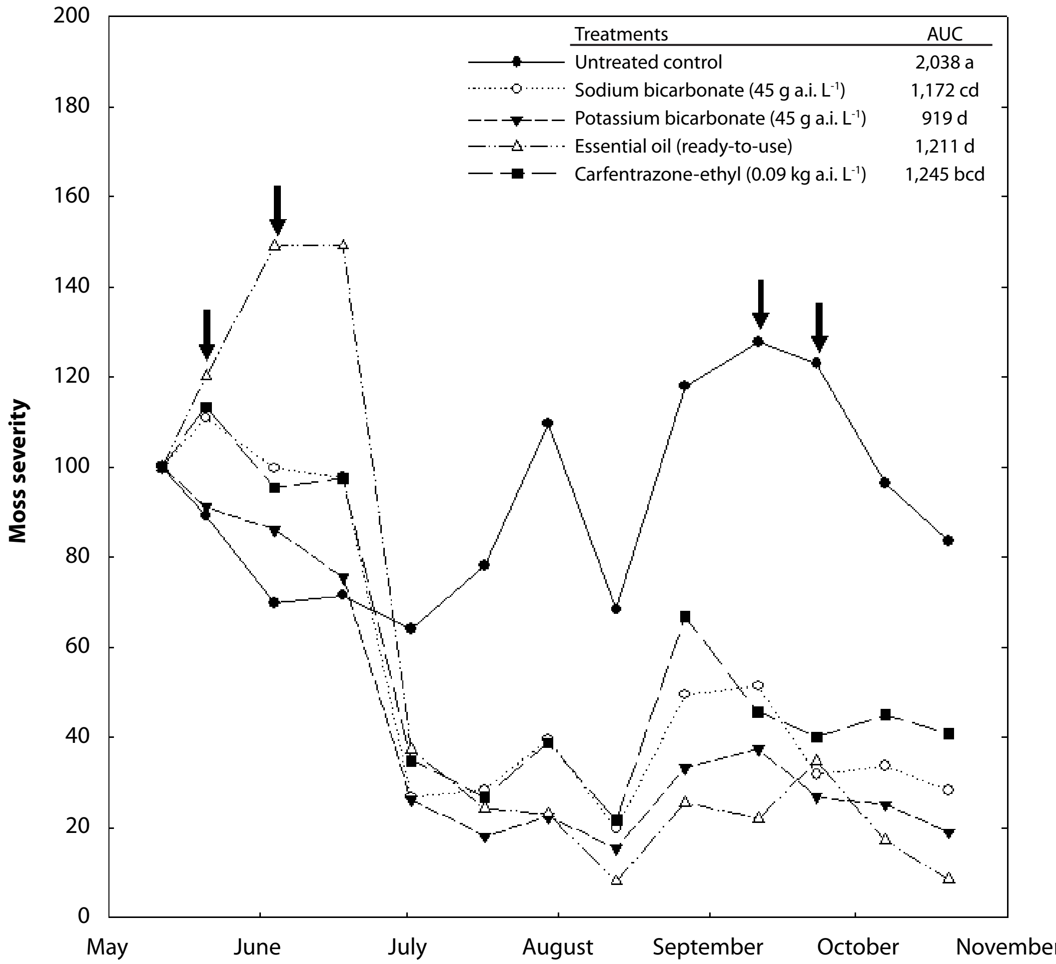


Figure 1. Effect of treatments on moss severity in 2009.

Treatments that reduced moss severity compared with untreated areas are displayed, and arrows signify application dates. Moss severity is a visual estimate of the percentage of research plots infested with moss. Moss levels were significantly different on the first rating date. For this reason, estimates for each plot were set to equal 100% on the first rating date, May 12. Subsequent estimates were then scaled accordingly: (Moss severity in each plot = [% moss on rating date / % moss on May 12] × 100). Area under the curve was calculated as $AUC = \sum^{ni-1}_{i=1} ([y_i + y_{(i+1)}] / 2)(t_{(i+1)} - t_i)$, where i is the order index for sampling dates, n_i is the number of sampling dates, y is moss severity, and t is time). Means followed by the same letter are not significantly different ($P < 0.05$) according to Fisher's Protected LSD.

Figure 2. Silvery-thread moss on May 22, 2009, one day after treatment with carfentrazone-ethyl (0.09 kg ai/ha) on May 21.

Figure 3. Creeping bentgrass phytotoxicity on perimeters of moss colonies on June 5, 2009, one day after spot treatment with potassium bicarbonate (45 g ai/L). Sodium bicarbonate applications had similar effects on moss colonies.

Figure 4. Creeping bentgrass phytotoxicity on perimeters of moss colonies on May 22, 2009, one day after spot treatment with essential oil.

Response of Silvery-Thread Moss to Nitrogen Source in Creeping Bentgrass Putting Greens

Objective: Evaluate response of moss colonies to different nitrogen sources.

Investigators: Cole Thompson, Megan Kennelly, and Jack Fry

Sponsors: Kansas Turfgrass Foundation

Introduction

Mosses are nonvascular plants that are considered weeds when found in creeping bentgrass (*Agrostis stolonifera*) putting greens. Silvery-thread moss (*Bryum argenteum*) is the most common moss species found on putting greens. Increased moss invasion is typically associated with low nitrogen (N) concentrations, but the effects of differing N sources on moss are relatively unknown. Earlier research at Kansas State University indicated that soluble N from urea may contribute to moss spread, but this needs further evaluation. The objective of this study was to compare moss spread in creeping bentgrass fertilized with different N sources.

Methods

This study was conducted in 2009 and 2010 at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. The study was conducted on a push-up 'Penncross' creeping bentgrass putting green that had been topdressed for years and a 30.5 cm sand cap was present on the surface.

Fertility Treatments

Treatments were applied biweekly from May 14 to October 30, 2009, and from May 21 to October 21, 2010. Four different N sources were used to deliver N at 16.3 kg/ha every other week until 210 kg/ha had been applied each year, and a nonfertilized control was included for comparison. Liquid urea (46-0-0) was applied to plots by dissolving granular urea in water and using a handheld CO_2-powered sprayer equipped with a single TeeJet 8008EVS Even Flat Spray Nozzle. The solution was applied at a water carrier rate equal to 1,019 L water/ha at 207 kPa. Granular urea (46-0-0), isobutylidene diurea (IBDU, 31-0-0), and a natural organic fertilizer (organic N, Sustane, 8-2-4, Sustane Natural Fertilizer Inc., Cannon Falls, MN) were mixed with 300 g of sand and applied in granular form using a shaker jar. The organic N source used is a complete fertilizer and application equal to N at 16.3 kg/ha resulted in 3.7 kg P_2O_5/ha and 7.3 kg K_2O/ha. To ensure that any observed effects were due to an N response, superphosphate (0-18-0) and sulfate of potash (0-0-50) were applied granularly with liquid urea, granular urea, and IBDU to equal the amount of P_2O_5 and K_2O applied with organic N. Superphosphate and sulfate of potash were mixed with granular treatments and applied separately to liquid urea plots after mixing with 300 g of sand.

Experimental Design and Plot Management

The putting green was mowed at 3.2 mm 6 days each week with a triplex reel mower and was irrigated at 100% evapotranspiration replacement. Evapotranspiration was estimated using an on-site weather station and the FAO-56 Penman-Monteith equation. Besides study treatments, no additional fertilizer was applied to the area from spring 2009 until the study concluded in the fall of 2010. Emerald (boscalid) was applied at 0.5 kg ai/ha on May 29, 2009, for dollar spot control. Dylox (trichlorfon) was applied at 6 kg ai/ha on six dates in 2009 (June 29, July 6 and 15, August 8, and September 2 and 25) to control black cutworms (*Agrotis ipsilon)*. In 2010, Dylox was applied once (May 25) and Acelepryn (chlorantraniliprole) was applied at 0.06 kg ai/ha on two dates (June 28 and August 25) for black cutworm control.

Data Collection and Analysis

Plots were assessed every 2 weeks for moss severity and every week for creeping bentgrass color in 2009 and 2010. Moss severity data were taken as a visual estimate of the percentage of each plot covered by moss colonies. Moss severity differed among plots at the beginning of the study. For this reason, moss severity was set to 100% at the time of the initial rating each year, and severity for later rating dates was scaled accordingly (moss severity in each plot = [% moss on rating date/% moss on first rating date] ×100). Area under the curve (AUC) analysis was conducted to give a cumulative, season-long indication of moss severity. Area under the curve was calculated as $AUC = \sum^{ni-1}_{i=1} ([y_i + y_{(i+1)}] / 2) (t_{(i+1)} - t_i)$, where i is the order index for the sampling dates, and n_i is the number of sampling dates.

Creeping bentgrass color was rated using a 1 to 9 scale where 1 = completely brown, 6 = minimum acceptable green color, and 9 = optimum dark green color. Tissue samples of creeping bentgrass and moss were taken on May 8, 2009, before the study began, and after fertilization ceased each year (November 19, 2009, and November 5, 2010). Creeping bentgrass tissue samples were collected from clippings after mowing. Three 2.5-cm moss plugs were removed from each plot and the top 2 to 3 mm of the plugs were then used for tissue analysis. Tissue samples were submitted to the K-State Research and Extension Soil Testing Laboratory, where samples were dried and ground prior to analysis. Nitrogen in plant tissue was analyzed using sulfuric peroxide digestion. Creeping bentgrass and silvery-thread moss tissue was analyzed for differences between plant species and among fertility treatments.

Effect of N Sources on Silvery-thread Moss Severity

Significant moss severity differences were observed among treatments on 3 of 13 dates in 2009, and on 3 of 12 dates in 2010 (Figure 1). On two dates in 2009, plots fertilized with granular urea had significantly lower moss severity than untreated plots, and plots fertilized with IBDU. Additionally, plots fertilized with granular urea had lower moss severity than plots fertilized with liquid urea on three dates, and lower severity than plots fertilized with organic N on one date. Fertilization with IBDU resulted in significantly higher moss severity than the untreated and organic N on one date. Plots fertilized with liquid urea were not different from untreated plots on any date in 2009.

In 2010, plots fertilized with liquid or granular urea were not different from one another on any rating date. Untreated plots or those fertilized with IBDU or organic N averaged significantly lower moss severity than plots fertilized with liquid urea on all three significant rating dates in 2010. Untreated plots and plots fertilized with IBDU averaged significantly lower moss severity than plots fertilized with granular urea on two rating dates in 2010.

Variances from AUC data in 2009 and 2010 were homogenous, and data were pooled for analysis. Area under the curve data were examined regarding the main effect (N source) to evaluate average performance from 2009 and 2010. Mean AUC values for plots fertilized with liquid urea were 147% to 155% higher than plots fertilized with other N sources, and 156% higher than the untreated areas (Figures 1 and 2).

Creeping Bentgrass Color

In 2009, fertilization with liquid or granular urea led to creeping bentgrass season-long color averages of 7.7 and 7.5, respectively, and were acceptable on every rating date. Fertilization with IBDU resulted in significantly lower average creeping bentgrass color of 6.8, and color was unacceptable on only 1 of 13 rating dates. Averaged across the season, creeping bentgrass fertilized with organic N had unacceptable quality in 2009 (5.8) and was acceptable on only 50% of rating dates. Untreated plots averaged the lowest creeping bentgrass color (4.8) and were acceptable on 13% of rating dates. Average season-long creeping bentgrass color in plots treated with liquid or granular urea in 2010 was 8.0 and 8.2, respectively. Fertilization with IBDU or organic N resulted in average creeping bentgrass color of 7.1. Untreated plots again had unacceptable creeping bentgrass color, with a season-long average of 4.8, and acceptable ratings on 52% of assessment dates. All other treatments were acceptable on every rating date in 2010.

Plant N Concentration

On May 8, 2009, before treatments, the baseline tissue N concentrations in creeping bentgrass and silvery-thread moss were 1.9% and 1.8%, respectively (Table 1). A plant species and plant species × fertility treatment interaction occurred at the end of each season, on November 19, 2009, and November 5, 2010, and creeping bentgrass had significantly higher tissue N concentrations compared to silvery-thread moss. On November 19, 2009, creeping bentgrass fertilized with liquid urea, granular urea, or IBDU had N concentrations from 1.8% to 2.1%, which were significantly greater than untreated creeping bentgrass, creeping bentgrass treated with organic N, and silvery-thread moss paired with any fertility treatment. No differences in silvery-thread moss occurred among N fertility treatments.

On November 5, 2010, no differences were detected in N concentrations in creeping bentgrass among treatments (Table 1). Silvery-thread moss had lower tissue N concentrations than creeping bentgrass for all fertility treatments. Silvery-thread moss fertilized with liquid urea had 1.0% foliar N, and was not different from moss fertilized with granular urea (0.9%) or organic N (0.8%). Untreated moss and moss treated with IBDU had the lowest tissue N concentrations (0.5% and 0.4%, respectively).

Conclusions

Silvery-thread moss response to N sources was variable in this study; however, liquid urea is capable of exacerbating moss encroachment. Optimizing fertility practices to give creeping bentgrass the competitive advantage may be possible. Mosses appear to most readily absorb nutrients foliarly. Further research is needed to determine how mosses absorb N and how and when to sample moss tissue to determine seasonal nutrient status.

Table 1. Effect of treatments on N concentrations in creeping bentgrass and silvery-thread moss

	N concentration (%)[1]		
Treatments[2]	May 8, 2009[3]	November 19, 2009	November 5, 2010
Creeping bentgrass			
Untreated	1.9	1.1 c	1.6 a
Liquid urea[4]		1.8 ab	1.5 a
Granular urea		2.1 a	1.6 a
IBDU		2.0 a	1.7 a
Organic N		1.2 bc	1.7 a
Silvery-thread moss			
Untreated	1.8	0.7 cd	0.5 cd
Liquid urea[4]		1.0 cd	1.0 b
Granular urea		0.8 cd	0.9 bc
IBDU		0.5 d	0.4 d
Organic N		0.8 cd	0.8 bc
	ANOVA		
Source of variation			
Nitrogen source		NS[5]	NS[5]
Plant species (creeping bentgrass or moss)		***[6]	***
Nitrogen source × plant species		*[7]	*

[1] Plots were sampled at the end of the season in 2009 and 2010 and analyzed for N concentration using a sulfuric peroxide digest. Within columns, means followed by the same letter are not significantly different according to Fisher's Protected LSD ($P < 0.05$).
[2] Treatments were applied at 16.3 kg N/ha biweekly from May 14 to October 30, 2009, and from May 21 to October 21, 2010.
[3] Creeping bentgrass and silvery-thread moss were sampled on May 8, 2009, before the study began.
[4] Granular urea was dissolved in water and applied with a handheld CO_2-powered sprayer.
[5] NS, not significant at $P = 0.05$.
[6] *** Significant at $P = 0.001$.
[7] * Significant at $P = 0.05$.

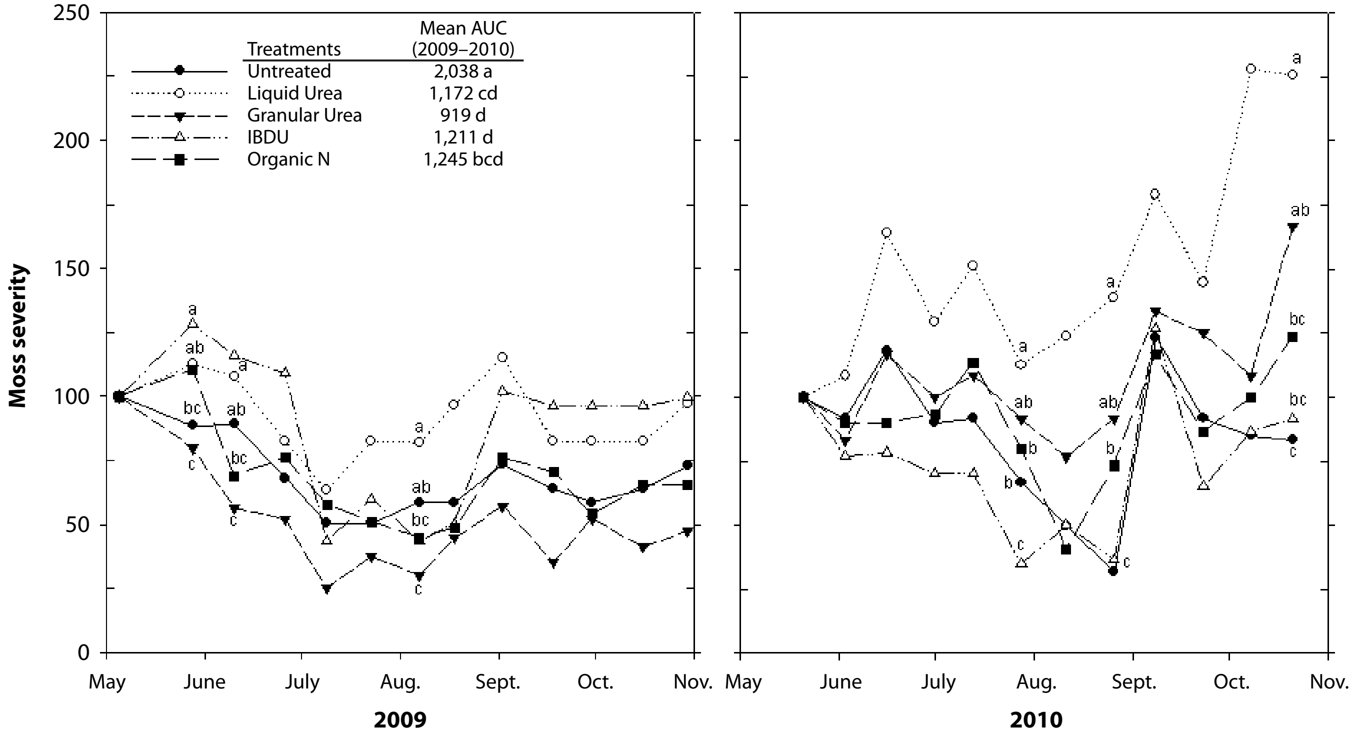


Figure 1. Effect of fertility treatments on moss severity in 2009 and 2010.
Moss severity is a visual estimate of the percentage of research plots infested with moss. Moss levels were significantly different on the first rating date. For this reason, estimates for each plot were set to 100% on the first rating date each year as a baseline. Subsequent estimates were then scaled accordingly as (moss severity in each plot = [% moss on rating date/% moss on initial rating date] × 100). Area under the curve (AUC) values are also displayed as AUC = $\sum^{ni-1}_{i=1}([y_i + y_{(i+1)}] / 2)(t_{(i+1)} - t_i)$, where i is the order index for sampling dates, and n_i is the number of sampling dates). Variances from AUC analysis in 2009 and 2010 were homogenous, and the mean AUC for 2009 and 2010 is displayed. On individual dates, and for mean AUC, means followed by the same letter are not significantly different ($P < 0.05$) according to Fisher's Protected LSD.

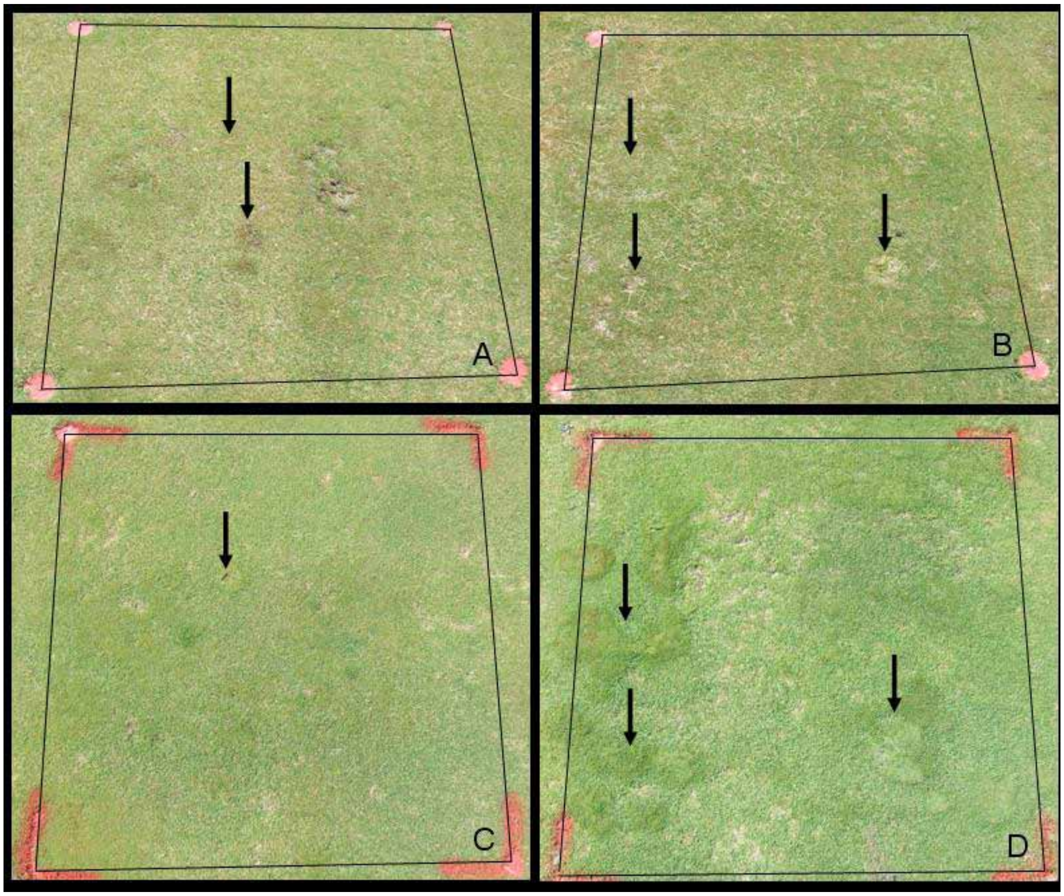


Figure 2. Change in silvery-thread moss populations in an untreated plot, and a plot fertilized with liquid urea in 2010.

Photographs A and C represent an untreated plot on May 21, 2010, (A) before fertilization began in 2010 and on October 28, 2010, and (C) 1 week after fertilization ceased. Photographs B and D represent a plot fertilized with liquid urea on May 21 (B) and October 28 (D). Silvery-thread moss did not increase between photographs A and C. In contrast, a 167% increase in silvery-thread moss was observed between photographs B and D. Arrows identify examples of moss colonies in each photograph.

Evaluation of Turf Reinforcement Mats and Their Effect on Establishment of Buffalograss and Zoysiagrass

Objective: Evaluate establishment of Buffalograss and zoysiagrass on erosion control mats.

Investigators: Tony Goldsby and Jack Fry

Introduction

Establishment of warm-season grasses in the upper transition zone can be an arduous task for homeowners. Incidents such as high-rainfall events that wash away seed can impede turfgrass establishment substantially. Furthermore, some warm-season grass species such as zoysiagrass can be slow to establish even from vegetative plugs. This may result in high weed populations, which compete with the desired turfgrass stand for water and nutrients. The most common method for control of broadleaf and grassy weeds is use of herbicides, but in cases where repeat applications are necessary, this option can prove costly for the homeowner. One alternative would be to use a warm-season grass that has been established in a turf reinforcement mat (TRM). Turf reinforcement mats combine vegetative growth and synthetic materials to form a high-strength mat and help prevent soil erosion. Additionally, turf reinforcement mats reduce light penetration and create a physical barrier, which can help prevent weed competition.

Methods

This study was conducted at Rocky Ford Research Turfgrass Research Center in Manhattan, Kan. Two warm-season grasses, 'Legacy' buffalograss and DALZ0102 zoysiagrass, were evaluated in separate studies for establishment from vegetative plugs using 1) TRM, 2) an application of Ronstar at 4 lb ai/acre just after planting, and 3) no treatment. Grasses were established as 2-in. diameter vegetative plugs in TRM in July 2010. A slit was cut in the mat and the base of the plug was inserted into the slit. The mats were laid over a layer of black plastic in the field during a 3-week establishment period. Irrigation was applied 3 times daily for 5 minutes to ensure mats stayed wet and to prevent plug stress. Each 5 ft × 5 ft mat contained 16 evenly spaced plugs of the respective turfgrass species.

After 3 weeks of establishment on mats, mats were lifted from the plastic and planted in an adjacent study area. Subsequently, Ronstar and untreated treatments were planted in 5 ft × 5 ft plots containing 16 evenly spaced plugs. For these treatments, plugs were planted directly into the soil. Plots assigned to Ronstar treatments received a single application using a shaker bottle. Plots were arranged in a randomized complete block design with three replicates. Irrigation was applied as needed to prevent stress during establishment. Starter fertilizer was applied to all treatments at the time of planting. Irrigation was applied as necessary to prevent stress from occurring during the study.

Overhead digital images in conjunction with visual ratings were collected monthly to compare plot establishment. Other environmental factors that were monitored included: soil moisture, soil temperature, and surface temperature of each plot. Weed counts to identify plant species other than desirable turfgrass began at 2 weeks after establishment.

Results

Zoysiagrass Establishment and Weed Control

Rate of turfgrass establishment was equal for all treatments for 8 weeks after study initiation (Figure 1). Thereafter, zoysiagrass planted in TRM exhibited significantly lower rates of establishment compared to the other treatments. The turfgrass plugs used in the TRM plots produced stolons, but they grew below the TRM, did not receive photosynthetic active radiation, and appeared etiolated (Figure 2). This resulted in slower growth of those stolons and low coverage ratings, because these stolons were not visible on the surface. Planting plugs on the surface of the mat, rather than in a slit, may help to prevent the stolon growth problem. Weed coverage in untreated plots was significantly higher in comparison to plots treated with Ronstar, or where turf was established in TRM (Figure 3). Both TRM and Ronstar suppressed weeds adequately; therefore, use of one or the other should be determined by cost and site specifications.

Buffalograss Establishment and Weed Control

Rate of turfgrass establishment was equal among all treatments for 8 weeks after planting (Figure 4). Thereafter, plots treated with Ronstar or TRM had significantly higher rates of coverage than untreated plots. Plots receiving Ronstar or TRM averaged 93% plot coverage by the end of the first growing season. This was significantly higher than the 78% plot coverage in untreated plots. Weed coverage in untreated plots was also higher than Ronstar-treated plots or plots where TRM was used (Figure 5). Lower coverage in untreated plots can be attributed to more competition for water and nutrients from presence of weeds. Both turfgrass species will be tested for a second growing season in the summer of 2011 to account for environmental variability.

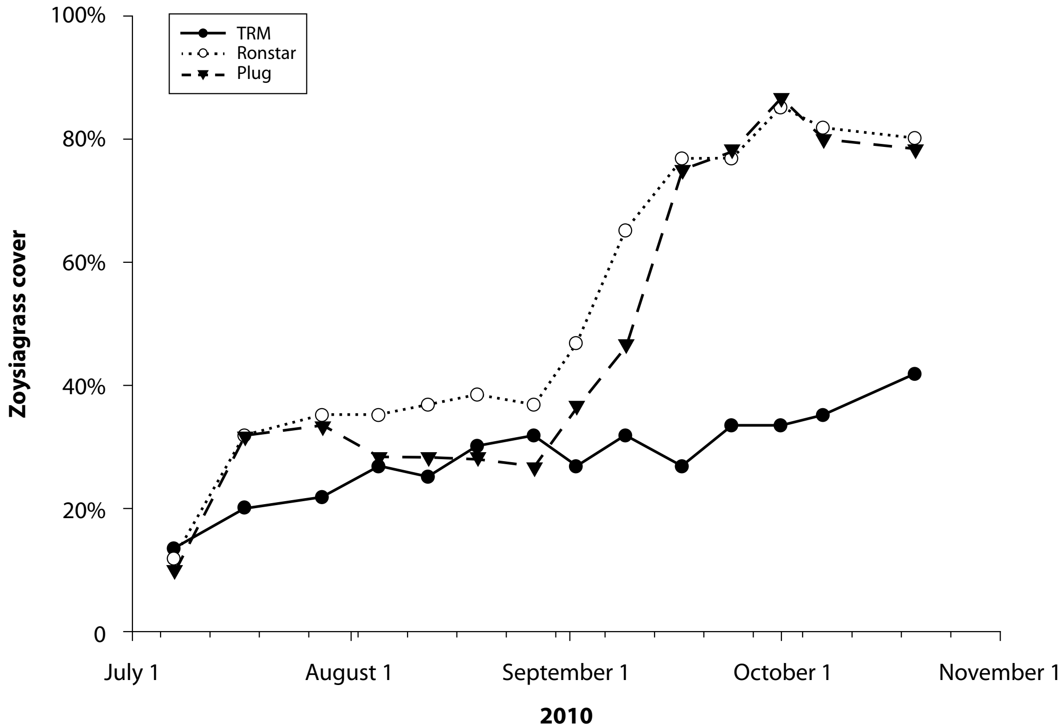


Figure 1. Weekly zoysiagrass cover of all three treatments. Percentage cover was determined by visual estimation of green turf cover per plot.

Figure 2. Zoysiagrass stolons green under a turf reinforcement mat.

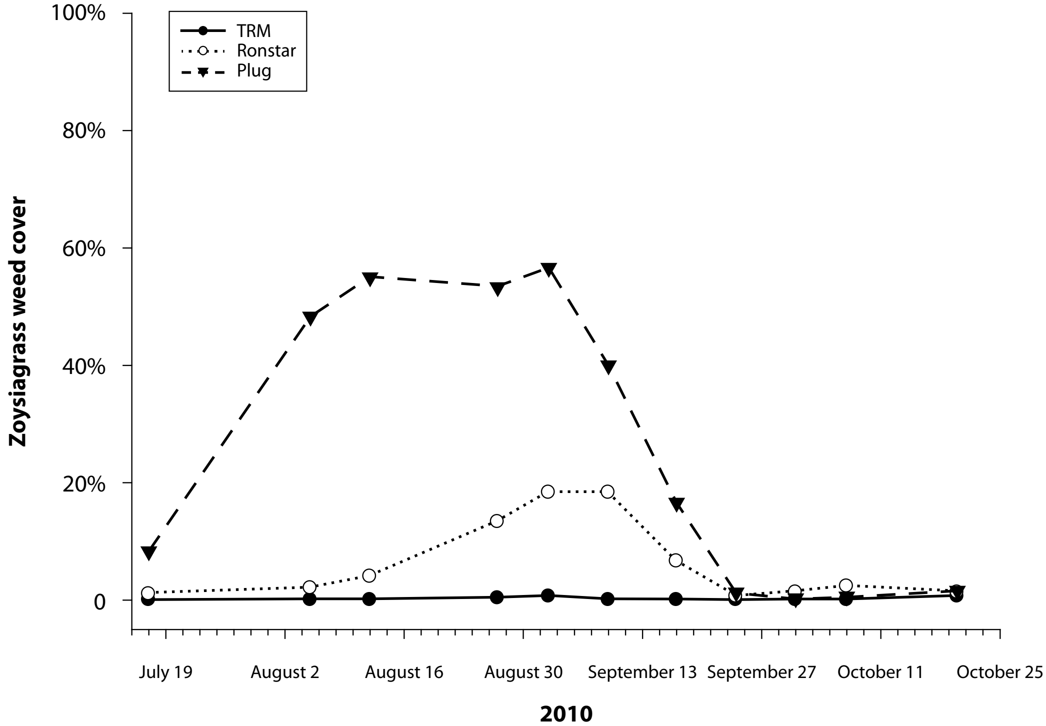


Figure 3. Weekly weed cover in all three zoysiagrass treatments. Percentage cover was determined by visual estimation of weed cover per plot.

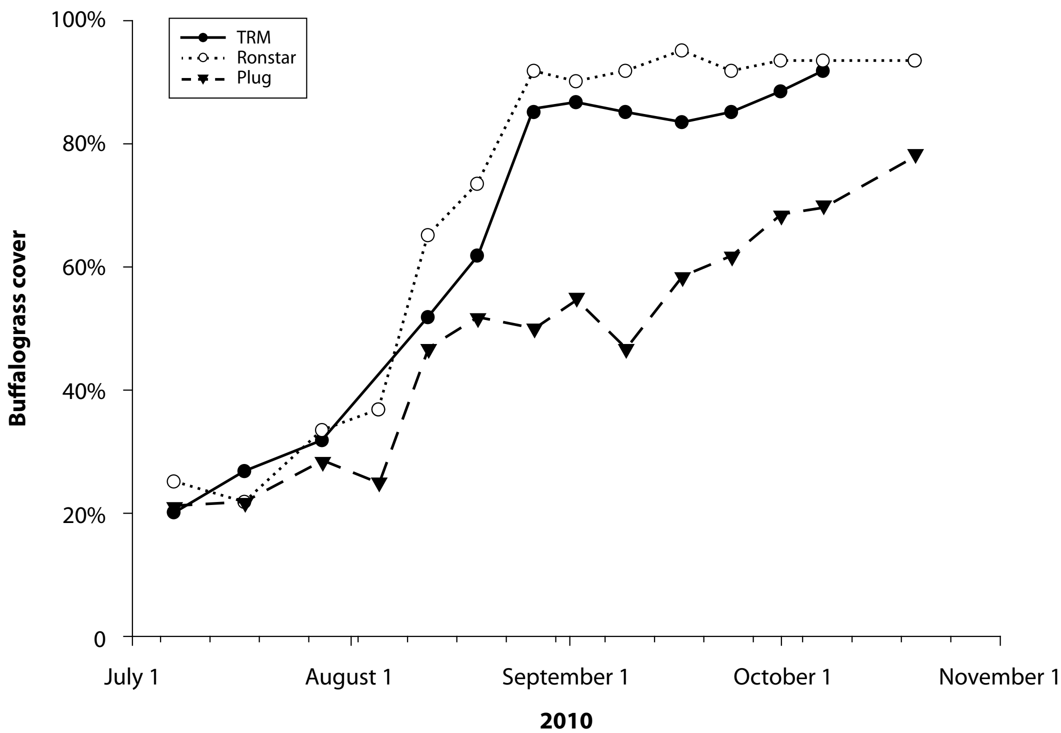


Figure 4. Weekly buffalograss cover in all three treatments. Percentage cover was determined by visual estimation of green turf cover per plot.

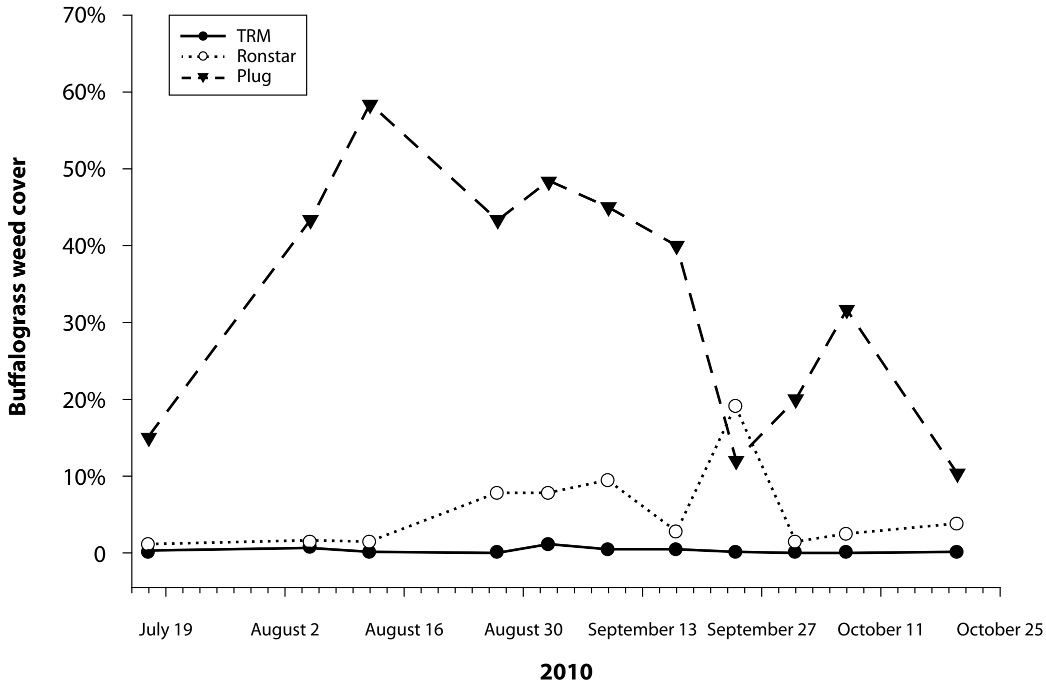


Figure 5. Buffalograss percentage weed cover, 2010.
Weekly weed cover of all three buffalograss treatments. Percentage cover was determined by visual estimation of weed cover per plot.

2006 National Turfgrass Evaluation Program Tall Fescue Evaluation

Objective: Evaluate tall fescue cultivars under Kansas conditions and submit data to the National Turfgrass Evaluation Program.

Investigators: Linda R. Parsons and Rodney St. John

Sponsor: National Turfgrass Evaluation Program

Introduction

Tall fescue is the best-adapted cool-season turfgrass for the transition zone because it is drought- and heat-tolerant and has few serious insect and disease problems. Tall fescue possesses a rather coarse leaf texture; it lacks stolons and has only very short rhizomes. Efforts to improve cultivar quality include selecting for finer leaf texture, a rich green color, and better sward density while maintaining good stress tolerance and disease resistance.

Methods

On September 8, 2006, we seeded 348 study plots, each measuring 5 ft × 5 ft, at the John C. Pair Horticultural Center in Wichita, Kan., with 116 tall fescue cultivars and experimental numbers in a randomized complete block design. We are maintaining fertility of the plots at 0.25 to 0.5 lb nitrogen/1,000 ft^2 per growing month. We mow plots weekly during the growing season at 2.5 in. and remove clippings. We irrigate as necessary to prevent stress, and we control weeds, insects, and diseases only when they present a threat to the trial.

During this 6-year study, we will collect information on establishment, spring greenup, genetic color, leaf texture, quality, fall color retention, and other measures when appropriate. Rating is done visually on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum).

Results

During the 2010 growing season, we started data collection on April 13 with spring greenup and found that 'Firenza,' 'Corona' (Col-M), and 'GO-1BFD' were the greenest (Table 1). Starting in May, we rated the turf for quality every month throughout the rest of the growing season. Ratings were influenced by degree of cover, weed infestation, and disease resistance as well as turf color, texture, and density. 'Talladega' (RP 3), 'Turbo RZ' (Burl-TF8), 'Braveheart' (DP 50-9407), 'PSG-TTRH,' and 'BAR Fa 6235' were the best overall performers for the year.

More information on NTEP and the nationwide 2006 National Tall Fescue Test results can be found online at: http://www.ntep.org/.

Table 1. 2010 performance of tall fescue cultivars, Wichita[1]

Cultivar/ experimental number[2]	Quality							
	Greenup	May	June	July	Aug.	Sept.	Oct.	Avg.
Talladega (RP 3)*	5.0	6.0	5.7	5.3	6.7	6.0	5.7	5.9
Turbo RZ (Burl-TF8)*	4.7	5.3	5.7	6.0	6.0	6.0	5.3	5.7
Braveheart (DP 50-9407)	5.0	5.3	5.3	6.0	6.0	6.0	5.0	5.6
PSG-TTRH	4.7	6.3	5.3	6.0	6.0	5.3	4.3	5.6
BAR Fa 6235	5.0	6.3	6.3	5.7	5.3	5.7	4.0	5.6
Bullseye*	4.3	5.3	4.3	6.0	5.7	6.7	5.0	5.5
Corona (Col-M)	5.7	6.3	5.7	5.7	6.0	5.0	4.3	5.5
Turbo*	5.3	5.7	5.3	6.0	6.7	5.3	4.0	5.5
Cochise IV (RKCL)	4.3	5.3	5.3	5.0	5.7	6.0	5.3	5.4
MVS-1107	4.7	5.3	5.7	4.7	6.3	5.7	5.0	5.4
Rhambler SRP (Rhambler)*	5.3	6.0	6.3	5.3	5.7	5.3	4.0	5.4
Shenandoah Elite (RK 6)	5.0	5.3	4.7	5.3	6.0	5.7	5.3	5.4
Finelawn Xpress (RP 2)	5.3	5.3	5.7	5.0	5.7	5.7	5.0	5.4
GWTF	5.0	5.3	5.0	6.0	6.0	5.7	4.3	5.4
Lindbergh*	4.7	5.7	5.3	4.7	6.0	5.3	5.0	5.3
AST 7001*	4.0	6.0	5.3	6.0	5.3	5.7	3.3	5.3
Rebel IV*	5.0	5.3	5.3	5.0	6.0	5.7	4.3	5.3
SC-1	5.0	5.0	5.3	6.0	5.7	5.7	4.0	5.3
STR-8GRQR	5.0	5.3	5.7	5.7	5.0	5.3	4.7	5.3
Wolfpack II (PST-5WMB)*	4.7	5.3	5.3	5.7	5.3	5.7	4.3	5.3
J-140	4.7	5.0	5.0	5.3	6.0	6.0	4.0	5.2
RK 5	4.3	5.3	5.0	5.7	5.0	6.0	4.3	5.2
Biltmore*	5.0	5.7	4.7	5.3	5.7	5.0	4.7	5.2
PSG-82BR	4.7	5.3	5.3	5.0	5.3	5.3	4.7	5.2
Traverse SPR (RK-1)*	4.0	5.7	4.7	5.3	5.7	5.3	4.3	5.2
Umbrella (DP 50-9411)	4.3	5.3	5.3	5.3	4.7	5.3	4.7	5.1
Falcon V (ATM)	5.3	5.7	5.3	5.0	5.0	5.7	4.0	5.1
KZ-2	4.0	5.0	5.0	5.0	5.0	5.7	5.0	5.1
Skyline*	4.3	5.3	5.3	5.7	5.3	5.0	4.0	5.1
Tulsa Time (Tulsa III)*	5.3	4.7	5.0	5.3	6.0	6.0	3.7	5.1
Faith (K06-WA)*	5.3	5.3	5.7	5.7	5.3	4.3	4.0	5.1
Falcon NG (CE 1)	5.3	6.0	5.7	4.7	5.7	5.0	3.3	5.1
PSG-TTST	4.3	5.0	5.0	5.0	5.0	5.7	4.7	5.1
SR 8650 (STR-8LMM)*	4.3	6.0	5.0	4.7	5.3	5.3	4.0	5.1
AST9003 (AST-1)*	4.3	6.0	5.0	6.0	5.0	4.7	3.7	5.1
ATF 1328	5.3	6.0	6.0	5.3	4.7	4.7	3.7	5.1
Einstein*	5.0	5.0	5.7	5.3	5.3	5.0	4.0	5.1
Trio (IS-TF-152)	3.7	5.3	5.0	5.3	5.7	5.3	3.7	5.1
BGR-TF1	4.3	5.3	5.0	5.3	5.7	5.3	3.3	5.0

continued

Table 1. 2010 performance of tall fescue cultivars, Wichita[1]

Cultivar/ experimental number[2]	Quality							
	Greenup	May	June	July	Aug.	Sept.	Oct.	Avg.
Crossfire 3 (Col-J)	5.3	5.3	5.7	6.0	5.3	4.3	3.3	5.0
Falcon IV*	4.7	5.7	5.0	5.0	5.0	5.0	4.3	5.0
Honky Tonk (RAD-TF17)*	4.7	4.7	5.3	6.0	5.7	4.7	3.7	5.0
Raptor II (MVS-TF-158)*	4.7	5.7	5.3	6.0	4.3	4.7	4.0	5.0
Spyder LS (Z-2000)*	4.3	5.3	5.3	5.7	5.0	5.3	3.3	5.0
Rembrandt*	5.0	5.0	5.0	5.0	5.3	5.0	4.3	4.9
STR-8BB5	4.3	5.3	4.7	5.3	5.3	5.0	4.0	4.9
Terrier (IS-TF-135)	4.0	5.3	5.0	5.7	5.3	4.3	4.0	4.9
Col-1	4.0	5.0	5.7	6.0	4.7	4.3	3.7	4.9
Hudson (DKS)*	4.0	5.0	5.0	5.0	4.7	5.3	4.3	4.9
JT-36	3.7	4.7	4.7	5.7	5.0	4.7	4.7	4.9
Hunter*	5.0	5.0	6.0	6.0	4.7	4.3	3.3	4.9
JT-42	3.3	5.3	5.0	4.7	4.3	5.7	4.3	4.9
Shenandoah III (SH 3)	5.0	5.3	5.0	4.7	5.0	5.0	4.3	4.9
AST9001 (AST-3)*	4.0	5.7	4.7	5.0	5.0	5.0	3.7	4.8
Aggressor (IS-TF-153)	3.7	5.3	5.0	4.0	5.0	5.7	4.0	4.8
Firecracker LS (MVS-MST)*	5.0	6.0	5.0	6.0	4.3	4.3	3.3	4.8
JT-41	4.0	5.7	5.3	4.7	5.0	4.7	3.7	4.8
JT-45	4.7	6.0	5.3	4.7	4.7	4.7	3.7	4.8
RNP	4.0	6.0	5.0	5.0	4.7	4.7	3.7	4.8
06-WALK	4.3	5.3	5.3	5.3	4.7	4.7	3.3	4.8
3rd Millennium SRP*	3.7	5.3	5.0	4.7	4.7	5.0	4.0	4.8
Aristotle*	4.7	5.0	5.3	4.7	4.7	3.7	5.3	4.8
Fat Cat (IS-TF-161)	4.3	5.3	4.3	5.3	4.7	5.0	4.0	4.8
IS-TF-159	4.0	5.3	4.3	4.3	5.0	5.3	4.3	4.8
JT-33	3.7	4.7	4.7	5.7	4.7	5.0	4.0	4.8
Rocket (IS-TF-147)	4.3	5.7	4.3	4.7	5.0	5.0	4.0	4.8
Speedway (STR-8BPDX)*	4.7	6.0	5.7	5.0	4.7	4.3	3.0	4.8
Firenza*	6.0	5.3	5.3	4.7	4.7	4.7	3.7	4.7
GO-1BFD	5.7	4.7	4.7	5.7	4.7	4.7	4.0	4.7
J-130	4.3	5.3	4.7	5.3	5.0	5.0	3.0	4.7
Justice*	4.7	5.3	4.7	4.7	5.0	4.3	4.3	4.7
Magellan*	3.7	5.0	4.3	5.0	4.3	5.7	4.0	4.7
Ninja 3 (ATF 1247)	3.7	4.7	4.7	5.3	5.0	5.0	3.7	4.7
RK 4	3.7	5.0	4.3	4.3	5.3	5.3	4.0	4.7
Tahoe II*	4.0	5.0	4.3	5.7	4.7	4.3	4.3	4.7
Greenbrooks (TG 50-9460)	4.7	5.7	5.3	5.7	4.7	4.3	2.7	4.7
MVS-341	4.7	5.3	5.0	5.7	4.0	5.0	3.3	4.7
Sidewinder (IS-TF-138)	4.7	5.0	5.0	5.0	5.0	5.0	3.3	4.7

continued

Table 1. 2010 performance of tall fescue cultivars, Wichita[1]

Cultivar/ experimental number[2]	Quality							
	Greenup	May	June	July	Aug.	Sept.	Oct.	Avg.
Catelyst (NA-BT-1)	4.3	5.0	4.3	4.0	5.7	5.3	3.7	4.7
Monet (LTP-610 CL)*	3.7	5.3	4.7	5.3	4.3	4.7	3.7	4.7
PSG-85QR	5.0	5.0	4.7	5.7	4.3	3.7	4.3	4.6
Pedigree (ATF-1199)	4.7	5.3	5.0	5.0	4.7	4.3	3.3	4.6
AST9002 (AST-2)*	4.7	5.0	5.0	4.7	4.7	4.7	3.7	4.6
Jamboree (IS-TF-128)	4.0	5.3	4.3	4.3	4.7	5.0	4.0	4.6
06-DUST	5.3	5.3	4.3	5.0	4.0	5.0	3.7	4.6
Hemi*	4.7	5.0	4.7	4.0	5.0	5.3	3.3	4.6
Mustang 4 (M4)*	4.7	5.7	5.0	4.7	4.0	4.7	3.3	4.6
Van Gogh (LTP-RK2)*	5.0	5.0	5.3	4.3	4.3	5.0	3.3	4.6
Cezanne Rz (LTP-CRL)*	5.3	6.0	5.0	4.0	4.7	4.3	3.3	4.6
Reunion (LS-03)*	4.0	5.3	5.0	5.3	4.3	4.0	3.3	4.6
0312	4.0	4.7	5.0	4.3	4.7	4.3	4.0	4.5
Toccoa (IS-TF-151)*	4.0	5.0	4.7	4.7	4.3	4.0	4.0	4.4
Escalade*	3.7	5.0	4.7	4.7	4.7	4.0	3.7	4.4
PSG-RNDR	4.0	5.0	4.7	5.3	4.0	3.7	3.7	4.4
Renovate (LS-11)*	4.0	5.3	5.3	5.0	3.7	4.0	3.0	4.4
Gazelle II (PST-5HP)*	4.0	4.0	4.3	4.7	4.3	4.7	4.3	4.4
Compete (LS-06)*	4.3	5.0	4.7	5.0	4.3	3.7	3.3	4.3
Essential (IS-TF-154)*	4.7	4.7	4.3	4.0	5.0	4.0	4.0	4.3
Padre*	4.7	5.3	5.0	4.3	4.3	4.3	2.7	4.3
AST 7002*	4.0	5.0	4.0	4.7	4.3	4.3	3.3	4.3
Plato*	4.3	5.0	4.3	4.3	4.3	4.3	3.3	4.3
AST1001 (AST-4)	4.7	5.3	4.3	4.7	4.0	3.7	3.3	4.2
BGR-TF2	4.0	4.7	4.7	4.7	4.0	4.3	3.0	4.2
KZ-1	4.0	5.0	4.0	4.0	4.7	5.0	2.7	4.2
Titanium LS (MVS-BB-1)*	4.7	5.3	5.7	3.0	4.7	4.0	2.7	4.2
AST 7003*	4.7	4.7	5.0	4.7	3.7	3.7	3.0	4.1
Cannavaro (DP 50-9440)	3.7	5.0	4.3	4.0	4.3	4.3	2.7	4.1
GE-1	4.7	5.3	5.3	3.7	4.0	4.0	2.3	4.1
Stetson II (NA-SS)	4.0	5.0	5.3	4.0	3.7	3.3	3.3	4.1
BAR Fa 6363	4.0	4.7	3.7	3.7	3.7	4.0	3.7	3.9
Darlington (CS-TF1)*	4.0	4.7	4.3	3.7	4.0	4.0	2.7	3.9
Silverado*	4.0	4.0	4.0	4.0	3.0	4.7	3.0	3.8
Ky-31*	4.0	3.0	3.0	2.3	2.3	2.7	2.7	2.7
LSD[3]	2.6	1.4	3.1	4.2	3.0	2.6	4.5	1.9

[1] Visual ratings are based on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum).
[2] Cultivars marked with * were commercially available in 2010.
[3] To determine statistical differences among entries, subtract one entry's mean from another's. If the result is larger than the corresponding LSD value, the two are statistically different.

Evaluation of Zoysiagrasses in Southern Kansas

Objective: Evaluate experimental zoysiagrasses for their performance in Wichita, Kan.

Investigators: Linda R. Parsons and Jack Fry

Sponsor: Kansas Turfgrass Foundation

Introduction

Kansas State University has been cooperating with Texas A&M University since 2004 to identify zoysiagrasses that have superior quality to 'Meyer' but equivalent or better freezing tolerance. Eight of these grasses were planted in Wichita in 2009, as well as several other locations throughout the transition zone.

Methods

During the summer of 2009, we established 'Meyer,' the industry standard, and eight experimental hybrids of zoysiagrass in 27 study plots, each measuring 5 ft × 5 ft, in a randomized complete block design at the John C. Pair Horticultural Center in Wichita, Kan. The experimental zoysiagrasses are progeny from crosses between *Z. matrella* cultivars ('Cavalier,' 'Zorro,' or the experimental type DALZ 8501) or Emerald (*Z. japonica* x *Z. pacifica*) x *Z. japonica* (either 'Meyer' or Chinese Common) (Table 1). Spring greenup, leaf texture, genetic color, fall color retention, and quality were rated visually on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum). Percentage coverage was rated visually.

Results

We rated stand establishment at the end of 2009 by looking at percentage cover. At that time, KSUZ 0803, and DALZ 0102 were the best established and 'Meyer' the poorest (Table 1). When we looked at percentage cover a year later, DALZ 0102, KSUZ 0802, KSUZ 0804, and 'Meyer' rated the best. We started the 2010 growing season by looking at turf greenup and for winter injury. By April 20, KSUZ 0803, DALZ 0102, and KSUZ 0802 were the greenest, and no winter injury was apparent. We rated turf quality every month throughout the 2010 growing season. Ratings were influenced by degree of cover, weed infestation, and disease resistance as well as turf color, texture, and density. The overall best performers were KSUZ 0802, DALZ 0102, and KSUZ 0803. During the course of the summer, we looked at leaf texture and genetic color and found that KSUZ 0802, KSUZ 0807, KSUZ 0804, and KSUZ 0803 had the finest texture and that KSUZ 0803, KSUZ 0805, and KSUZ 0806 were the darkest green. Toward the end of October, we looked at turf color retention as the stands were becoming dormant. At that time, KSUZ 0803, KSUZ 0806, DALZ 0102, and KSUZ 0807 retained the most color.

Table 1. Performance of experimental zoysiagrasses in Wichita, 2010

Cultivar/ experimental number	% cover October 2009[1]	% cover October 2010	Spring greenup[2]	Leaf texture	Genetic color	Fall color	Quality					
							May	June	July	Aug.	Sept.	Avg.
KSUZ 0802 (Cavalier x Chinese Common)	50.0	93.3	4.3	8.0	5.3	3.7	5.0	4.3	5.3	6.3	5.7	5.3
DALZ 0102 (Z. japonica type)	65.0	97.3	4.3	4.0	4.0	5.7	5.0	4.7	4.3	5.3	5.0	4.9
KSUZ 0803 (8501 x Meyer)	84.3	81.7	5.0	7.0	7.0	6.7	4.3	4.7	4.7	6.3	4.0	4.8
KSUZ 0807 (8501 x Meyer)	60.0	83.3	3.7	7.7	6.0	5.7	4.3	4.3	4.3	5.7	4.3	4.6
KSUZ 0804 (Zorro x Meyer)	60.0	86.7	2.7	7.3	5.3	3.7	4.7	4.0	4.0	4.7	5.0	4.5
KSUZ 0805 (Zorro x Meyer)	56.7	80.0	3.3	6.7	7.0	4.3	3.3	3.7	4.0	5.3	4.7	4.2
KSUZ 0806 (Emerald x Meyer)	53.3	80.0	3.0	6.7	7.0	6.3	3.3	3.3	4.0	5.3	4.0	4.0
Meyer	38.3	86.7	3.0	5.0	6.0	4.0	4.0	3.0	3.3	4.7	4.7	3.9
KSUZ 0801 (Cavalier x Chinese Common)	53.3	82.7	2.7	6.3	5.0	4.7	2.0	3.7	3.3	5.7	4.7	3.9
LSD[3]	47.0	13.7	3.3	0.7	0.4	0.9	1.4	3.1	4.0	4.3	1.4	2.2

[1] Percentage cover was rated visually on a scale of 0 to 100%.
[2] Spring greenup, leaf texture, genetic color, fall color retention, and quality were rated visually on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum).
[3] To determine statistical differences among entries, subtract one entry's mean from another's. If the result is larger than the corresponding LSD value, the two are statistically different.

University of Nebraska–Lincoln Buffalograss Experimental Lines and Cultivars Evaluation

Objective: Evaluate buffalograss cultivars under Kansas conditions and submit data collected to the University of Nebraska.

Investigators: Linda R. Parsons and Rodney St. John

Sponsor: University of Nebraska

Introduction

Buffalograss is the only native turfgrass that performs well in Kansas. It requires little maintenance and is heat- and drought-tolerant. Because the introduction of many new selections, both seeded and vegetative, has aroused considerable interest, further evaluation of these new releases is needed to determine their potential for use by Kansas consumers.

Methods

In the summer of 2008, we established nine seeded and eight vegetative buffalograss cultivars and experimental numbers in 51 study plots, each measuring 5 ft × 5 ft, in a randomized complete block design at the John C. Pair Horticultural Center in Wichita, Kan., and at the Horticulture Research and Extension Center in Olathe, Kan. Vegetative types were plugged on 1-ft centers with 16 plugs per plot, and seeded types were planted at 2.0 lb/1,000 ft^2 of pure live seed or 22.7 g of seed per plot. We incorporated a starter fertilizer into the plots at a rate of 1.0 lb nitrogen (N)/1,000 ft^2 to support establishment. We added an additional 1.0 lb N/1,000 ft^2 a month later. To help with weed control during establishment, we applied Drive at 1.0 lb ai/acre (0.17 g/16 ft^2 of the 75% DF product) in two applications. After establishment, we added 2 lb N/1,000 ft^2 to the area (1 lb in June and 1 lb in July). We apply Barricade every spring to prevent annual weeds. During the growing season, we mow the plots at 2 in. and drop clippings, and irrigate to prevent dormancy.

During the course of this study, we will collect information on establishment, spring greenup, quality, genetic color, leaf texture, density, fall color retention, dormant color, and other measures when appropriate. We rate leaf texture, genetic color, and turf stand density on scales of 1 to 9 (leaf texture: 1 = very wide blades and 9 = very fine blades; genetic color: 1= straw brown, 5 = light-yellow green, and 9 = dark green; turf stand density: 1 = bare soil and 9 = complete coverage). We record overall quality monthly during the growing season on a scale of 1 to 9 (1 = poorest quality, 6 = lowest acceptable turf quality, 9 = optimum).

Wichita Results

We started the 2010 growing season by watching spring greenup. By the end of April, vegetative types NE-BFG07-13 and NE-BFG07-12 were the greenest, followed by the seeded types, which all rated the same (Table 1). We rated turf quality every month throughout the growing season. Ratings were influenced by degree of cover, weed infestation, and disease resistance as well as turf color, texture, and density. The overall best performers were vegetative types '609' and NE-BFG07-09 and seeded types NE-BFG07-01, NE-BFG07-03, and NE-BFG07-02. We looked at stand density in spring, summer, and fall. At the beginning of the growing season, vegetative types NE-BFG07-13, NE-BFG07-10, and NE-BFG07-11 were the densest, followed by seeded types NE-BFG07-08, NE-BFG07-02, and NE-BFG07-04. By midsummer, vegetative types '609,' 'Legacy,' and 'Prestige' had developed the densest stands followed by seeded types NE-BFG07-02 and NE-BFG07-03, a ranking they retained into fall. Throughout the summer, we looked at leaf texture and genetic color and for the absence of seed heads. Vegetative types 'Prestige,' '609,' NE-BFG07-09, and NE-BFG07-13 had the finest texture followed by a group of seeded types comprising NE-BFG07-01, NE-BFG07-02, NE-BFG07-03, NE-BFG07-08, and 'Texoka.' Vegetative types '609,' NE-BFG07-09, and NE-BFG07-11 and seeded types 'Bison' and NE-BFG07-03 were the greenest. Vegetative types '609,' NE-BFG07-12, and 'Prestige' had virtually no seedheads, and 'Texoka' and NE-BFG07-08 had the fewest seedheads of the seeded types. During October, we recorded at turf color retention as the stands began to go dormant. By October 26, vegetative types '609' and NE-BFG07-09 and seeded type 'Texoka' retained the most color.

Olathe Results

As in 2009, most of the vegetative varieties performed the better than the seeded varieties in terms of color, density, and texture. 'Prestige,' BFG07-09, BFG07-10, BFG07-11, and 'Legacy' had the best overall quality. As in 2009, differences in performance were evident between Olathe and Wichita; for example, '609' performed very well in Wichita, but had very low quality and spring greenup ratings in Olathe. 'Legacy,' BFG07-11, BFG07-12, and BFG07-13 had the darkest genetic color. 'Prestige,' '609,' BFG07-03, BFG07-04, BFG07-01, BFG07-02, and 'Bison' had finest leaf texture, and '609,' BFG07-09, and 'Prestige' maintained the greenest fall color.

Table 1. 2010 performance of buffalograss cultivars, Wichita[1]

Cultivar/ experimental number	Type	Spring greenup	Leaf texture	Genetic color	Seed heads	Spring density	Summer density	Fall density	Fall color	Quality					
										May	June	July	Aug.	Sept.	Avg.[3]
609	V	3.0	8.0	7.0	9.0	5.7	6.0	7.0	8.3	6.0	6.0	6.7	6.0	5.3	6.0
NE-BFG07-09	V	3.7	7.3	7.0	7.3	5.3	5.3	5.7	5.0	6.7	6.0	6.0	5.7	4.3	5.7
NE-BFG07-01	S	4.0	7.0	5.0	5.0	5.7	5.3	5.3	2.7	6.0	6.0	5.3	5.7	5.0	5.6
NE-BFG07-03	S	4.0	7.0	6.0	5.3	5.3	5.7	5.7	2.3	6.0	5.7	5.3	6.0	5.0	5.6
NE-BFG07-02	S	4.0	7.0	5.7	5.3	6.0	5.7	5.7	2.7	6.7	5.7	5.7	6.0	4.0	5.6
NE-BFG07-08	S	4.0	7.0	5.0	5.7	6.3	4.7	5.3	2.0	6.0	5.7	5.0	6.3	4.7	5.5
NE-BFG07-10	V	3.3	7.0	5.3	8.0	6.7	5.0	5.7	3.3	6.3	6.3	5.7	5.3	4.0	5.5
NE-BFG07-11	V	4.0	5.3	6.3	7.0	6.7	5.3	5.7	4.3	6.0	5.0	5.7	6.0	5.0	5.5
Legacy	V	3.7	7.0	5.7	2.7	5.0	6.0	6.7	2.7	5.7	5.7	5.0	6.3	4.7	5.5
NE-BFG07-04	S	4.0	6.7	5.0	5.0	6.0	5.0	4.7	2.3	6.0	5.7	5.3	5.7	4.3	5.4
Prestige	V	3.0	8.7	5.3	9.0	6.3	6.0	6.3	3.7	6.3	6.3	4.7	4.7	4.3	5.3
NE-BFG07-12	V	4.3	7.0	5.3	9.0	6.0	5.3	5.7	4.0	5.7	5.3	5.3	5.0	4.7	5.2
Cody	S	4.0	6.3	5.7	5.3	5.0	5.0	5.0	2.7	5.3	5.0	5.0	5.7	4.3	5.1
Texoka	S	4.0	7.0	5.0	6.3	4.3	5.3	4.0	4.7	5.3	5.7	5.0	5.3	4.0	5.1
Bison	S	4.0	6.0	6.0	5.0	4.0	4.0	5.0	3.5	5.0	5.0	5.5	4.5	5.0	5.0
Bowie	S	4.0	6.0	5.3	4.7	5.3	4.7	5.0	2.0	5.7	5.0	4.3	5.0	4.0	4.8
NE-BFG07-13	V	4.7	7.3	5.0	7.3	7.0	4.7	5.0	1.0	5.7	5.0	4.7	4.3	4.0	4.7
LSD[2]		0.7	1.5	0.6	1.1	1.5	1.3	1.3	1.3	1.3	1.6	1.9	1.7	1.8	0.8

[1] Visual ratings based on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum).

[2] To determine statistical differences among entries, subtract one entry's mean from another's. If the result is larger than the corresponding LSD value, the two are statistically different.

[3] Average of the monthly quality ratings.

Table 2. 2010 performance of buffalograss cultivars, Olathe[1]

Cultivar/ experimental number	Type	Spring greenup	Leaf texture	Genetic color	Spring density	Summer density	Fall density	Oct. 7 color	Oct. 15 color	Oct. 27 color	Quality					
											May	June	July	Aug.	Oct.	Avg.
Prestige	V	7.0	9.0	7.3	8.0	8.3	8.0	8.0	6.3	4.0	5.7	8.7	9.0	9.0	8.3	8.1
NE-BFG07-09	V	7.3	7.3	7.0	7.3	8.3	7.7	8.0	6.3	3.3	6.0	7.0	7.7	9.0	8.0	7.5
Legacy	V	7.0	7.7	8.0	7.0	7.7	7.7	7.3	6.3	2.7	6.0	8.0	8.3	7.7	7.7	7.5
NE-BFG07-11	V	7.0	7.7	7.7	7.3	7.3	7.7	7.0	5.7	2.3	6.0	7.3	8.3	8.0	8.0	7.5
NE-BFG07-10	V	7.7	7.7	6.7	8.0	7.3	8.0	7.0	6.0	2.0	6.3	6.7	7.7	8.7	8.0	7.5
NE-BFG07-12	V	7.7	7.3	7.7	7.7	8.0	7.7	7.0	5.7	2.0	6.0	7.3	8.0	8.0	7.3	7.3
NE-BFG07-03	S	7.0	8.0	7.0	7.0	7.7	7.3	7.0	5.0	2.3	6.0	6.3	8.0	8.0	8.0	7.3
NE-BFG07-04	S	7.0	8.0	7.0	7.0	7.7	7.3	7.0	5.0	2.0	6.0	7.0	8.0	7.7	7.7	7.3
NE-BFG07-08	S	7.0	7.7	7.0	7.0	7.7	7.7	7.0	5.3	2.3	6.0	6.7	8.0	7.7	7.7	7.2
NE-BFG07-01	S	7.0	8.0	7.0	7.0	7.0	7.3	7.0	5.0	1.7	6.0	6.7	8.0	7.7	7.7	7.2
NE-BFG07-02	S	7.0	8.0	7.0	6.3	7.0	6.7	7.0	5.0	2.0	5.7	6.7	8.0	7.7	7.3	7.1
Cody	S	7.0	7.7	7.0	6.3	7.0	6.7	7.0	5.0	2.0	5.3	6.7	8.0	7.7	8.0	7.1
609	V	6.7	8.0	7.3	7.1	7.3	7.7	9.0	8.0	5.0	4.3	5.0	7.7	8.7	8.7	6.9
Texoka	S	7.0	7.7	7.0	6.3	7.3	6.3	8.0	5.3	2.0	5.0	6.0	8.0	8.0	7.7	6.9
Bowie	S	7.0	7.7	7.0	6.7	7.3	7.3	7.0	5.3	1.7	5.0	6.0	8.0	7.7	8.0	6.9
Bison	S	7.0	8.0	7.0	7.0	7.0	6.7	8.0	6.0	2.3	5.0	5.3	7.3	8.0	7.7	6.7
NE-BFG07-13	V	7.7	7.0	7.7	7.3	7.7	7.7	6.7	5.3	1.0	4.7	7.3	8.0	7.0	6.7	6.7
LSD[2]		0.5	0.6	0.6	0.8	ns	0.8	0.3	1.0	0.7	1.0	0.9	0.6	0.7	0.8	ns

[1] Visual ratings based on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum).

[2] To determine statistical differences among entries, subtract one entry's mean from another's. If the result is larger than the corresponding LSD value, the two are statistically different.

[3] Average of the monthly quality ratings.

Ornamental Grass Trial

Objective: Evaluate different species and cultivars of ornamental grasses for their winter hardiness, appearance, and growth characteristics in two different locations in Kansas.

Investigators: Rodney St. John and Robin Dremsa

Introduction

Ornamental grasses, sedges, and rushes can be great additions to Midwest landscaping, but little research has evaluated them in the Kansas climate. This project will evaluate many species and cultivars of ornamental grasses for many years. The study will record their winter and summer survival rates, the rate at which they spread, their average height, and their appearance. The study will also include a picture record of each grass as it progresses through the season and throughout the trial.

Ornamental grasses come in a wide variety of sizes, shapes, colors, and textures. Most ornamental grasses used in the Midwest are clump-forming and keep their round shape; however, some have rhizomatous growth habits and can be more active spreaders. One of the purposes of this study is to evaluate the spreadability of these grasses. Some users may want a spreading grass to fill in a larger area, whereas others may want the grass to remain in clump form.

Methods

The original study had two locations: Haysville, Kan., and Olathe, Kan. The research presented here is from the ongoing research trial at the K-State Horticulture Research and Extension Center in Olathe (Johnson County). New grasses are added to the trial each year. The grasses were watered until established, then no other supplemental water was given throughout the duration of the trial. A pre-emergent herbicide (Treflan) was applied three days after planting, and a layer of hardwood mulch was put down for additional weed suppression. Hand-pulling and occasional spot-spraying of herbicides such as glyphosate and halosulfuron were used to keep weeds in check. The foliage remained on the plants throughout the winter and was cut to a height of about four in. each March. This trial site has a tree line at the southern edge, but is otherwise open and exposed to the sun and wind.

At the end of the growing seasons (September), the grasses were counted for survival and measured for foliage height and flower height. Qualitative ratings on a 1 to 7 scale were taken for vigor (growth, strength, and substance of the vegetation) and floriferousness (overall visual impact of the foliage and flowers) to determine the cultivar's suitability for landscape use (1 = almost dead, 4 = acceptable, 7 = exceptional). If a grass had a survival rate ≥67% and received an average visual rating of 6 or higher, it was designated as a recommended variety for Kansas. Height and width data were collected all three years, but only the last year's data are presented, representing a mature plant.

Results

Hot and dry conditions made several of the *Miscanthus sinensis* cultivars turn red/brown, so the variegation was not as prominent. The *Sorghastrum nutans* (Indian Grass) is reseeding heavily. Although this native grass has attractive red seed heads, the foliage growth is not particularly ornamental for a landscape setting; consequently, it likely will not make the recommended list, but it could be used in naturalized areas.

This is the second year for several new *Panicum virgatum* (Switchgrass) varieties. 'Badlands,' 'Cheyenne Sky,' and 'Thundercloud' all look like excellent cultivars and bring our total Switchgrass cultivar numbers up to 10 in the trial. Although these are cultivated from native prairie grass, some cultivars perform better than others. 'Prairie Sky' has been particularly poor in both Olathe and Wichita. 'Shenandoah' was a beautiful grass for its first 3 years, but had very poor survival in 2010 and was not nearly as attractive as before. The cultivars 'Cloud Nine' and 'Dallas Blues' have had consistently good performances, with 'Northwind' and 'Heavy Metal' also looking to be strong cultivars for Kansas.

Some new native grasses will be added to the trial beginning in 2011, including *Bouteloua gracilis* 'Blonde Ambition' Sideoats, *Andropogon gerardii* 'Red Bull' Big Bluestem, *Schizachyrium scoparium* 'Blaze' Little Bluestem, and *Sporobolus heterolepis* 'Tara' Prairie Dropseed.

This trial will run for several years, and you can find more detailed information about each grass on the KSU Turf website at http://ksuturf.com/OrnamentalGrasses.html and http://www.prairiestarflowers.com/Prairie Bloom pages/OrnamentalGrasses.html.

Table 1. Recommended ornamental grasses for Kansas

Genus, species	Cultivar	Flower color	Height (in.)	Width (in.)
Arundo donax	Variegata	Tan	156	84
Calamagrostis × acutiflora	Avalanche	Tan	18	20
Calamagrostis × acutiflora	Karl Foerster	Tan	40	20
Calamagrostis × acutiflora	Overdam	Tan	25	26
Eragrostis elliotii	Wind Dancer	Tan	40	30
Miscanthus × giganteus	Giant Miscanthus	Tan	120	72
Miscanthus sinensis	Adagio	Tan	45	62
Miscanthus sinensis	Little Kitten	Tan	47	62
Miscanthus sinensis	Little Zebra	Tan	54	84
Molinia arundinacea	Skyracer	Tan	29	28
Panicum virgatum	Cloud Nine	Tan	78	90
Panicum virgatum	Dallas Blues	Pink	64	66
Panicum virgatum	Northwind	Tan	51	24
Pennisetum orientale	Karley Rose	Pink	35	59
Saccharum ravennae	Hardy Pampas	Tan	60	60
Schizachyrium scoparium	Little Bluestem	Tan	16	14
Sporobolus heterolepis	Prairie Dropseed	Tan	15	16

Long-Term Changes of Selected Zoysiagrass Grown Under Dense Shade

Objective: To determine changes and differences among selected *Zoysia* genotypes grown under a shaded environment over a three-year period.

Investigators: Kenton Peterson, Jack Fry, and Dale Bremer

Sponsors: Kansas Turfgrass Foundation and Heart of America Golf Course Superintendents Association

Introduction

Zoysiagrass (*Zoysia* Willd.) is becoming a more common turfgrass for use in home lawns and golf courses throughout the transition zone and the southeastern United States. The lower input requirements of zoysiagrass compared with other available turfgrasses are driving its popularity. The shade tolerance of zoysiagrass is considered good, but it typically thins over time.

Three species of *Zoysia* are used for turfgrass: *Z. japonica*, *Z. matrella*, and *Z. pacifica*, but only *Z. japonica* and *Z. matrella* exhibit sufficient cold tolerance for use outside subtropical regions. *Zoysia japonica* is defined by its coarser texture, lower shoot density, and superior cold tolerance compared with the other *Zoysia* species. Previous research based on plug growth has shown that progeny crosses from 'Emerald' x 'Meyer' have improved shade tolerance.

Methods

The study was conducted at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. (Figure 1). Turfgrass plots were 61cm × 61cm and arranged in a randomized complete block design with five replications. Treatment design was a single factor (zoysiagrass genotype). Plots were planted under natural silver maple tree shade. Photosynthetically active radiation was measured on August 10 and 11, 2010, (Figure 2) using the AccuPar LP-80 ceptometer (Decagon Devices, Pullman, WA). The effect of the tree shade on light quality was estimated using a UniSpec-DC Spectral Analysis System (PP Systems, Amesbury, MA).

Eight zoysiagrass genotypes were selected for evaluation. The genotypes selected for this study were 'Zorro' (*Z. matrella*), 'Emerald' (*Z. matrella* x *Z. pacifica*), 'Meyer' (*Z. japonica*), Chinese common (*Z. japonica*), and the experimental progeny 5313-46 ('Zorro' x 'Meyer'), 5321-3 ('Emerald' x 'Meyer'), 5321-18 ('Emerald' x 'Meyer'), and 5321-45 ('Emerald' x 'Meyer').

Zoysiagrass was established in the greenhouse from plugs prior to sodding in the field on June 10, 2010. Chinese common zoysiagrass sod was harvested from a local golf course and planted on June 11, 2010. Plots were fertilized at planting with 5 g N/m^2 with 18-20-0 N-P-K fertilizer. Plots were maintained at 7 cm mowing height and received 5 g N/m^2 per year.

Data collected included shoot elongation rate (mm/day), tiller density (tillers/m^2), leaf width (mm), gross photosynthesis (µmols CO_2/m^2 per second), and turfgrass reflectance. Visual ratings for genetic color, density, quality, fall color retention, and spring greenup were taken monthly on a 1 to 9 scale (1 = poor, 6 = minimum acceptable, 9 = superior).

Results

Visual color, density, and quality ratings decreased from June to July (Table 1); however, all visual ratings increased from July to August. The decrease in ratings observed from June to July may be due to the zoysiagrass expending more energy on establishment than vegetative growth. Color of experimental progeny 5321-18 appeared to be the least affected by the shade because ratings remained constant throughout the growing season whereas all other genotypes exhibited decreases in color. Visual quality of 'Emerald,' 'Meyer,' 'Zorro,' and '5321-18' all maintained minimally acceptable quality ratings throughout all rating dates during summer 2010 (Table 1).

Mean tiller count data exhibited a decrease in total tillers from June to September (Table 2). Tiller counts decreased 4% to 29% from June to September, respectively. The experimental progeny 5321-3 exhibited only a 4% decrease in tillers. Progeny 5321-18, 'Emerald,' and 'Zorro' had the highest tiller counts in September.

The growth rate of the zoysiagrass genotypes decreased from July to September. Chinese common exhibited the fastest growth rate and 'Emerald' showed the lowest rate during July. Leaf width for the zoysiagrass progeny 5313-46 and 5312-45 increased from July to September. The leaf width of the other genotypes decreased during that time. 'Zorro' and 'Emerald' retained their color later in the fall than the other genotypes and maintained an acceptable color through the rating date on November 15, 2010. All other genotypes rated below 6.0.

Table 1. Mean zoysiagrass visual quality ratings in 2010

	Visual quality (1 to 9 scale)[1]				
Genotype	June	July	August	September	Season mean
Common	7.0 d[2]	6.8 b	6.8 bc	6.6 b	6.80 c
Emerald	8.4 ab	7.2 ab	7.6 ab	8.0 a	7.80 ab
Meyer	7.8 bc	7.4 ab	7.8 a	7.2 b	7.55 bc
Zorro	8.8 a	7.8 a	8.0 a	8.0 a	8.15 a
5313-46	8.2 abc	7.2 ab	7.2 abc	6.8 b	7.35 c
5321-3	5.4 e	5.0 c	6.2 c	5.3 c	5.45 e
5321-18	8.6 a	8.0 a	8.0 a	8.2 a	8.20 a
5321-45	7.6 cd	6.8 b	7.4 ab	7.2	7.25 c

[1] 1 = poor, 6 = minimum acceptable, 9 = optimum
[2] Means within a column followed by a different letter are significantly different based on Fisher's Protected LSD at $P<0.05$.

Table 2. Mean zoysiagrass tiller counts in 2010

	Number of tillers/m²				% change
Genotype	June	July	August	September	June-September
Common	5,163 cd	4,400 e	4,355 d	4,085 e	-21%
Emerald	9,517 a	8,305 ab	8,979 a	7,542 a	-21%
Meyer	6,240 bc	6,106 dc	6,330 c	4,579 dc	-27%
Zorro	9,293 a	7,228 bc	8,620 ab	7,228 ab	-22%
5313-46	8,395 a	7,542 abc	7,318 bc	5,926 bc	-29%
5321-3	4,180 d	4,510 de	4,401 d	4,004 e	-4%
5321-18	8,350 a	8,979 a	8,575 ab	6,465 abc	-23%
5321-45	7,722 ab	6,689 bc	6,554 c	5,612 cd	-27%

[1] Means within a column followed by a different letter are significantly different based on Fisher's Protected LSD at $P < 0.05$.

Figure 1. Zoysiagrass shade study research plots at the Rocky Ford Turfgrass Research Center.

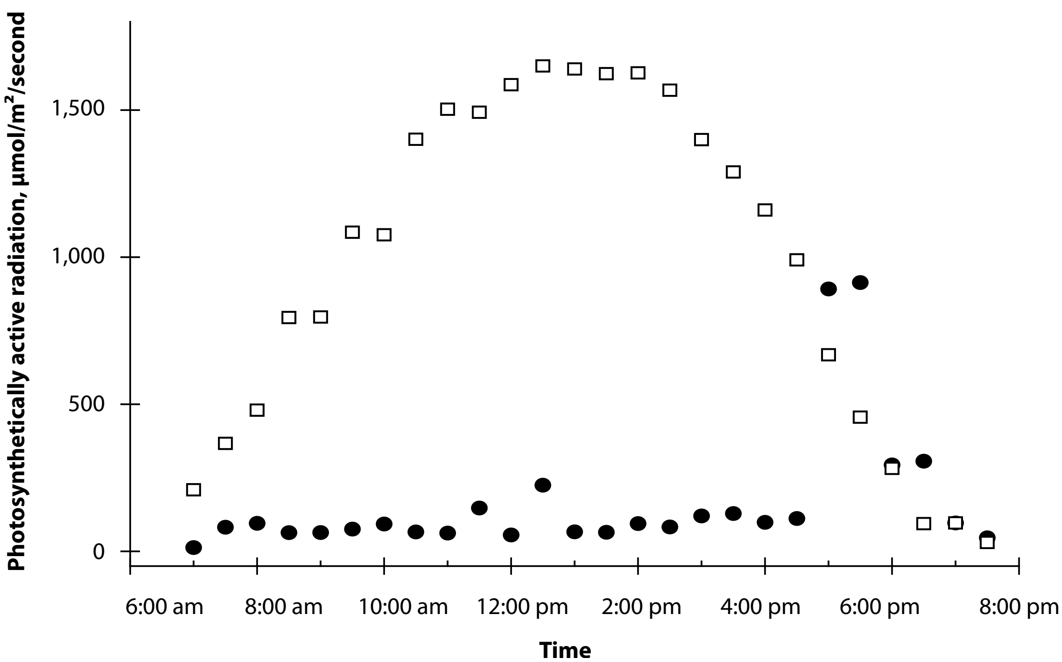


Figure 2. Mean photosynthetically active radiation under tree shade and in full sun on August 10 and 11, 2010.
Open squares and filled circles represent full sun and tree shade radiation, respectively.

Response of Kentucky Bluegrass Cultivars to Prolonged Drought in the Transition Zone

Objective: Evaluate the response of 28 Kentucky bluegrass cultivars to prolonged drought exposure in the transition zone.

Investigators: Tony Goldsby, Dale Bremer, Steve Keeley, and Jack Fry

Introduction

Water availability and restrictions are increasingly serious issues in the Midwest and across the United States. Drought restrictions may be imposed on turf managers with no regard for damage to turfgrass. For turf managers, thriving in an industry where turf quality is the top priority is difficult when water is limited; therefore, research investigating turfgrass resistance to drought stress has become increasingly important.

Kentucky Bluegrass (KBG) (*Poa Pratensis)* is the most widely used cool-season turfgrass in the U.S. It can be found in lawns, golf courses, cemeteries, parks, school grounds, athletic fields, and other areas where a dense grass cover is desired. Because of substantial diversity among cultivars of KBG, researchers have classified KBG into several phenotypic groups. This classification system groups cultivars that have similar growth and stress performance characteristics.

A fully automated rainout shelter (Figure 1) located at Rocky Ford Turfgrass Research Center in Manhattan, Kan., offers the ability to compare multiple KBG cultivars while restricting water. Kentucky bluegrass cultivars that have the ability to survive and recover from long periods of drought stress may be useful in areas where water restrictions are expected. The objective of this study is to evaluate the response of 28 cultivars of KBG to prolonged drought exposure in the transition zone. This study, although unique, is an extension of an earlier study that evaluated water requirements of the same bluegrasses; results were reported in K-State Turfgrass Research 2010 (see "Irrigation Requirements of 28 Kentucky Bluegrass Cultivars and Two Texas Bluegrass Hybrids in the Transition Zone," page 74).

Cultivars, Turfgrass Management, Experimental Design

The selected 28 KBG cultivars were chosen to include representatives from each of the major KBG phenotypic groups. Several of the cultivars were chosen due to their excellent performance in National Turfgrass Evaluation Program trials. Preparation of the plot area included cultivation, fumigation, leveling, and insertion of 30-cm-deep metal edging around individual plots to prevent lateral movement of water. Plots (3.7 ft × 4.0 ft each) were seeded on September 19, 2006, at approximately 2 lb/1,000 ft^2 pure live seed in a randomized complete block design; cultivars were replicated three times each for a total of 90 plots. Starter fertilizer (18-46-0 N-P-K) was applied at a rate of 1 lb N/1,000 ft^2. Plots were covered with a seed germination blanket (Futerra F4 Netless, Profile Products LLC, Buffalo Grove, IL) to prevent movement of seed across plots from water or wind and were irrigated several times daily to maintain a wet seedbed during germination. Plots were mowed at approximately 2 in. as needed.

Methods

Plots were well watered until July 4, 2010, then allowed to dry down without irrigation or precipitation for 60 days (until September 4, 2010) (Figure 2). All 28 cultivars were rated visually for color and quality on a weekly basis. Turfgrass quality was rated on a 1 to 9 scale; 1 = poor, 6 = minimally acceptable, and 9 = best. Percentage green turfgrass cover was estimated from digital images, which were acquired weekly in all cultivars. Additional physiological measurements were collected from 7 of the 28 cultivars. These 7 cultivars were selected based on results from the earlier study, which ranked cultivars by the amount of water applied in a 2-year study. We selected cultivars that had a broad range of water use to better understand the physiological mechanisms behind their drought resistance or lack thereof. The physiological measurements included were leaf water potential (measured bi-weekly), electrolyte leakage, and gross photosynthesis (measured weekly). Volumetric soil water content was monitored daily at 5 and 20 cm by utilizing the dual probe heat pulse technique. In addition, volumetric soil water content from 0 to 50 cm was measured weekly in the 7 cultivars with time domain reflectometry.

Results

First-year results suggest the Compact-America and Mid-Atlantic groups may recover quicker from prolonged drought stress than the other groups. Specifically, cultivars 'Cabernet' and 'Apollo' both exhibited higher visual quality (Figure 3) during recovery than the other cultivars. Additionally, 'Apollo' had the highest percentage green turfgrass cover on 9 of 10 dates in 2010 (Figure 4). This study will be replicated in the same location in the summer of 2011.

Figure 1.Well-watered plots on July 4, 2010, prior to the initiation of the 60-day drydown.

Figure 2. Plots on September 4, 2010, after receiving no irrigation for 60 days.

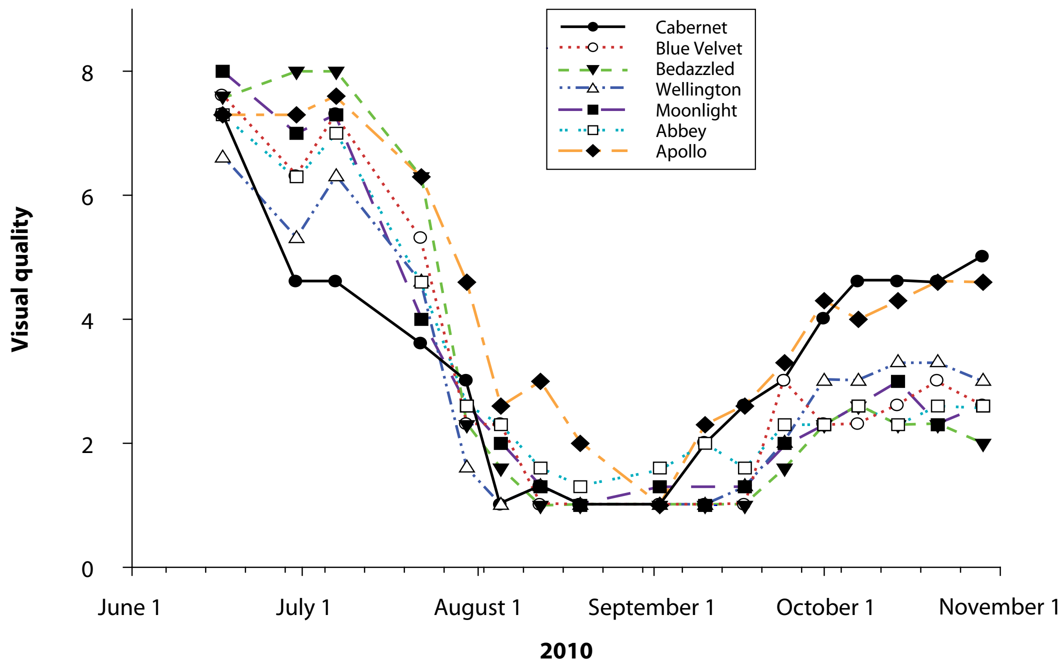


Figure 3. Visual quality ratings for 7 of the 28 cultivars included.
Ratings were on a scale of 1 to 9 (1 = poor, 6 = minimally acceptable, 9 = best).

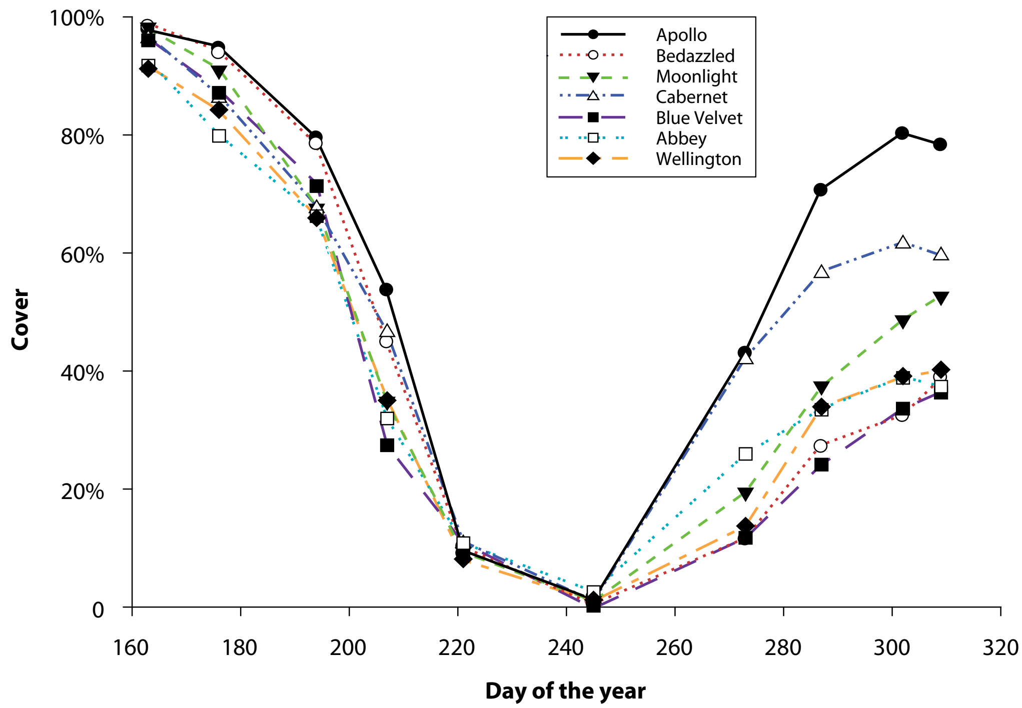


Figure 4. Percentage green turfgrass coverage for 7 of the 28 cultivars included in the study.

Responses of Turfgrass and Ornamental Landscape Species to Prolonged Drought Stress

Objectives: Evaluate quality and water status of one turfgrass species and eight groundcover species during a severe drydown and subsequent recovery.

Investigators: Cody Domenghini, Dale Bremer, Jack Fry, and Greg Davis

Sponsor: Kansas Turfgrass Foundation

Introduction

Water resources are being depleted as the world's population continues to grow. As a result, water conservation continues to be an important issue in the lawn and landscape industry. Turfgrasses are often singled out for replacement by more drought-resistant plant species to reduce the amount of water needed to maintain a landscape at an acceptable level of quality. Additionally, despite the frequency of municipal water restrictions on residential landscapes, scientific research about drought stress of many landscape plants compared common turfgrass species is limited.

Methods

This research was conducted in the Kansas State University Throckmorton Greenhouses (Figure 1) in Manhattan, Kan., in the spring and fall of 2010. The performance of one cool-season turfgrass (*Poa pratensis*) and eight common landscape species (*Achillea millifolium, Ajuga reptans, Liriope muscari, Pachysandra terminalis, Sedum album, Thymus serpyllum, Vinca major,* and *Vinca minor*) was evaluated during a severe drydown and subsequent recovery. The pots were arranged in a randomized complete block design with three replicates of each species. Plant performance was evaluated three to four times a week during the drydown and recovery by visually rating pot quality on a scale of 1 to 9 (1 = dead, dormant; 6 = minimum acceptable quality for a home landscape; and 9 = optimum quality). Additionally, water status measurements were taken throughout the drydown. Pot weight and volumetric water content measurements were taken three to four times per week, stomatal conductance was measured one to two times a week, and leaf water potential and electrolyte leakage measurements were taken when the soil moisture of each pot was within the following ranges: 23 to 36%, 18.5 to 21%, 15.9 to 17%, 14.3 to 15%, 10 to 14%, and less than 10%. Environmental conditions in the greenhouse were also monitored (Figure 2) throughout the studies.

Results

During the drydown, several species deteriorated faster than others to the lowest quality rating of 1. *Sedum album* consistently performed the best during each study, taking 220 to 266 days to decline to a quality rating of 1. *Liriope muscari* and *Pachysandra terminalis* also performed well, with a mean range of 62.3 to 122 days. *Vinca minor* and *Vinca major* declined faster than the previous three species, averaging 48.3 to 78.6 days to drop to a quality rating of 1. Finally, *Achillea millifolium*, *Ajuga reptans*, *Poa pratensis*, and *Thymus serpyllum* performed the worst by declining to a quality rating of 1 within 39 to 73 days (Table 1). *Poa* pratensis, *Ajuga reptans*, *Vinca major*, and *Sedum album* were the only species to recover in the first study, with 13.3% to 46.6% recovery after 60 days; the greatest recovery was in the turfgrass *Poa pratensis* (Table 1). None of the species recovered during the second study, probably because of a more severe vapor pressure deficit (Figure 3) caused by artificial lights that were needed in the fall, which caused the pots to dry down faster. Results from this study indicate *Sedum album*, *Liriope muscari*, and *Pachysandra terminalis* would be most successful in landscapes where severe drought may occur. In landscapes with intermittent or less severe droughts, *Vinca minor* and *Vinca major* may also be good selections, as well as *Poa pratensis* and *Ajuga reptans* if periods of dormancy are acceptable to homeowners.

Table 1. Average days to receive a quality rating of 1 and percentage of species recovery after 60 days

	Spring 2010		Fall 2010	
Species	Days to quality rating of 1	Recovery after 60 days	Days to quality rating of 1	Recovery after 60 days
Sedum album	266 a[1]	33.3%	220 a	NR
Liriope muscari	122 b	NR[2]	78.6 b	NR
Pachysandra terminalis	62.3 c	NR	81.3 bc	NR
Vinca minor	51 d	NR	72 bc	NR
Vinca major	48.3 d	23.3%	78.6 c	NR
Thymus serpyllum	41.6 e	NR	57 cd	NR
Poa pratensis	39 e	46.6%	65.3 d	NR
Ajuga reptans	39 e	13.3%	73.3 d	NR
Achillea millifolium	39 e	NR	64.6 e	NR

[1] Within a column, means followed by the same lowercase letter are not statistically different according to LSD ($P < 0.05$).
[2] NR indicates that the plants did not recover within 60 days, therefore no data were collected.

Figure 1. Well-watered pots in May 2010 at the beginning of the severe drydown.

Figure 2. Environmental conditions (temperature, relative humidity, and photosynthetically active radiation) in the greenhouse were monitored.

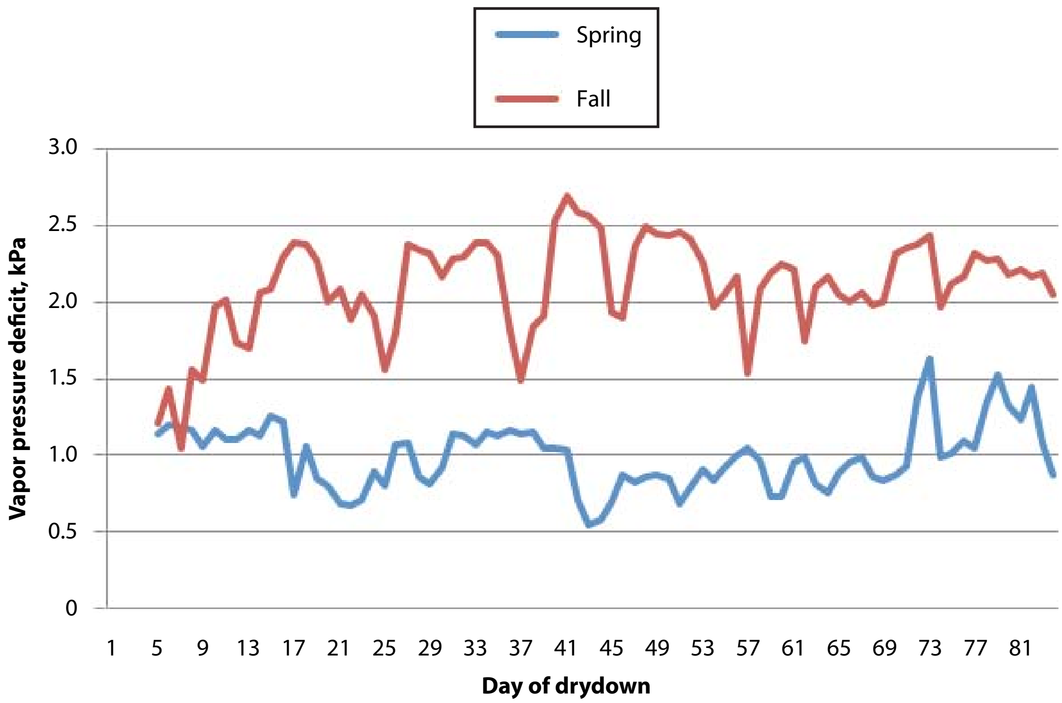


Figure 3. Average vapor pressure deficit for spring and fall 2010.

Modifying Homeowners' Lawn Watering Habits: A Survey

Objective: Survey residential homeowners in Wichita, Olathe, and Salina, Kan., about guiding principles when making decisions to irrigate and their willingness to adopt water-saving practices.

Investigators: Dale Bremer, Jack Fry, Steve Keeley, Cathie Lavis, and Laura Moley

Sponsors: USDA National Integrated Water Quality Program; Wichita Department of Environmental Services; Olathe Municipal Services; Salina Utilities Department; Kansas Turfgrass Foundation

Introduction

Urban growth is replacing significant areas of land with turfgrass that once were occupied by native vegetation or agricultural crops. Up to 50 million acres, or as much as 18% of the land in some parts of the United States, are covered with turfgrasses. This represents an area three times larger than any irrigated crop. Furthermore, urban growth in the U.S. alone is projected to increase 79% by 2025, indicating a continued expansion of land covered with turfgrasses.

The rapid increase of turfgrass in the landscape has significant implications for both water quality and quantity. For example, urban growth has been linked with declining water quality in surface and groundwater reservoirs due to increased concentrations of nutrients and pesticides, including those used in lawns. Irrigation of turfgrass is typical in urban areas, which increases demand for already limited water resources. Water scarcity is even more critical in arid or semi-arid regions experiencing rapid urban growth.

Water quality in urban areas is affected, in part, by runoff and leaching of fertilizer nutrients and pesticides from lawns, typically during intense rainstorms or when turfgrass is overirrigated. Runoff and leaching is typically a result of inadvertent application of fertilizers and pesticides to hard surfaces such as driveways or sidewalks, or when heavy rates are used on sandy soils. The extent of excessively irrigated turfgrass is not known, but overirrigation apparently has altered the hydrologic system of the Las Vegas Valley such that historically dry washes have become perennial streams. This indicates a critical need to change the behavior of urbanites to reduce their irrigation inputs in lawns, thus conserving water and improving water quality.

The greatest opportunity for conserving water and minimizing runoff and leaching in urban areas is probably in residential lawns. About 50 to 65% of all land area covered with turfgrass in the U.S. comprises residential lawns, and up to 90% of residential water use may be for outdoor purposes in some regions. The use of automatic irrigation systems by homeowners, which are typically installed during construction of new single-family homes in urbanizing watersheds, may be both problematic and advantageous to water conservation efforts. In-ground irrigation systems may use twice the amount of water as manual irrigation if the systems are improperly adjusted. These systems, however, also may present opportunities for more accurate irrigation (for example, applying only the minimal or actual water needs of the turfgrass) if residents are properly educated.

Surveys of U.S. homeowners, including in Kansas, have indicated their willingness, in principle, to conserve water. Perceptions about water requirements for turfgrass or even societal expectations about lawn appearance (e.g., maintaining "trophy lawns," or perfectly green lawns even during drought), however, may result in continued overirrigation; therefore, research is needed to carefully evaluate perceptions and practices of homeowners in irrigating their lawns. In this study, residential homeowners in three Kansas metropolitan areas were surveyed about guiding principles when making decisions to irrigate and their willingness to adopt water-saving practices.

Methods

Residential homeowners were surveyed in Wichita, Olathe, and Salina, Kan., in the late spring and early summer of 2009. Wichita is about 160 miles to the west-southwest and Salina is about 151 miles west of Olathe. The climates of Wichita and Salina are more similar to each other than to Olathe. Both Wichita and Salina receive about 6 to 12 in. less annual precipitation than Olathe, resulting in greater irrigation demands for lawns in Wichita and Salina.

Each household surveyed received a one-page, tri-fold survey mailer. Surveyees were asked 11 questions related to how they made decisions to irrigate their lawns, their knowledge about water requirements of their lawns and how much water they were applying, whether they swept or blew their driveways after applying lawn-care products or mowing (grass clippings), whether they had in-ground irrigation sprinklers, and their perceptions about the importance of the quality of their lawns, water conservation, water bills, etc. Homeowners were asked to complete the survey and return it postage paid. The total number of surveys mailed included 15,534 to Wichita, 10,000 to Olathe, and 5,000 to Salina. The return rate was about 11.1 to 13%, with total returns of 1,772 from Wichita, 1,110 from Olathe, and 652 from Salina.

Results

When asked about the appearance of their lawns, 48 to 63% of residential homeowners indicated it was very to moderately important that their lawns looked green all the time (Figure 1). When asked about the importance of water conservation, 63 to 79% of respondents indicated it was very to moderately important (Figure 2). Interestingly, Salina residents were the most concerned about water conservation and the least concerned about having green lawns, which was reflected in their lawn-watering habits (Figure 3). For example, in Salina, 44% indicated they watered their lawn once per week or less during dry periods of the summer, whereas in Wichita, which has a similarly semi-arid climate as Salina, only 23% watered their lawns that infrequently (Figure 3). Economics may have been a driving factor in Salina, because 55% of Salina residents indicated it was very important their water bills didn't get too high compared with only 37% in Wichita (Figure 4).

Survey results indicated residential homeowners need more information about the water requirements of their lawns and about the amount of water they are applying to their lawns when they irrigate. For example, 61 to 63% of respondents in all three metropolitan areas did not know how much water their lawns required. Of those who indicated they did know, nearly 25% overestimated their lawns' water requirements when asked to specify the amount of water their lawns needed. Significantly, 71 to 77% of respondents in all three metropolitan areas did not know how much water they applied to their lawns when they irrigated. This indicates a need to educate homeowners about how to measure the amount of water they apply during irrigation. An example would be teaching them how to audit their sprinkler systems. In Wichita, the majority (55%) of residential homeowners had in-ground irrigation sprinklers, indicating a significant population with potential for conserving water.

Regarding water quality, residents were asked whether they swept or blew their driveways after applying lawn-care products and after mowing (grass clippings). Nearly half (43 to 46%) indicated they didn't, which is significant because lawn-care products or clippings left on impervious surfaces such as driveways, sidewalks, and streets are highly prone to washing down the storm drain, which leads directly to local streams or reservoirs. Of those residents who did sweep or blow their driveways after applying lawn-care products or mowing, 77 to 84% indicated they swept or blew them back into the lawn, which is preferred because research has demonstrated that runoff of lawn-care products from a lawn's surface is minimal. About 8% of homeowners swept or blew directly into storm drains (Figure 5). Although 8% initially seems small, it translates to nearly 7,900 homeowners in Wichita alone who sweep or blow lawn-care products or clippings directly into storm drains, and hence into local streams or reservoirs. Clearly, homeowners in urban areas need education about important issues of lawn care as it relates to water quality and water conservation.

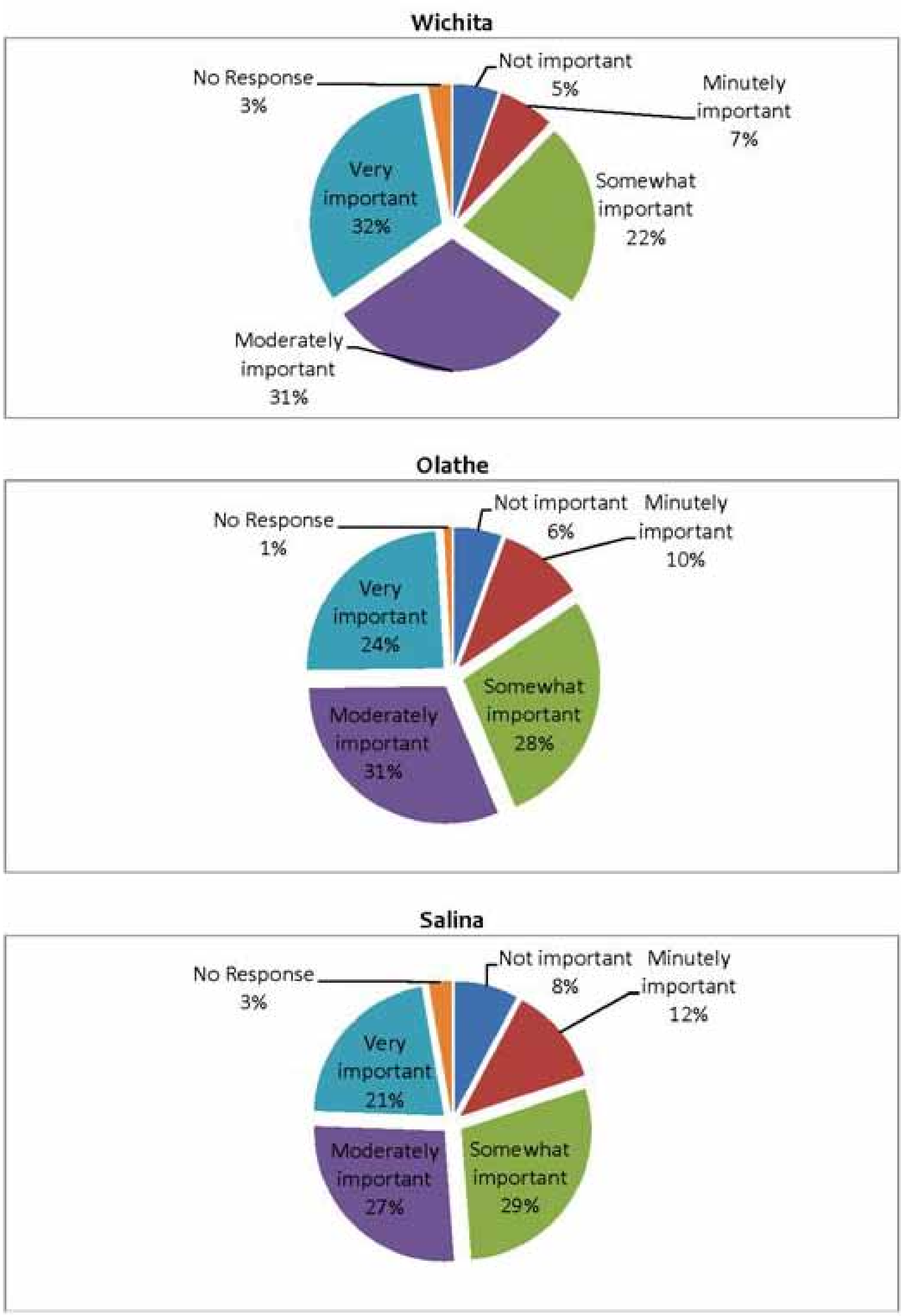
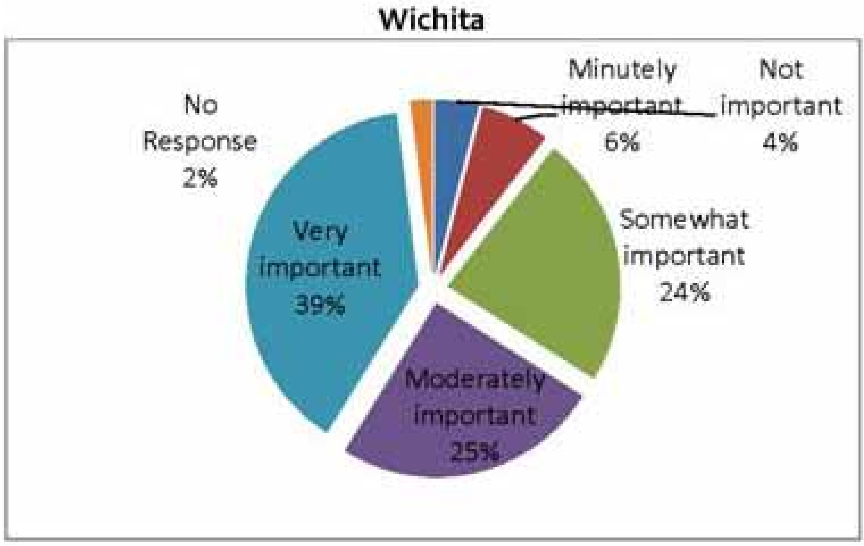
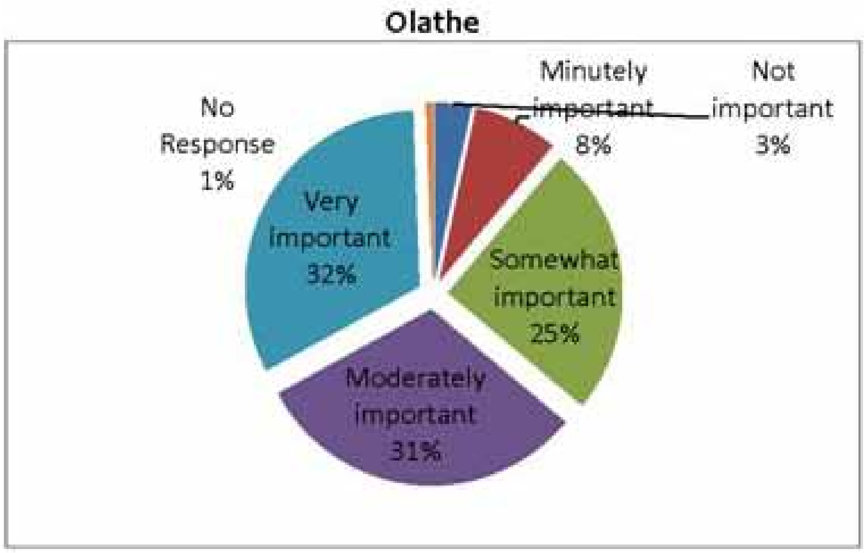


Figure 1. Residential homeowners were asked to rate the importance of their lawn appearance on a scale of 1 to 5, with 1 = important and 5 = very important.





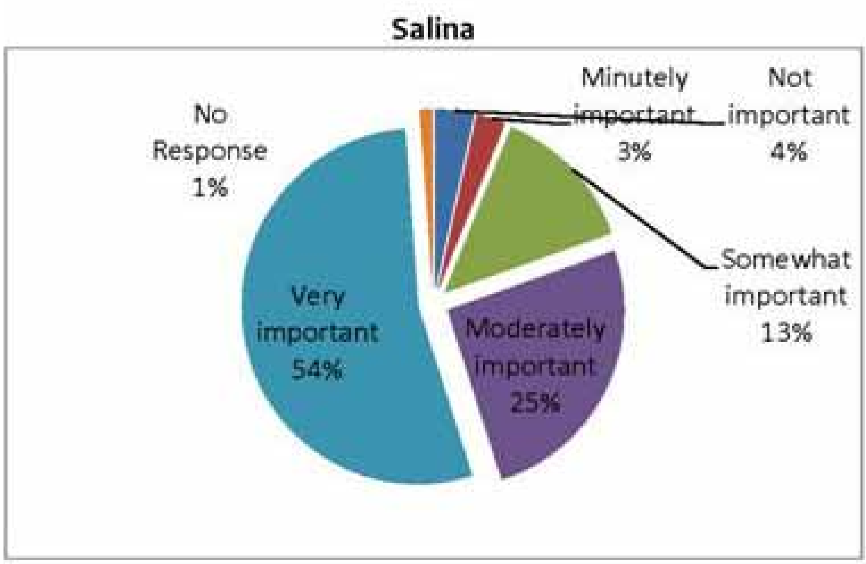
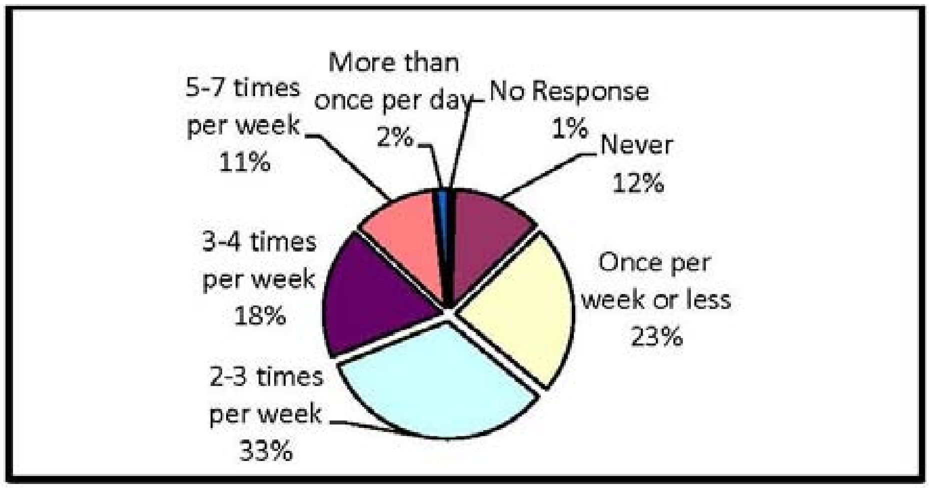
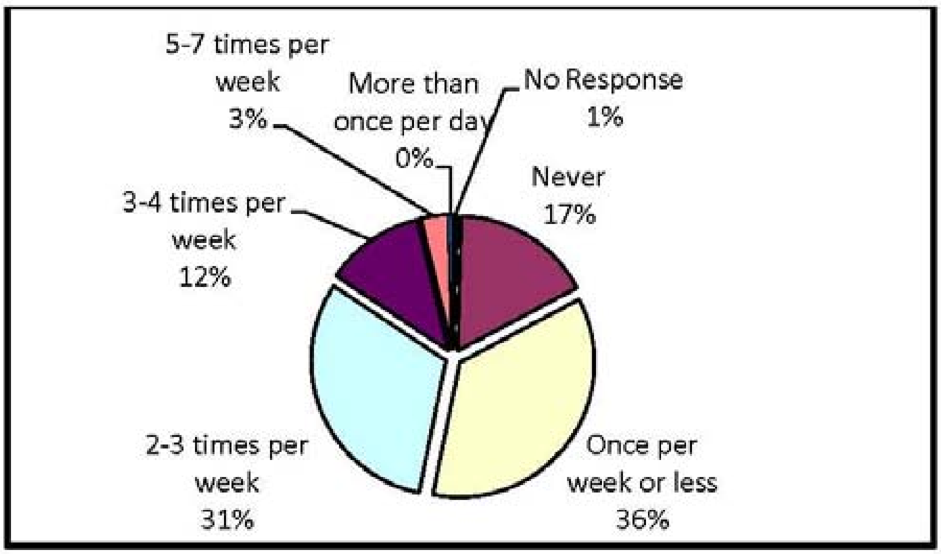


Figure 2. Residential homeowners were asked to rate the importance of water conservation on a scale of 1 to 5, with 1 = not important and 5 = very important.

Wichita



Olathe



Salina

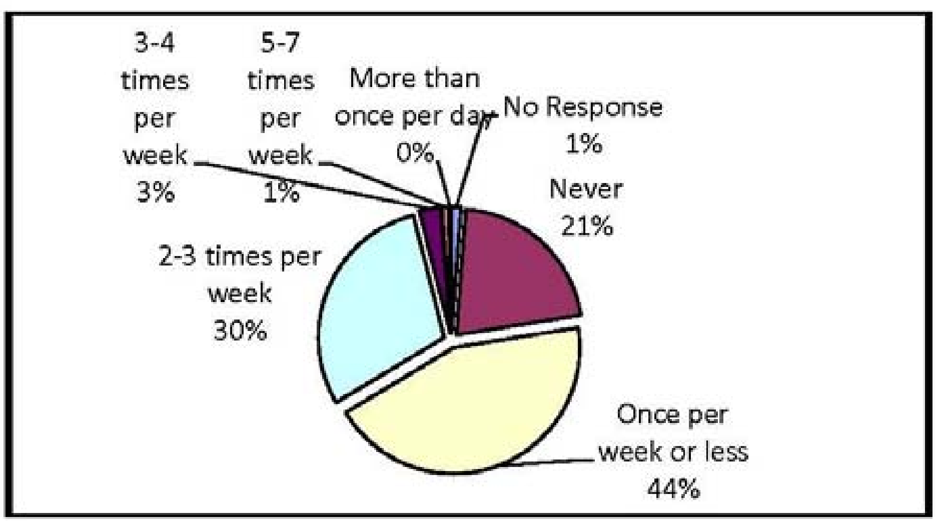
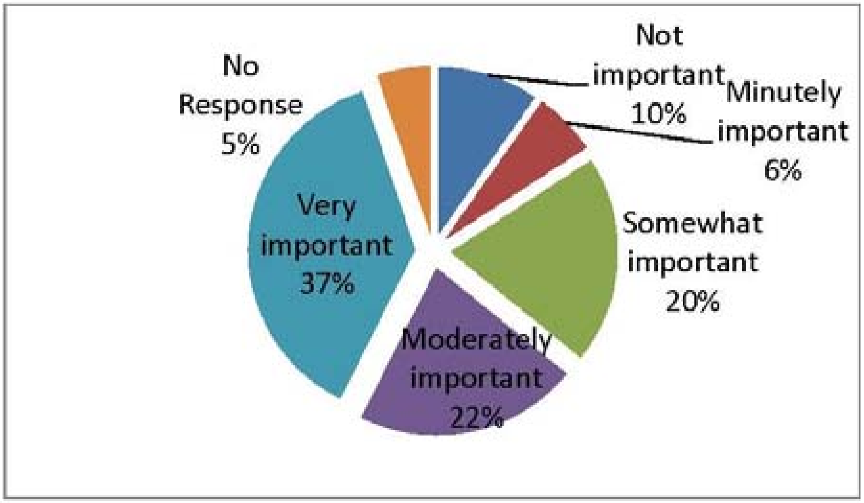
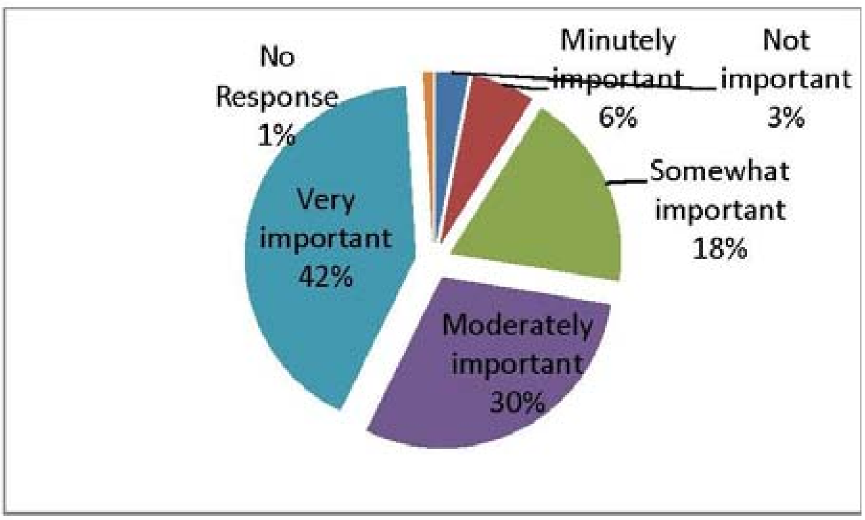


Figure 3. Residential homeowners were asked how often they watered their lawns during dry periods of the summer.

Wichita



Olathe



Salina

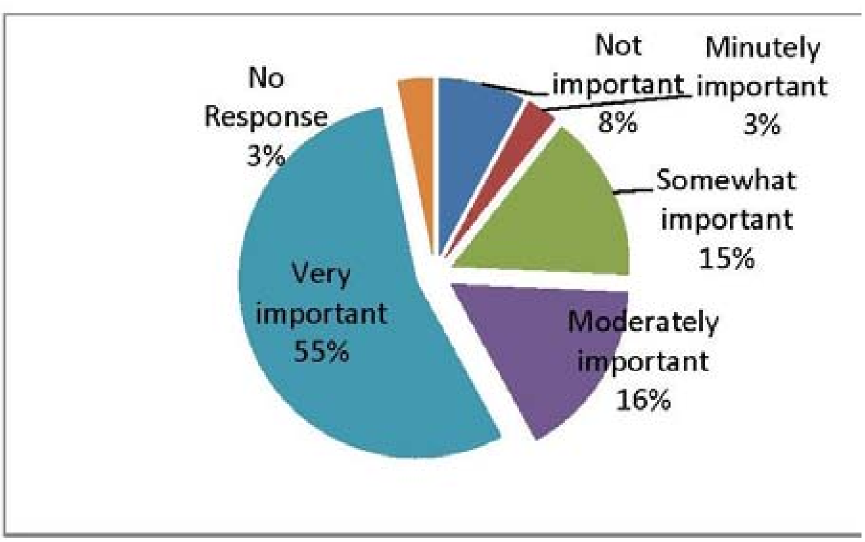


Figure 4. Residential homeowners were asked to rate the importance of preventing their water bill from getting too high on a scale of 1 to 5, with 1 = not important and 5 = very important.

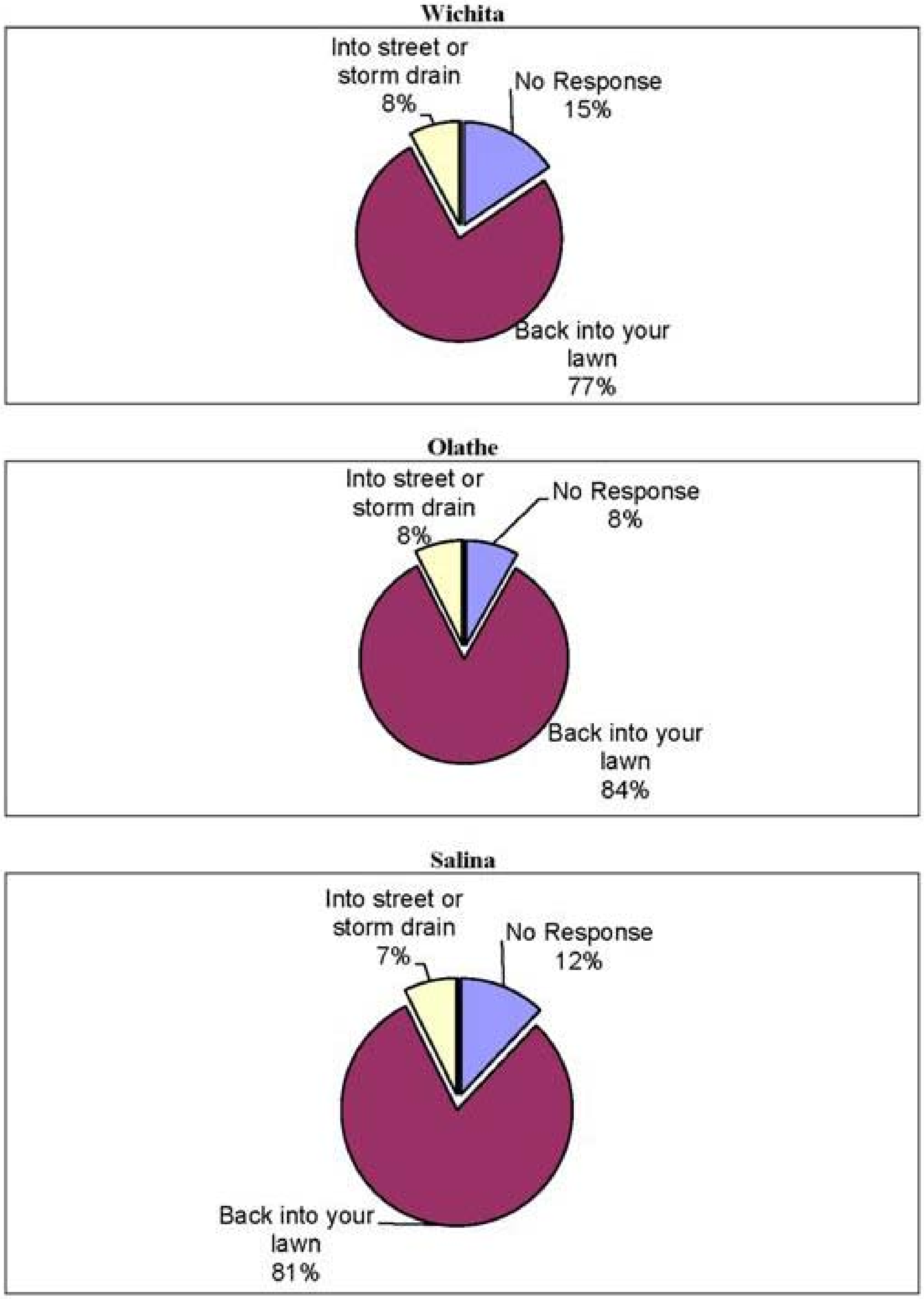


Figure 5. Residents who indicated they swept or blew their driveways after applying lawn-care products or mowing (grass clippings) were then asked whether they swept back into the lawns or directly into the storm drain.

Fabrication of a New Custom Photosynthesis Chamber

Objective: To improve upon previous designs by reducing air leakage.

Investigators: Kira Shonkwiler Arnold, Kenton Peterson, Dale Bremer

Introduction

The measurement of turfgrass photosynthesis using a large portable chamber has been investigated at Kansas State University for several years. In 2007, a "turf chamber" to measure photosynthesis over turfgrass was fabricated, tested, and compared with other chambers with successful results (see "Measurement of Photosynthesis and Respiration in Turfgrass With Large and Small Surface Chambers," K-State Turfgrass Research 2008, page 20, and "Measurements of Photosynthesis, Respiration, and Evapotranspiration in Turfgrass with a Custom Surface Chamber," K-State Turfgrass Research 2009, page 20). The design of the original turf chamber, "old chamber," led to difficulties in eliminating air leaks, which is important because leaks may result in inaccurate measurements of photosynthesis. To resolve this issue, an improved chamber was designed and fabricated to address air leakage.

Methods

The new turf chamber was constructed using 3/16-in. acrylic to the same dimensions as the previous chamber (0.5 × 0.5 m). To reduce the number of holes and seams necessary for fabrication, an acrylic bender was used to form an acrylic box (Figure 1). All seams were sealed with acrylic cement. A transparent, removable plenum was created for easy cleaning (Figure 2). Panel mount holes were sealed with rubber gaskets, and air-sampling tubes within the chamber were passed through the wall of the chamber using airtight threaded nylon connectors. This is an improvement from the old chamber, which utilized silicone sealant that needed periodic replacement. A cardboard box was used on the old chamber for dark measurements, which was cumbersome. A cover was sewn from blackout cloth to fit the chamber for dark measurements (Figure 3). The data logger and battery was stored in a small cooler on the old chamber; to allow for more flexibility of the user, the data logger and battery were moved to a backpack (Figure 3). The backpack also stores the cover for dark measurements, tools, storage module, and keypad.

Results

Air leakage was reduced in the new turf chamber compared with the previous chamber (Figure 4). Increasing CO_2 concentration 15ppm, both chambers held relatively consistent concentrations of CO_2 over the 60-second period. Increasing CO_2 concentration 100ppm, the old chamber showed a much greater decline in CO_2 concentration over time than the new chamber. The new chamber exhibits a better resistance to air leakage compared to the old chamber. Additionally, the other design modifications make the chamber easier to use in the field. Further field testing will be conducted to evaluate measurements of photosynthesis with the new chamber.

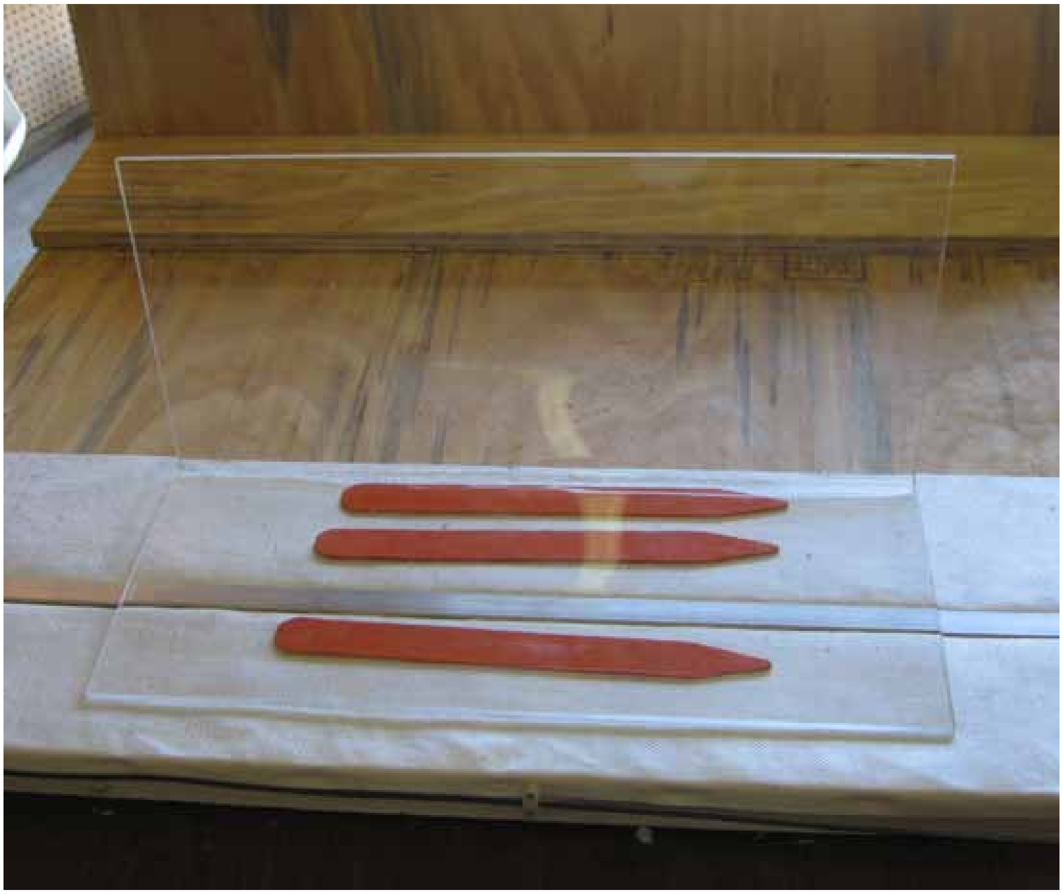


Figure 1. A custom-made acrylic bender that uses a strip heater makes acrylic pliable enough to bend.

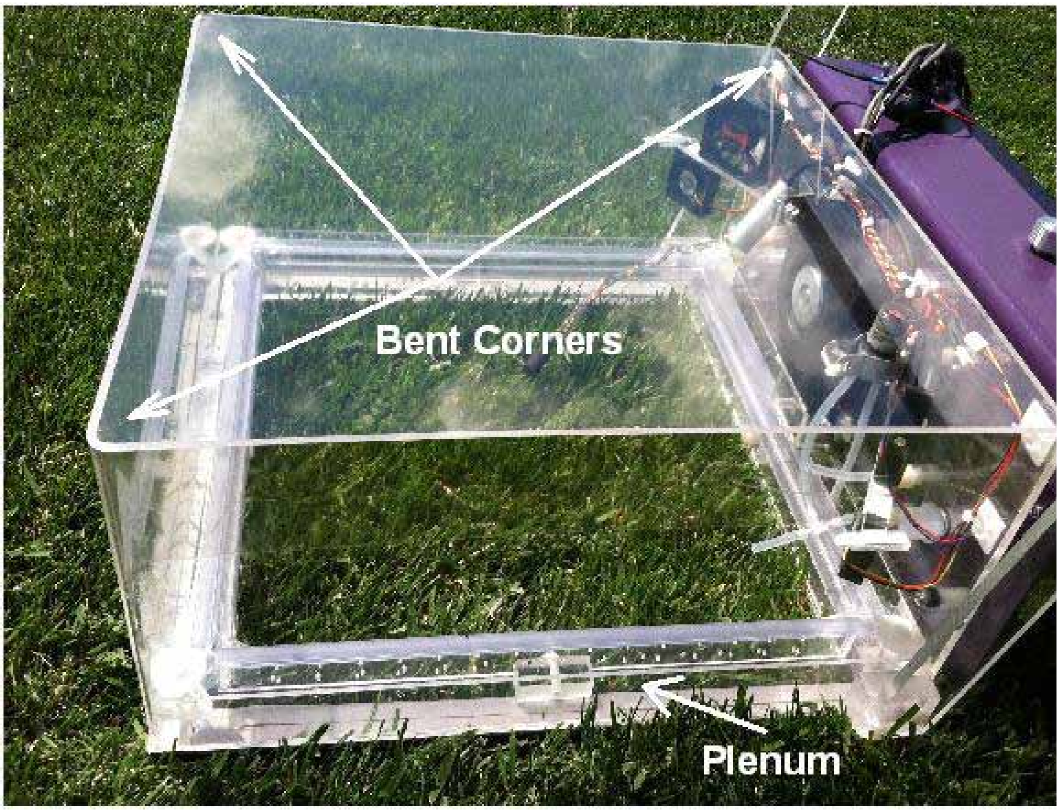


Figure 2. The new turf chamber design has bent corners and a transparent, removable plenum.

Figure 3. The new fabric cover facilitates dark measurements.
The operator is wearing the backpack containing the data logger and battery.

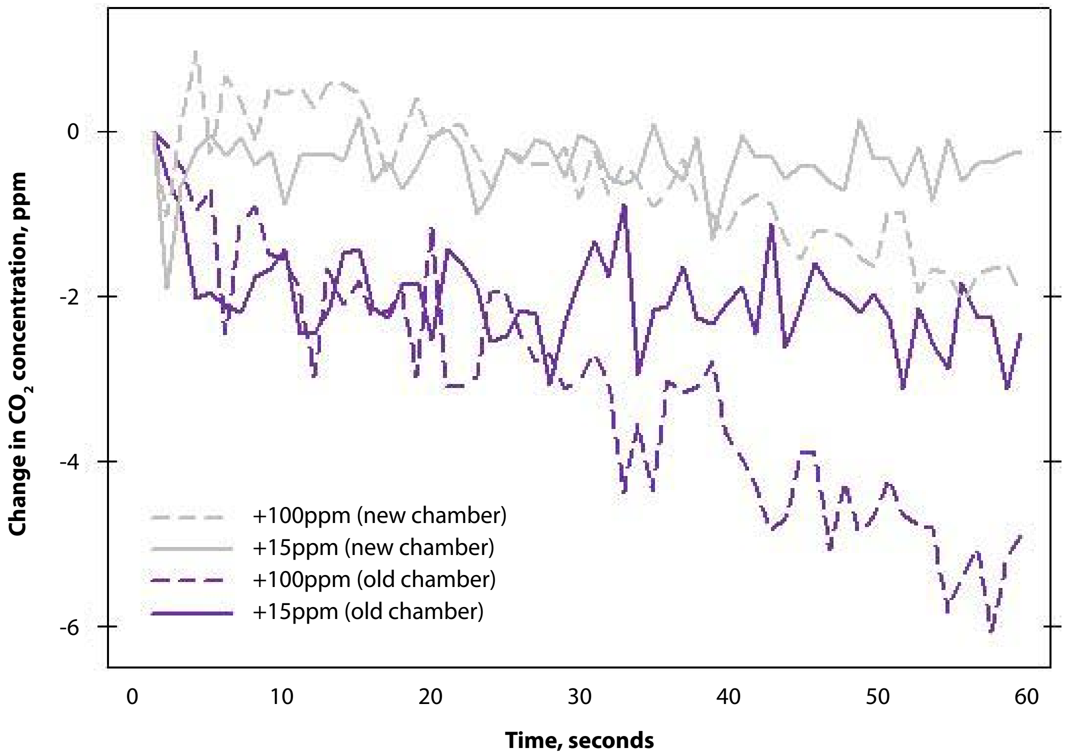


Figure 4. Change in CO_2 concentration over time at two increased concentrations of CO_2 above ambient CO_2 under laboratory conditions.

Custom Light Box for Digital Image Turfgrass Analysis

Objective: To fabricate a custom light box for taking digital images of turfgrass plots.

Investigators: Kenton Peterson, Kira Shonkwiler Arnold, Dale Bremer

Introduction

Turfgrass studies often require visual assessments of canopy traits such as color or percentage green cover, but visual analysis is subjective and therefore can be unintentionally biased. Environmental conditions such as variable cloud cover, sunlight intensity, and solar angle are often non-optimal. A light box provides a uniform environment in which unbiased and quantitative measurements of turfgrass percentage cover and color can be obtained.

Methods

The light box (20 × 24 × 22 in.) was fabricated from 0.063-in.-thick aluminum. Constructing the light box from aluminum makes it light enough to be moved by hand. Four compact fluorescent light bulbs (model CF13EL/MICRO/C/865/BL2; color temperature = 6,500K; Sylvania, Danvers, MA) mimicking natural sunlight color temperature (5,500 to 6,500K) were installed inside the box (Figure 1). The light bulbs are powered by a portable power pack (Duracell Power Pack 600, Duracell, Bethel, CT) (Figure 2). The camera is mounted in the center of the box and a sponge surrounding the lens prevents sunlight from entering the light box and provides support to the camera (Figure 2). Images will be processed with SigmaScan Pro 5.0 using a macro created by researchers at the University of Arkansas for analysis of turfgrass color and percentage cover.

Results

The successful fabrication of this light box will enable turfgrass researchers at Kansas State University to take more quantitative, and thus more accurate, measurements than qualitative visual ratings of turfgrass quality and percentage cover. For example, Figure 3 illustrates how digital photos taken with the light box can be analyzed using the software and macro. Pixels of interest (green) are quantified, and the proportion of green pixels to the total number of pixels in the photo is used to calculate percentage green cover. Also, we will be able to measure different hues of green with the light box, which will assist in the evaluation of turfgrass quality.

Figure 1. Internal view of the light box showing the wiring and light bulb placement.

Figure 2. The light box, powered by the portable pack, in use over a research plot.

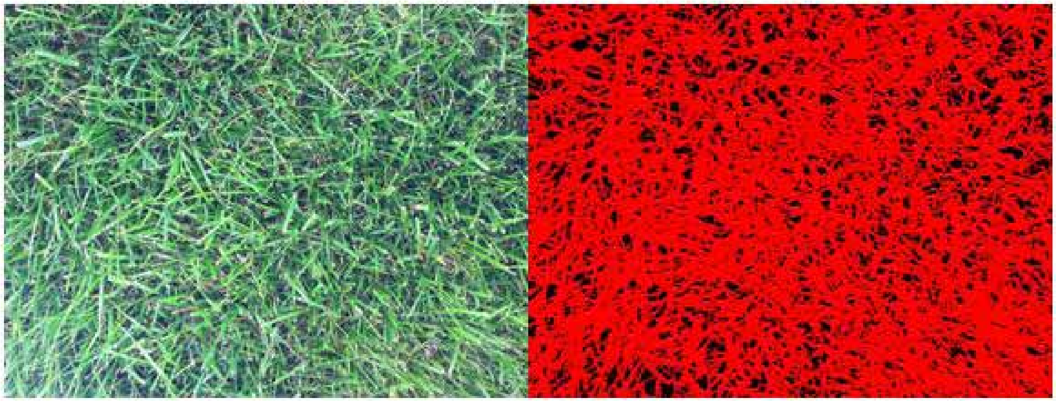


Figure 3. The image on the left is a photo taken using the light box. The image on the right shows, in red, the rendering of the green pixels from the original photo using image analysis software.

Relationships Between NDVI and Visual Quality in Cool-season Turfgrass, Part I: Variation Among Species and Cultivars

Objective: Evaluate the practicality of using spectral reflectance models to predict visual quality across multiple turfgrasses and years.

Investigators: Dale Bremer, Hyeonju Lee, Kemin Su, and Steve Keeley

Sponsor: Kansas Turfgrass Foundation

Introduction

Turfgrass quality is evaluated by integrating factors of canopy density, texture, uniformity, color, growth habit, and smoothness. The traditional method of evaluating turfgrass quality is visual, in which an observer rates the appearance of turfgrass on a numeric scale. Although this method is relatively fast to implement, it is subjective. Some researchers have contended that visual ratings may vary significantly among evaluators or even with the same evaluator over time, and that such ratings tend to be inaccurate and non-reproducible.

Multispectral radiometry, which measures the spectral reflectance of plant canopies at a number of wavelengths, has been proposed as an alternative to visual ratings because spectral reflectance may provide objective measurements of turfgrass quality; however, evaluations of visual quality may be confounded by differences in reflectance among species or cultivars. Because of the increasing interest in the use of spectral reflectance to evaluate turfgrass visual quality, conducting a test to evaluate the practicality of using spectral reflectance models to predict visual quality across multiple turfgrasses and years is timely.

In this 3-year study, we examined effects of species and cultivars on relationships between normalized difference vegetation index (NDVI) and visual quality ratings in Kentucky bluegrass (*Poa pratensis*, 'Apollo'), two Kentucky bluegrass x Texas bluegrass (*Poa arachnifera*) hybrids ('Thermal Blue' and 'Reveille'), and tall fescue (*Festuca arundinacea*, 'Dynasty').

Methods

The study was conducted under an automated rainout shelter (40 ft × 40 ft) at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. Thirty-two plots (4.5 ft × 5.8 ft) were bordered by metal edging (4-in. depth) to prevent lateral soil water movement between adjacent plots. Two irrigation treatments were imposed to broaden the turfgrass quality range in the study. The two treatments were 60% (water deficit) and 100% (well-watered) evapotranspiration replacement. Plots were arranged in a randomized complete block design with four replications. Water was applied by hand twice a week through a metered fan spray nozzle attached to a hose. Plots were mowed at 3 in. twice weekly with a walk-behind rotary mower.

Visual quality was rated on a scale from 1 to 9 (1 = brown and dead turf, 6 = minimally acceptable turf for use in home lawns, and 9 = optimum). Spectral reflectance of the canopy was measured with a handheld multispectral radiometer (model MSR16, Crop-Scan, Rochester, MN) concurrently with visual quality ratings.

Data among plots were analyzed for comparisons between visual quality ratings and NDVI. Regression data were analyzed among grasses, separately in each year to determine whether relationships between NDVI and visual quality varied: 1) among grasses within each year, and 2) among years within each grass. Analysis of covariance was used to test for equal slopes and intercepts in regression models among species and years. Inverse prediction was used to estimate visual quality from NDVI and 95% confidence intervals.

Results

Distinct linear regression models of visual quality were found for each grass, and models were also distinct among years in each grass (Table 1 and Figure 1). Relationships between NDVI and visual quality were stronger in the bluegrasses ($r^2 = 0.41$ to 0.83) because they had a greater range in quality under deficit irrigation than tall fescue. The 95% confidence intervals surrounding predictions of visual quality from NDVI ranged from ±1.25 to 2.10 (on a 1 to 9 scale). In general, the confidence intervals overlapped among grasses and years, which indicates these models are not precise enough for practical detection of differences in visual quality among grasses and years with NDVI.

Different models among turfgrass cultivars and species may be related to differences in canopy characteristics. In our study, the hybrid bluegrass 'Thermal Blue' was generally lightest in color among grasses and tall fescue was generally the densest, which probably affected both visual quality ratings and NDVI. In addition, tall fescue had wider leaves than the bluegrasses, which may have affected quality ratings and perhaps NDVI. Inter-annual variability among models may have been related to differences in heat and drought stress among years. Atmospheric effects such as differences in illumination also may have contributed to differences among years.

The different scales used by NDVI and visual quality ratings may have contributed to imprecision in the models. Specifically, visual quality is estimated on a discrete scale and NDVI is measured on a continuous scale. This probably predisposes NDVI to greater variability at each discrete increment of visual quality (Figure 2). For example, at a visual quality rating of 4, NDVI ranged widely from 0.46 to 0.69 in the hybrid 'Thermal Blue' in 2005, the year when the strongest relationships between NDVI and visual quality during the study were observed (Table 1). In the same grass and year, measurements of NDVI of 0.69 were observed across visual quality ratings from 4 to 6, and a similar NDVI of 0.71 was even observed at a visual rating of 7. Indeed, it was typical for the same values of NDVI to be observed across three levels of visual quality among all cultivars in 2005.

In summary, this research illustrated that using NDVI to predict visual quality would require development of separate models for each turfgrass and for each season. This requirement severely reduces the practicality of using NDVI for this purpose. Even if a single model could be used, the wide range in confidence intervals surrounding predictions of visual quality from NDVI would be problematic. These requirements represent a practical limitation to predicting visual quality with NDVI.

Table 1. Models from Kentucky bluegrass (KBG), two hybrid bluegrasses (HBG) ('Thermal Blue' [TB] and 'Reveille' [R]), and tall fescue in 2004 (n = 64 per grass), 2005 (n = 96 per grass), and 2006 (n = 96 per grass); 95% confidence interval ranges (CI) of models in predicting visual quality (VQ) from normalized difference vegetation index (NDVI), coefficients of determination (r^2) between VQ and NDVI, and range in VQ and NDVI among grasses in each year.

Year	Turfgrass	Models	CI range: Predicting VQ from NDVI[1]	r^2	Range VQ	Range NDVI
2004	KBG	NDVI=0.042*VQ+0.513	±2.10	0.38[2]	6 to 8	0.69 to 0.90
	HBG (TB)	NDVI=0.063*VQ+0.356	±1.89	0.44[2]	5 to 8	0.55 to 0.91
	HBG (R)	NDVI=0.052*VQ+0.424	±1.51	0.41[2]	6 to 8	0.65 to 0.87
	Tall fescue	NDVI=0.018*VQ+0.729	--[3]	0.09[2]	6 to 8	0.80 to 0.92
2005	KBG	NDVI=0.068*VQ+0.330	±1.25	0.83[2]	4 to 8	0.50 to 0.89
	HBG (TB)	NDVI=0.068*VQ+0.310	±1.38	0.80[2]	4 to 8	0.46 to 0.86
	HBG (R)	NDVI=0.051*VQ+0.430	±1.36	0.71[2]	4 to 8	0.54 to 0.85
	Tall fescue	NDVI=0.035*VQ+0.580	±1.51	0.56[2]	5 to 8	0.71 to 0.90
2006	KBG	NDVI=0.062*VQ+0.397	±1.96	0.68[2]	3 to 8	0.43 to 0.89
	HBG (TB)	NDVI=0.053*VQ+0.428	±1.39	0.42[2]	5 to 8	0.60 to 0.90
	HBG (R)	NDVI=0.061*VQ+0.380	±1.81	0.59[2]	5 to 8	0.60 to 0.90
	Tall fescue	NDVI=0.019*VQ+0.725	--[3]	0.05[2]	6 to 8	0.73 to 0.93

[1] Inverse prediction method.
[2] All r^2 values were significant ($P = 0.05$).
[3] CI could not be estimated because of large mean square error.

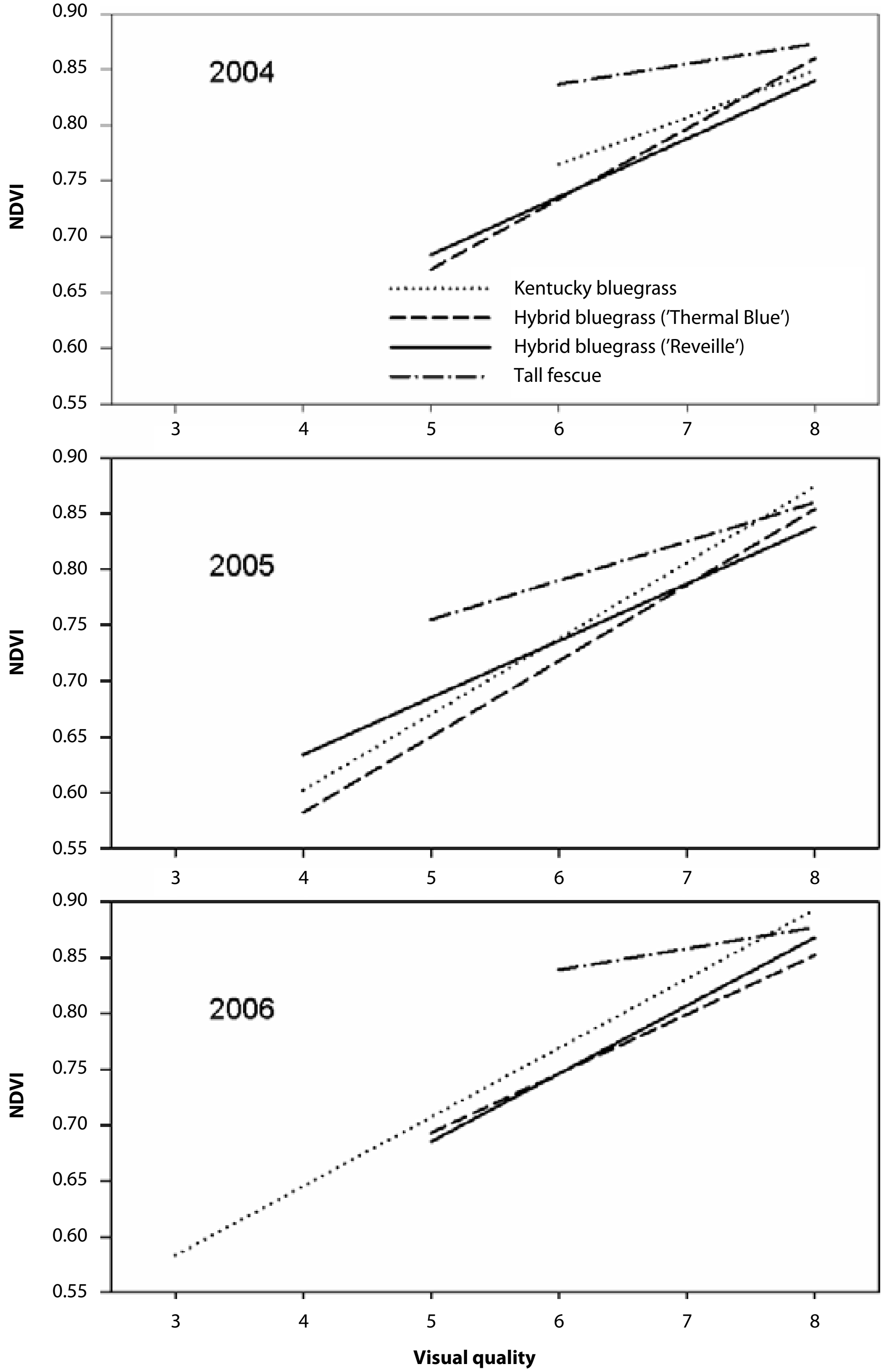


Figure 1. Relationships between normalized difference vegetation index (NDVI) and visual quality on a 1 to 9 scale, with 9 = highest quality.
Models are presented for each grass in 2004 (n = 64), 2005 (n = 96), and 2006 (n = 96).

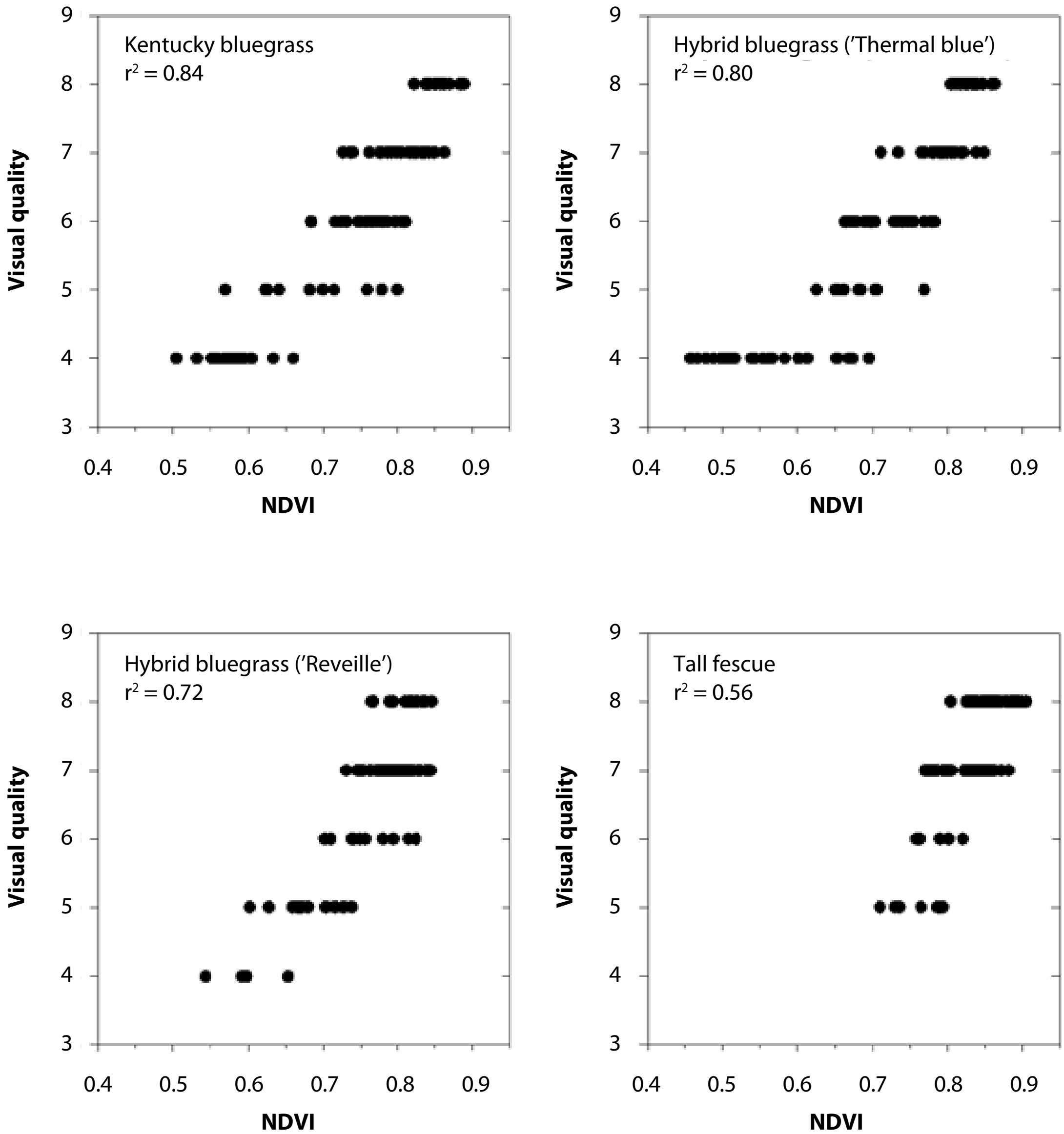


Figure 2. Normalized difference vegetation index (NDVI) corresponding to individual rankings of visual quality among grasses by human evaluators in 2005.
The wide range in NDVI at each rating illustrates the difficulty in using objective measurements of canopy reflectance with subjective estimates of turfgrass quality.

Relationships Between NDVI and Visual Quality in Cool-Season Turfgrass, Part II: Factors Affecting NDVI and Its Component Reflectances

Objectives: 1) Better understand the relative contributions of red and near-infrared (NIR) reflectance to NDVI among the same four cool season turfgrasses as presented in Part I; and 2) clarify the effects of percentage green cover and canopy density on NDVI and its component reflectances.

Investigators: Dale Bremer, Hyeonju Lee, Kemin Su, and Steven Keeley

Sponsor: Kansas Turfgrass Foundation

Introduction

The Normalized Difference Vegetation Index (NDVI), computed as [near-infrared (NIR)-red)]/[NIR+Red], is a common vegetation index that may provide a more objective means of evaluating turfgrass quality than the more traditional subjective method of visually estimating turfgrass quality. The NDVI is influenced by red (visible) and NIR (invisible) reflectance. Although related, these are distinct biophysical phenomena that may respond differently to environmental factors such as water stress. Basic information is lacking about the two components in relation to turf quality.

In a companion report (see "Relationships Between NDVI and Visual Quality in Cool-season Turfgrass, Part I: Variation Among Species and Cultivars," page 92), we reported significant differences among four cool-season turfgrasses in their relationships between NDVI and visual quality (Kentucky bluegrass, 'Apollo'; two Kentucky bluegrass x Texas bluegrass hybrids, 'Thermal Blue' and 'Reveille,'; and tall fescue 'Dynasty'). In this study, the overarching goal was to gain a more fundamental understanding of factors that affect NDVI in turfgrass so greater accuracy can be obtained in predicting visual quality from NDVI.

Methods

For a detailed description of most of the methods used in this study, see the methods section of "Relationships Between NDVI and Visual Quality in Cool-season Turfgrass, Part I: Variation Among Species and Cultivars," page 92. In 2005 and 2006, additional measurements of percentage green cover were evaluated from images taken with a digital camera. The color digital images were then analyzed for percentage green cover with software (SigmaScan Pro 5.0). In 2006, shoot density ratings also were evaluated visually on the same day visual quality was rated and NDVI and percentage green cover was measured. Similar to visual quality, the density scale consisted of ratings from 1 to 9, but were based only on shoot density (1 = no grass; 6 = minimally acceptable condition, or about 60% density; and 9 = dense grass). Density estimates were added in 2006 to help differentiate relative contributions of shoot density from percentage green cover, as measured with digital images, to NDVI and its reflectance components.

Results

Clear patterns of NDVI and reflectance at 661 and 935 nm emerged when viewed incrementally across visual quality ratings, as illustrated in 2005 (Figure 1). For example, NDVI increased with visual quality, with significant differences among grasses at every quality rating from 5 to 8. The increase in NDVI with quality was likely caused in large part by increased percentage of green cover and density of the canopies, both of which were strongly positively correlated with NDVI (Figures 2 and 3).

Reflectance at 661 nm decreased as visual quality increased (Figure 1). In general, the patterns of differences in R661 among grasses were mirrored with NDVI at each increment of visual quality. For example, red reflectance at a visual quality of 5 was low in tall fescue, which corresponded with greater NDVI in tall fescue among grasses. The reduction in red reflectance with increasing turf quality, which likely indicates greater light absorption by increasing amounts of chlorophyll, illustrates the strong relationship between visual quality and reflectance in the visible (red) wavelengths. Red reflectance was strongly affected by density and green cover (Figures 2 and 3).

Reflectance at 935 increased with quality in the three bluegrasses, but not in tall fescue (Figure 1). The increase in reflectance with quality in the bluegrasses was probably caused by decreasing amounts of brown, senesced leaves as turf quality improved; reflectance in the NIR is typically lower from senesced leaves than from photosynthesizing, green leaves. Reflectance at 935 remained relatively steady in tall fescue as quality increased from 5 to 8, probably because of its higher density and less severe stress than the bluegrasses. In addition, NIR reflectance remains steady or even increases in the early stages of leaf dehydration and leaf yellowing; therefore, even at a quality rating of 5 in tall fescue, most leaves may not have deteriorated sufficiently to reduce NIR reflectance. The NIR reflectance was affected by density, but only negligibly by green cover (Figures 2 and 3).

In summary, the differences in NDVI among turfgrasses at each increment of visual quality were caused by corresponding differences in both red (visible) and NIR (invisible) reflectance. Differences in red reflectance may have been indicative of differences in green leaf density among grasses, which probably would have affected chlorophyll content per unit of ground area. The causes for differences in NIR reflectance were possibly related to differences in density among grasses, but other less evident factors also may have been involved (e.g., plant water status, leaf cell constituents, or shadows in the canopies). These factors may confound relationships between NDVI and turf quality and require further study if we are to advance the science of using reflectance data to evaluate turfgrass quality.

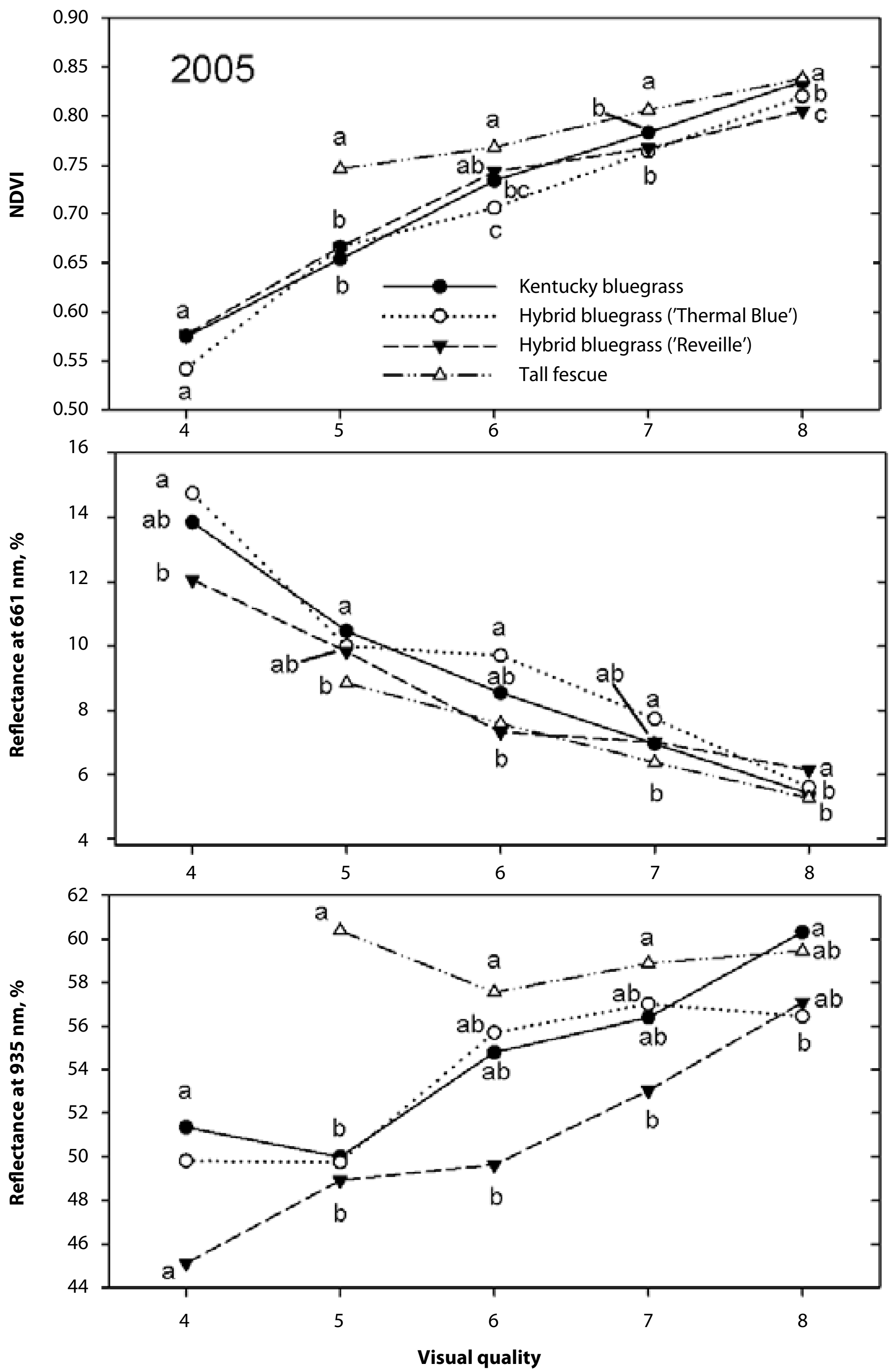


Figure 1. In 2005, mean NDVI (top), reflectance at 661 nm (middle), and reflectance at 935 nm (bottom) among grasses at each visual quality rating from 4 to 8, with 8 the greatest quality.
Grasses included Kentucky bluegrass, two hybrid bluegrasses ('Thermal Blue' and 'Reveille'), and tall fescue (n = 48 per grass). Means with the same letters at each visual quality rating (compare vertically) within each reflectance group (i.e., NDVI, R661 nm, R935 nm) are not significantly different (P = 0.05).

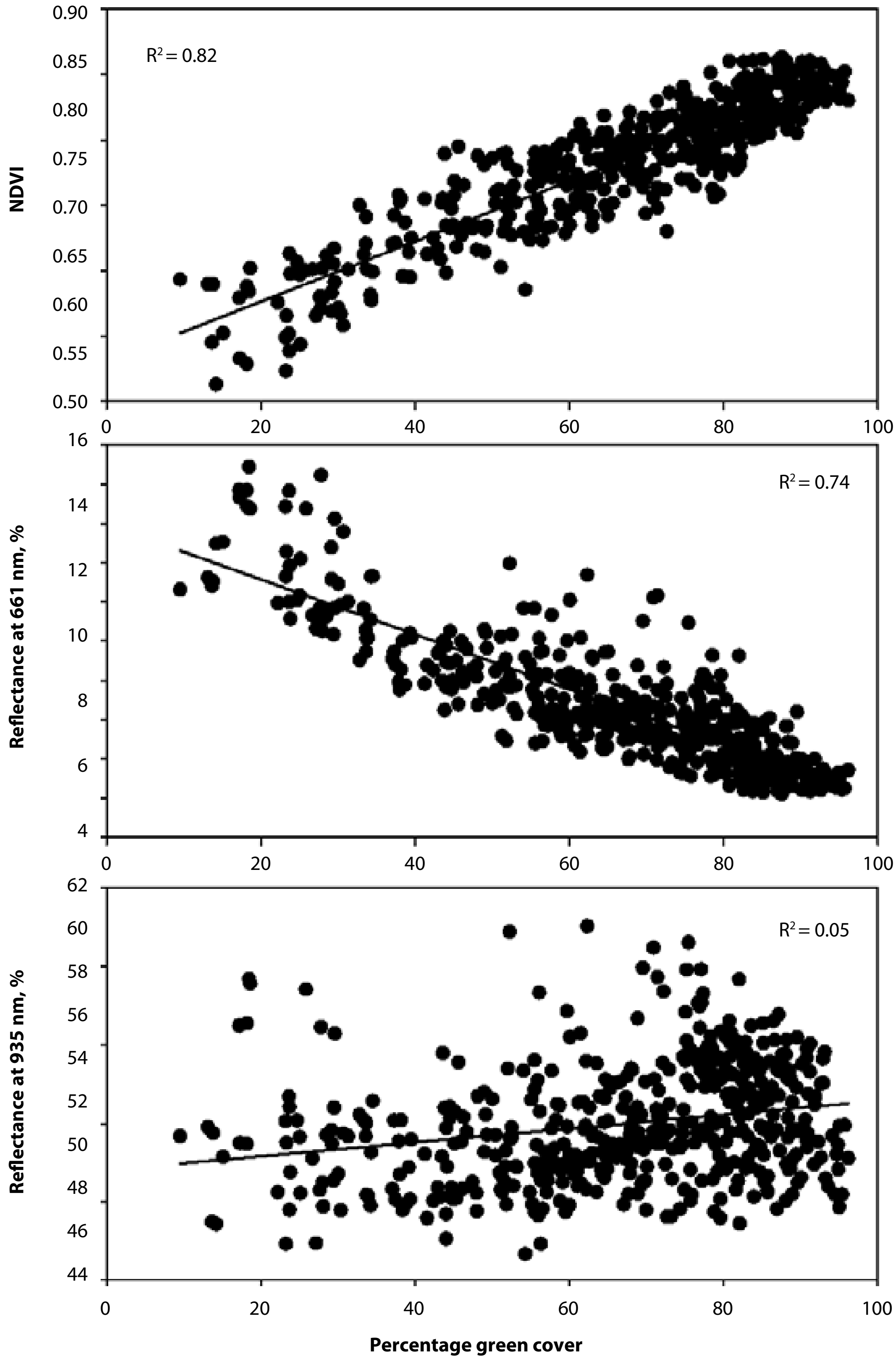


Figure 2. Relationships between percentage green cover and NDVI (top), reflectance at 661 nm (middle), and reflectance at 935 nm (bottom). Data are pooled among grasses from 2005 and 2006.

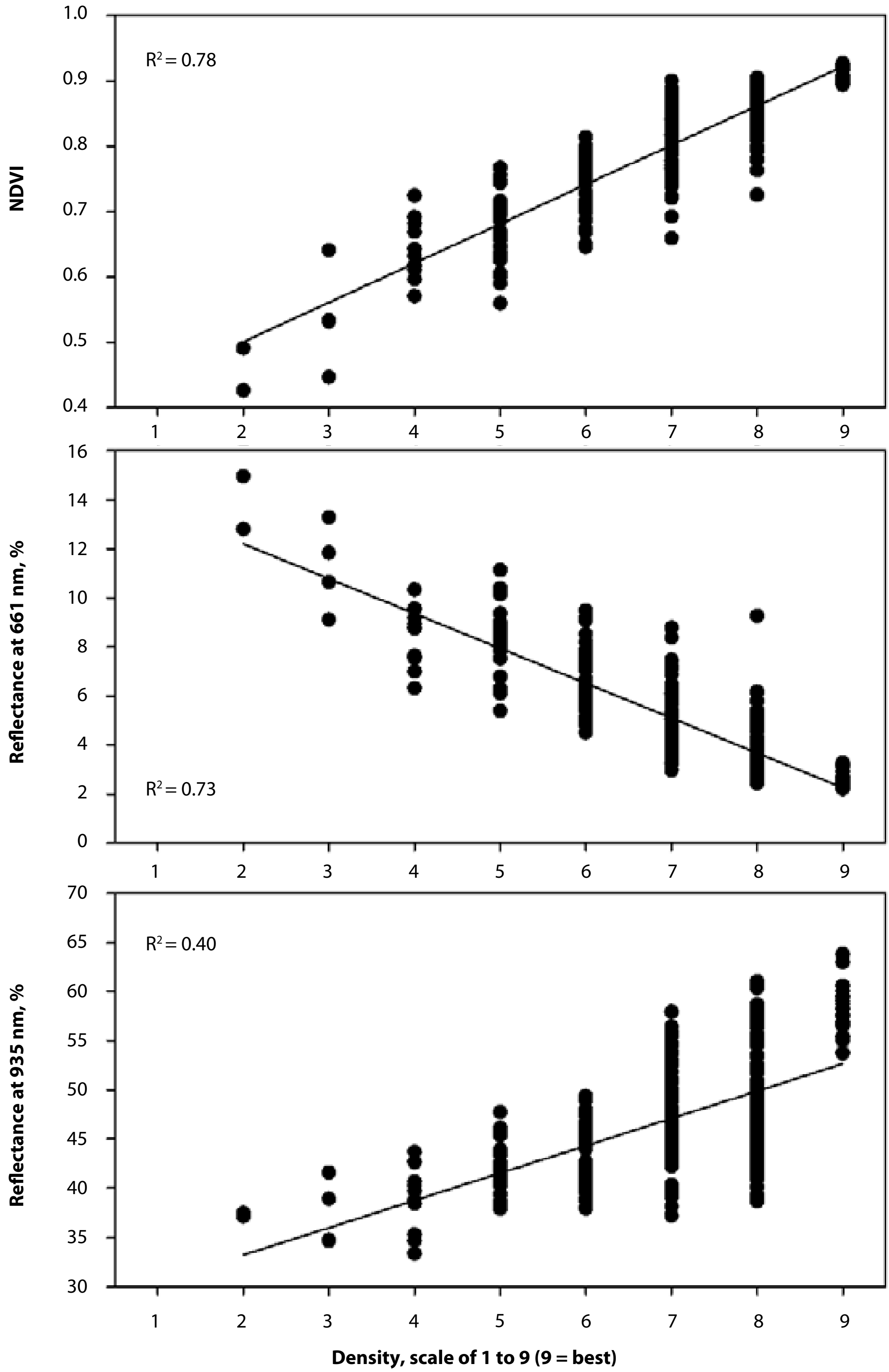


Figure 3. Relationships between shoot density and NDVI (top), reflectance at 661 nm (middle), and reflectance at 935 nm (bottom). Data are pooled among grasses from 2006.

Utilizing Hyperspectral Radiometry to Predict Green Leaf Area Index of Kentucky Bluegrass

Objective: Evaluate whether hyperspectral radiometry can be utilized to accurately predict green leaf area index of Kentucky bluegrass.

Investigators: Tony Goldsby and Dale Bremer

Introduction

Green leaf area index (LAI) provides an important measure of the photosynthetic capacity of a canopy. There are several methods for determining green LAI in turfgrass, but typical sampling methods are destructive and time-consuming. Destructive sampling requires large research plots to allow for multiple sampling dates throughout a growing season. Recently, the use of spectral reflectance to predict LAI in turfgrass has been suggested as an alternative to destructive sampling because previous research in agronomic crops has indicated that certain vegetative indices (VI) obtained from spectral reflectance were good predictors of LAI.

Hyperspectral radiometry measures the spectral reflectance of plant canopies in approximately 2,000 narrow wavelength bands. These small bands result in a spectral signature with greater resolution than its predecessor, multispectral radiometry, which measures spectral reflectance in substantially wider bands than hyperspectral radiometry. Previous research indicated little success in estimating green LAI in turfgrass with multispectral radiometry (see "Evaluation of Turfgrass Quality and Green Leaf Area Index and Aboveground Biomass with Multispectral Radiometry," K-State Turfgrass Research 2007, SRP981, page 6); however, because of its greater resolution, hyperspectral radiometry may provide a means of discerning green LAI with spectral reflectance, and thus provide an alternative to destructive sampling in turf. The objective of our study was to evaluate whether hyperspectral radiometry can be utilized to accurately predict LAI of Kentucky bluegrass (*Poa Pratensis*).

Methods

Plots (5 ft × 6 ft) were mowed and maintained at three heights, 2, 3.5, and 5 in.; plots were arranged in a completely randomized block design. All treatments were fertilized with 1 lb of nitrogen per 1,000 ft^2 in May, September, and November. Irrigation was applied as needed to prevent turfgrass stress.

Monthly hyperspectral measurements were acquired with a FieldSpec 3 Portable Spectoradiometer (ASD Inc., Boulder, CO) (Figure 1). Multiple radiometer scans were obtained from each plot and then averaged (Figure 2). Direct measurements of leaf area index were obtained immediately after radiometer measurements by destructively harvesting two random areas of the turfgrass canopy, each 7 $in.^2$ (3-in.-diameter PVC ring). The grass samples were then measured with an image analysis system (WinRHIZO, Regent Instruments, Quebec, Canada) to calculate total leaf area.

Preliminary Results

Vegetation Indices (VI) are dimensionless, radiometric measures that indicate relative activity of green vegetation. Spectroradiometer data were used to calculate several different vegetation indices. One common index is the normalized differential vegetation index (NDVI), and several wavelength combinations can be used to calculate NDVI. In this report we present results using the 548 and 945 nm wavelengths, which preliminary data indicate are promising for the detection of green vegetation. Because 548 nm is in the green portion of the spectrum, our index is designated "green NDVI." Standard calculations of NDVI typically use the smallest wavelength from the red portion of the spectrum. The high wavelength used for both standard and green NDVI calculations is from the near infrared portion of the spectrum, which in this study was 945 nm.

By using the 548- and 945-nm wavelengths, differences in green NDVI were observed between two of the three mowing heights on three out of four dates from summer 2010 (Figure 3). However, in our study NDVI was less sensitive in detecting differences in green vegetation between the 5- and 3.5-in. mowing heights. The decreased sensitivity at the highest mowing height may have been caused by the presence of micro-shadows in the canopy (Figure 4), which affect the reflective properties of the canopy. Because NDVI can saturate at high levels of green vegetation, it is also possible that turfgrass at 5 in. had saturated the NDVI.

This study will be replicated in the summer of 2011 and final results will be presented in next year's report. Linear regression and correlation analysis will be used to evaluate relationships between reflectance data, including other indices in addition to NDVI and direct measurements of LAI. Evaluating these relationships will help discern whether any vegetative indices can be used to accurately predict LAI in turfgrasses.

Figure 1. Researchers set up and calibrate the spectroradiometers prior to acquiring measurements.

Figure 2. Researchers obtain radiometer readings from the various mowing heights.

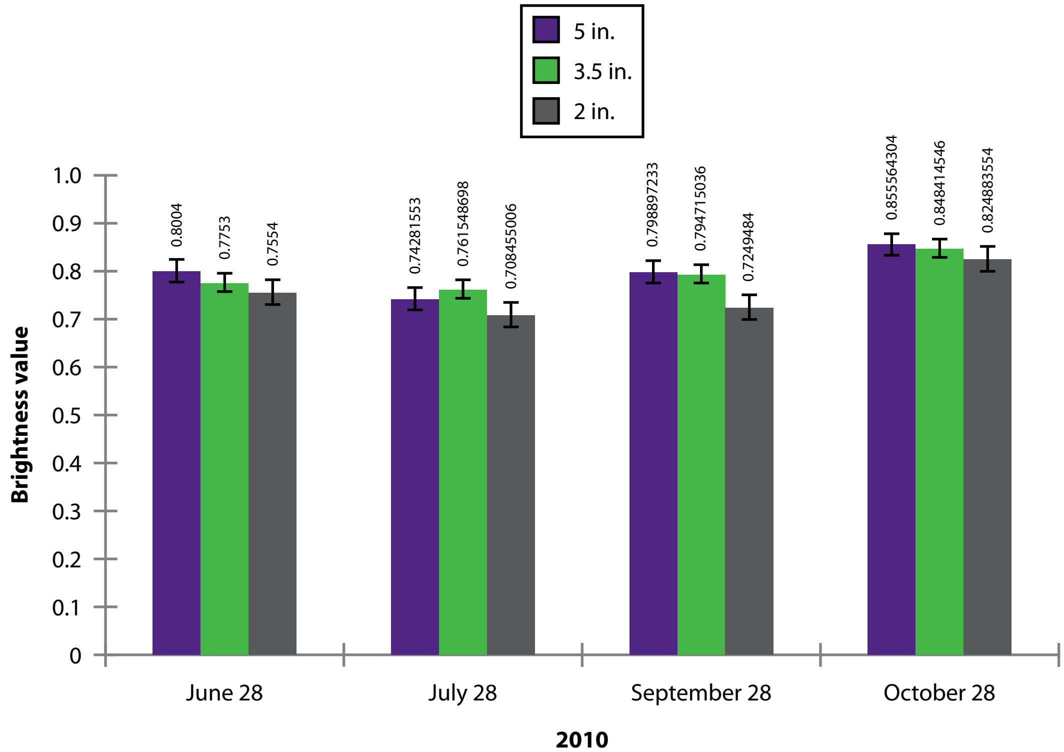


Figure 3. Normalized differential vegetation index (548 and 945 nm wavelengths) values for all three mowing heights for the four sampling dates in 2010.

Figure 4. Forage height of turf can cause micro-shadows in the turf canopy.

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