K-STATE TURFGRASS RESEARCH

2010

REPORT OF PROGRESS 1035

Kansas State University
Research and Extension

KANSAS STATE UNIVERSITY
AGRICULTURAL EXPERIMENT
STATION AND COOPERATIVE
EXTENSION SERVICE

K-STATE TURFGRASS RESEARCH 2010

Contents

Note. Photos by K-State turfgrass faculty, staff, and students unless otherwise noted.

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Foreword

Turfgrass Research 2010 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 on Aug. 5, 2010, at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. Articles in this Report of Progress summarize 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 industry needs. If you have problems that you feel need to be addressed, please let one of us know. In addition to the CD format, 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.ksre.ksu.edu/library*

Personnel Associated with the K-State Turfgrass Program

Faculty

Bob Bauernfeind
Extension Entomologist, Department of Entomology
133A Waters Hall, Kansas State University
Manhattan, KS 66506
Phone: (785) 532-4752; Fax: (785) 532-6258; *rbauernf@ksu.edu*

Dale Bremer
Associate Professor, Turfgrass, Department of Horticulture, Forestry and Recreation Resources
2021 Throckmorton Hall, Kansas State University
Manhattan, KS 66506
Phone: (785) 532-1420; Fax: (785) 532-6949; *bremer@ksu.edu*

Ray Cloyd
Associate Professor, Department of Entomology
235 Waters Hall, Kansas State University
Manhattan, KS 66506
Phone: (785) 532-4750; Fax: (785) 532-6258; *rcloyd@ksu.edu*

Jack Fry
Professor, Turfgrass Research and Teaching, Department of Horticulture, Forestry and Recreation Resources
2021 Throckmorton Hall, Kansas State University
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*

Steve Keeley
Associate Professor, Turfgrass Teaching and Research, Department of Horticulture, Forestry and Recreation Resources
2021 Throckmorton Hall, Kansas State University
Manhattan, KS 66506
Phone: (785) 532-1420; Fax: (785) 532-6949; *skeeley@ksu.edu*

Megan Kennelly
Assistant Professor, Extension Plant Pathologist, Department of Plant Pathology
4063 Throckmorton Hall, Kansas State University
Manhattan, KS 66506
Phone: (785) 532-1387; Fax: (913) 532-5692; *kennelly@ksu.edu*

Larry Leuthold
Professor Emeritus, Horticulture

Rodney St. John — Assistant Professor, Extension Turfgrass Specialist,
K-Sate Research and Extension Center–Olathe
35125 W. 135th St., Olathe, KS 66061
Phone: (913) 856-2335; Fax: (913) 856-2350; *rstjohn@ksu.edu*

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

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

Support Staff

Kira Arnold — Research Assistant, Department of Horticulture, Forestry and Recreation Resources
2748 Throckmorton Hall, Kansas State University
Manhattan, KS 66506
Phone: (785) 532-1421; *arnoldk@ksu.edu*

Christy Dipman — Extension Horticulture Secretary, Department of Horticulture, Forestry and Recreation Resources
2021 Throckmorton Hall, Kansas State University
Manhattan, KS 66506
Phone: (785) 532-6173; Fax: (785) 532-5780; *cdipman@ksu.edu*

Robin Dremsa — Research Assistant, K-Sate Research and Extension Center–Olathe
35230 W. 135th St. Olathe, KS 66061
Phone: (913) 856-2335, Ext. 106; *rdremsa@ksu.edu*

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

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

Ward Upham — Extension Associate, Department of Horticulture, Forestry and Recreation Resources
2021 Throckmorton Hall, Kansas State University
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
Jason Lewis	Ph.D. Student, Horticulture
Ken Obasa	Ph.D. Student, Plant Pathology
David Okeyo	Ph.D. Student, Horticulture
Kenton Peterson	Ph.D. Student, Horticulture
Cole Thompson	M.S. Student, Horticulture
Zane Raudenbush	M.S. Student, Horticulture

Measuring Evapotranspiration in Urban Irrigated Lawns: Current Findings and Future Research

Objective: Determine actual evapotranspiration in residential lawns.

Investigators: Kira Arnold, Dale Bremer, and Jay Ham

Introduction

Management of residential lawns comprises a significant portion of the turfgrass industry. Lawns are often susceptible to seasonal climatic stress, and the desire to maintain attractive lawns drives much research in turfgrass science. However, few studies have used micrometeorological measurements to explore the impact of lawn care on water resources within a community and, specifically, the effect of increasing numbers of in-ground automated irrigation systems. These systems are often maladjusted, which may result in wasted water. A greater understanding of the water demand within individual lawns would allow homeowners and landscape managers to adjust irrigation systems for better accuracy and, therefore, conserve water. Determining the amount of water actually used by the vegetation and comparing this with the amount of water actually applied would help identify, and eventually avoid, overwatering. Micrometeorological methods may help determine actual lawn water use by measuring evapotranspiration (ET) from urban lawns.

Methods

This research was conducted from Sept. 29 to Oct. 30, 2009, in Manhattan, Kan. Evapotranspiration measurements were collected using five tripod-mounted weather stations. Each tripod measured wind speed, wind direction, solar and net radiation, air temperature, relative humidity, canopy temperature, and soil moisture (Figure 1). Data from the tripods were used to calculate reference crop evapotranspiration (ET_o) via the standardized and widely used FAO-56 method. Four of the tripods were deployed in residential lawns (Figure 2). Eight residential properties were selected within the northwest portion of the city, and all had lawns that met the following criteria: in-ground automated irrigation systems installed, well maintained, and composed of cool-season grasses.

A mobile trailer-mounted eddy covariance (EC) station (Figure 3) was deployed within 5 km of where the tripods were sampling residential lawns. The EC station provided direct measurements of actual evapotranspiration (ET_{actual}) from a uniform, unshaded stretch of similarly well-watered and maintained turf at the Rocky Ford Turfgrass Research Center (RFTC) in Manhattan, Kan. The EC station was equipped to make the same measurements as each tripod (i.e., ET_o also could be estimated from the EC station). The EC system was also capable of measuring ET_{actual} by using high-speed data acquisition from an infrared gas analyzer and a three-dimensional sonic anemometer that continuously measured water vapor flux over a large, lawn-sized area. The fifth tripod was placed in the vicinity of the EC station to serve as a reference to the other four tripods.

Reference crop evapotranspiration gives an idea of the water need from a hypothetical canopy with an assumed mowing height and aerodynamic properties, but it is not necessarily equivalent to ET_{actual}. To determine ET_{actual} within the lawns, we established a lawn coefficient (K_c) to relate the EC station's direct measurements of ET_{actual} to determine actual water usage via ET by each lawn. The lawn coefficient is the ratio of ET_o, determined from the lawn-deployed tripods ($ET_{o,tripod}$), to the reference ET of the EC system ($ET_{o,EC}$) at the RFTC; hence, $K_c = ET_{o,tripod} / ET_{o,EC}$. Averaging all of the lawn-specific coefficients ($K_{c,i}$) provides one overall coefficient (K_c) that represents a much larger area (in this case, northwest Manhattan).

Typically, two tripods were deployed simultaneously at two different residences to sample different microclimates within each lawn. The exception was when three tripods were set up in two lawns on a property measuring approximately 1.4 acres and a fourth tripod was set up separately on a smaller property during the same timeframe. Tripods remained in position in the lawns for 6 to 8 days. Dates involving transportation between properties were excluded from data analysis.

Results

On days with optimal conditions (i.e., southerly winds, temperatures well above freezing, and sunny), on which tripods should provide more accurate ET_o estimates, $K_{c,i}$ ranged from 0.49 to 0.84 with the exception of one outlier (0.17) obtained when temperatures were near freezing for most of the deployment period (Table 1). The overall average K_c was 0.64 in optimal conditions.

Estimates of ET_{actual} for the entire northwest portion of Manhattan were obtained by multiplying the overall lawn coefficient ($K_c = 0.64$) by actual ET as measured by the EC station ($ET_{actual,EC}$). Similarly, multiplying $ET_{actual,EC}$ by individual $K_{c,i}$ yielded ET_{actual} for each respective yard; obviously, this method was applicable only on a yard-to-yard basis. Values of ET_{actual} for lawns in our study estimated using the overall K_c were within ±26.1% of ET_{actual} calculated using the lawn-specific coefficients ($K_{c,i}$). If the outlier was removed ($K_{c,i} = 0.17$), this improved to 16.6%.

Cumulative $ET_{actual,EC}$ at RFTC for the duration of each lawn deployment (about 7 days) averaged 10.9 ± 3.0 mm, whereas cumulative ET_{actual} in residential lawns calculated using $K_c = 0.64$ averaged 7.0 ± 1.9 mm (Figures. 4 and 5). Low windspeeds (due to greater turbulent motion caused by trees and grouped houses within neighborhoods) and shaded areas in home lawns contributed to the lower ET in town compared with that measured by the EC system at the RFTC. When average daily cumulative ET_{actual} was calculated with $K_{c,i}$ from individual lawns, ET_{actual} was 4.2 ± 2.4 mm/day. Considering differences between the EC site and individual lawns, which included variations in lawn maintenance and microclimates, estimates of in-town ET obtained by correcting EC data with an overall lawn coefficient were good.

Future Research

In summer 2010, the same yards shown will be sampled again to test for consistency in the lawn coefficient. Additional yards in different locations of Manhattan, Kan. will be added for testing if possible. Research will also be done in the most demanding portion of the summer (June through August).

Table 1. Cumulative reference crop evapotranspiration (ET_o) and actual evapotranspiration (ET_{actual}) for each period of residential deployment based on individual yard-specific lawn coefficients ($K_{c,i}$) and the overall lawn coefficient (K_c)

Property	Deployment period in 2009	Individual lawn coefficient ($K_{c,i}$)	Total $ET_{o,\ tripod}$	Total $ET_{o,\ EC}$	Total ET_{actual}	Total ET_{actual} using individual coefficients ($K_{c,\ i}$)	Total ET_{actual} using average overall coefficient (K_c)	Difference in ET_{actual} between using K_c and $K_{c,i}$	
			----------------------------------mm----------------------------------					mm	%
1	9/30 – 10/5	0.52	6.9	12.8	14.7	7.6	9.4	1.8	18.9
2	9/30 – 10/5	0.78	10.7	12.8	14.7	11.5	9.4	-2.1	-22.5
3	10/7 – 10/13	0.85	5.2	8.4	7.5	4.7	4.8	0.1	1.7
4	10/7 – 10/14	0.17	2.6	4.5	7.4	2.4	4.8	2.3	49.5
5	10/15 – 10/21	0.69	7.9	9.9	12.4	7.7	7.9	0.2	3.1
6	10/16 – 10/22	0.56	6.9	9.6	12.0	5.9	7.7	1.8	23.0
7	10/23 – 10/29	0.69	5.6	7.0	10.1	6.9	6.5	-0.4	-6.8
8	10/24 – 10/29	0.50	3.5	6.2	8.2	4.2	5.3	1.0	20.3

Standard deviation of the difference between using K_c and $K_{c,i}$ is ±21.9% (±1.5 mm).

Figure 1. Schematic of the small tripod-mounted weather stations deployed in residential lawns.

Figure 2. Two tripods deployed in a residential lawn.
One sampled a relatively open area (left), and the other sampled a shady portion of the yard (right) to examine microclimates within the lawn.

Figure 3. Trailer-mounted eddy covariance tower located at the Rocky Ford Turfgrass Research Center.
The two white devices on the extended arm in the center of the image are the high-frequency instruments that measure water vapor flux (ET_{actual}).

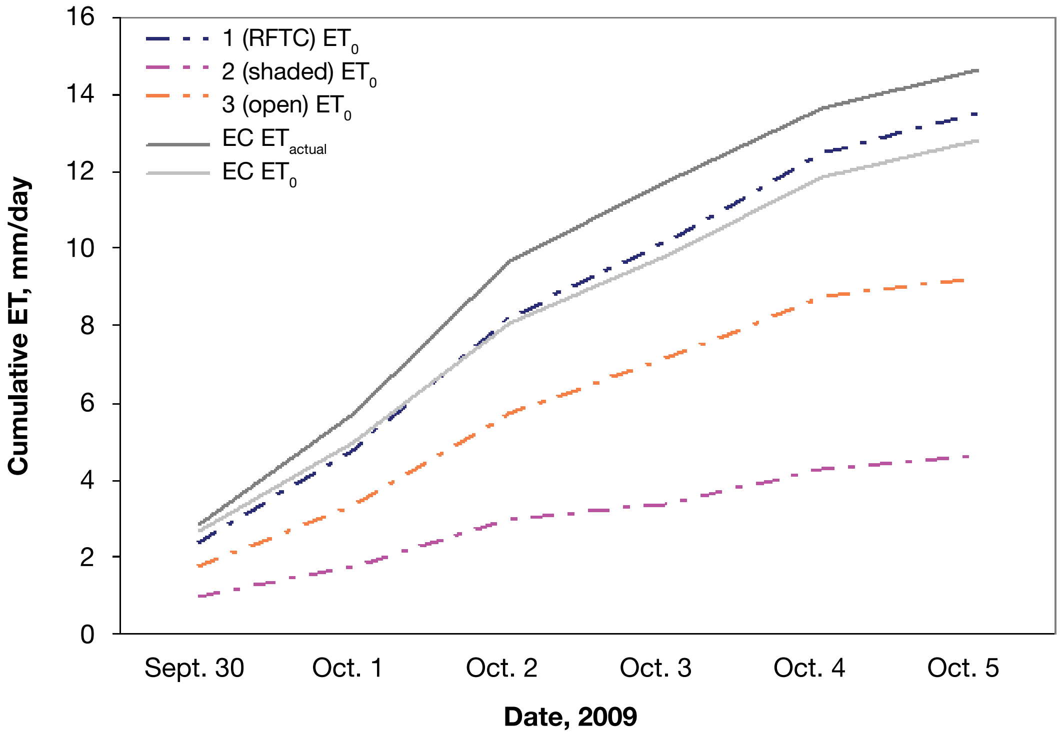

Figure 4. Cumulative reference crop evapotranspiration (ET_o) reported by three tripods during deployment on one property and cumulative ET_o and actual evapotranspiration (ET_{actual}) as measured at the eddy covariance (EC) site.

Tripods 2 and 3 were deployed in a lawn, and tripod 1 remained at the Rocky Ford Turfgrass Research Center in the vicinity of the EC station.

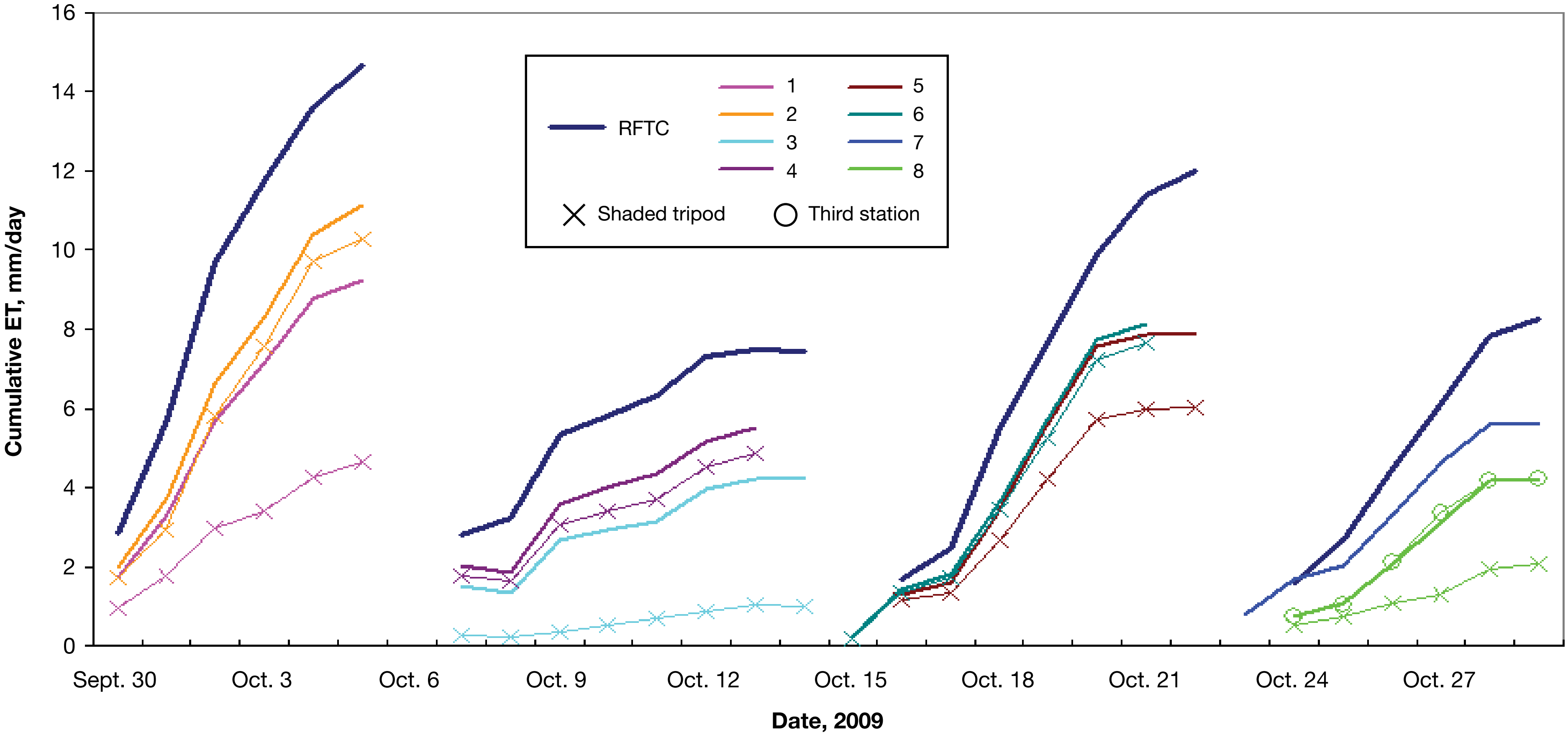

Figure 5. Cumulative reference crop evapotranspiration (ET_o) from all lawn-deployed tripods compared with that from the tripod at the Rocky Ford Turfgrass Research Center.

Unmarked lines indicate tripods that were in a relatively open (i.e., unshaded) portion of the lawn throughout the day, lines marked with "x" are from tripods that were in more shaded portions of the yards, and the light green line marked with "o" indicates the third station during the last deployment that was in an open part of the lawn.

Measurements of Photosynthesis, Respiration, and Evapotranspiration in Turfgrass with a Custom Surface Chamber

Objective: Compare measurements of photosynthesis in four Kentucky bluegrasses and one hybrid bluegrass during a simulated drydown in a rainout facility by using a new custom chamber developed and fabricated at Kansas State University.

Investigators: Jason Lewis and Dale Bremer

Sponsor: Kansas Turfgrass Foundation

Introduction

Canopy photosynthesis is a fundamental indicator of turfgrass sensitivity to drought and other stresses. In this study, we used a new, portable photosynthesis system to investigate photosynthesis in four Kentucky bluegrasses and one hybrid bluegrass during a 26-day drydown under a rainout shelter.

The custom chamber (Figure 1) was fabricated in our lab at Kansas State University (K-State).[1] The five turfgrasses were selected from a larger study under the rainout shelter[2] because they represent a wide range of water requirements (to maintain acceptable quality) and phenotypic groups. Cultivars selected (listed in ascending order by water requirement with phenotypic group in parentheses) were 'Apollo' (Compact America), 'Nu Destiny' (Compact Midnight), 'Thermal Blue Blaze' (Hybrid bluegrass), 'Baron' (BVMG), and 'Kenblue' (Common).

Ancillary measurements of soil moisture were collected at two depths, 2 and 8 in., with dual-probe heat-capacity soil moisture sensors, which were also fabricated in our lab at K-State (Figure 2). These sensors are ideal for turfgrass because they provide measurements at specific depths, which may indicate soil moisture uptake by nearby roots.

Methods

Plots were arranged in a randomized complete block design under an automated rainout shelter with three replicates of each turfgrass cultivar. The rainout shelter shielded all plots from precipitation during the drydown. The 26-day drydown lasted from Aug. 4 through Aug. 30, 2009, during which time the plots received no water from irrigation or precipitation. Turfgrass was maintained at 2.5 in.

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[1] See K-State's 2008 (publication no. SRP998) and 2009 (publication no. SRP1015) turfgrass research reports for more detail about chamber fabrication and theory.

[2] See article on p. 74 in this report, *Irrigation Requirements of 28 Kentucky Bluegrass Cultivars and Two Texas Bluegrass Hybrids in the Transition Zone.*

Fluxes of CO_2 were measured with the chamber in each plot every 4 to 5 days during the drydown from 11:00 a.m. to 1:30 p.m. CST on clear, sunny days. Measurements were collected simultaneously under full sunlight (Figure 1) and shaded conditions (Figure 3).

Gross photosynthesis (P_g) was calculated as $P_g = P_{net} + (R_{canopy} + R_{soil})$; P_{net} is net photosynthesis obtained from the sunlit measurement (Figure 1), and ($R_{canopy} + R_{soil}$) are canopy and soil respiration, respectively, obtained from the covered measurement (Figure 3).

Soil moisture at 2 and 8 in. was measured with dual-probe heat-capacity sensors on measurement days. Data were recorded with a datalogger and accessories (CR10x, two AM 16/32, one AM 416, Campbell Scientific, Logan, UT; Figure 4).

Results

Photosynthesis and Respiration Measurements with Chamber During Drydown

In general, photosynthesis decreased most rapidly during the first 2 weeks (Figure 5). Despite the severe drought conditions, none of the turfgrasses decreased to zero P_g, which would indicate photosynthesis had completely stopped.

Apollo consistently had the greatest P_g during the drydown, which indicates good performance under drought (Figure 5). Baron consistently had the lowest P_g, which implies poorer performance under drought. Gross photosynthesis of Thermal Blue Blaze, Nu Destiny, and Kenblue was similar overall as the drydown progressed and intermediate between that of Apollo and Baron.

Cumulative P_g estimates during the study were greatest for Apollo, followed by Kenblue, Nu Destiny, and Thermal Blue Blaze. Baron had the least cumulative P_g (Figure 5).

Volumetric Water Content Among Cultivars During Drydown

For all cultivars, a greater amount of soil moisture was depleted at 2 in. than at 8 in. (Figure 6). This result indicates greater absorption of soil moisture by roots at 2 in. and, perhaps to a lesser degree, greater evaporation of water from the soil surface.

At the 2-in. depth, Apollo and Baron depleted the most soil moisture, whereas the other three cultivars depleted less water and were similar to each other (Figure 6). At the 8-in. depth, Thermal Blue depleted the most soil moisture (Figure 6), indicating it may have greater capacity to use water at deeper depths. Kenblue depleted the least water at 8 in., followed by Nu Destiny, Apollo, and Baron.

Summary

- Apollo had the greatest P_g, meaning it performed better under drought stress than the other four cultivars.
- Greater soil water depletion did not necessarily translate to greater P_g as evidenced by Baron, which depleted significant amounts of water but had the lowest P_g. Conversely, Apollo depleted significant amounts of water and had the greatest P_g.
- Further research is required to measure other physiological parameters of these cultivars including electrolyte leakage (indicator of membrane stability during drought), water potential of leaves, root and shoot production, and percentage green cover to identify the best performers and understand underlying mechanisms of good turfgrass performance under severe drought stress.

Figure 1. Large chamber fabricated to measure CO_2 fluxes in turfgrass.
The system was connected to and controlled by a datalogger in the red cooler. Measurements with the sunlit chamber represented net photosynthesis of the turfgrass ecosystem.

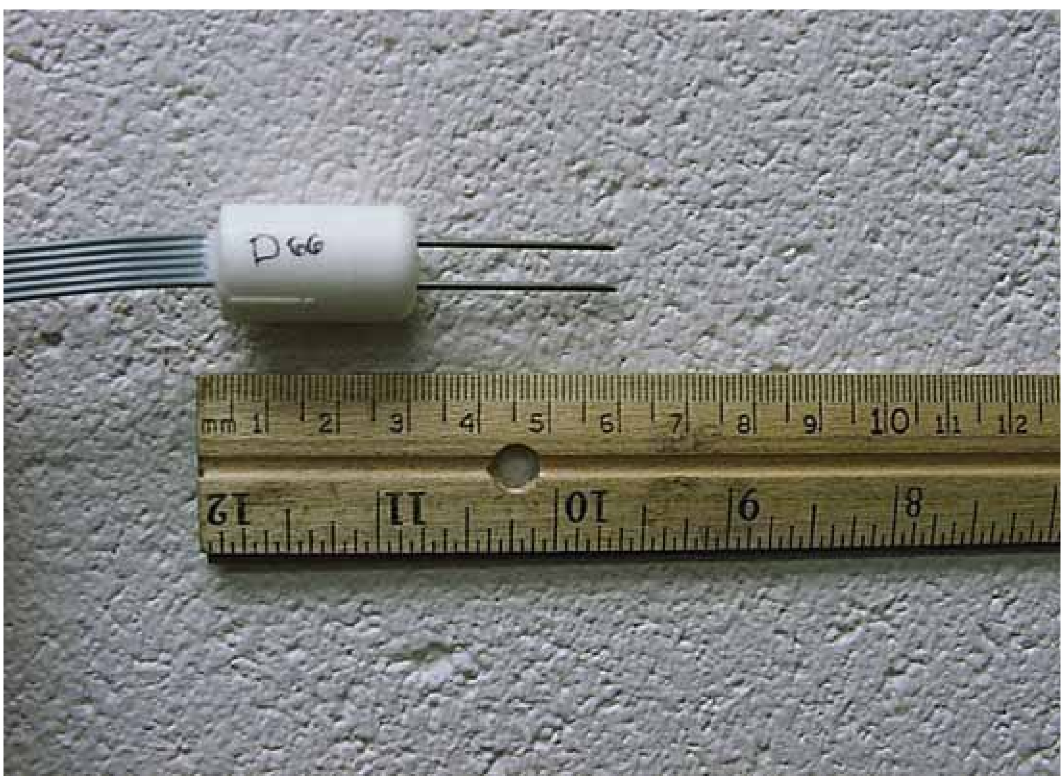


Figure 2. A dual-probe heat-capacity sensor built at K-State to measure soil moisture at specific depths.

Figure 3. The chamber was shaded with an opaque, cardboard box to obtain measurements of canopy and soil respiration (R_c + R_s) with no photosynthesis.

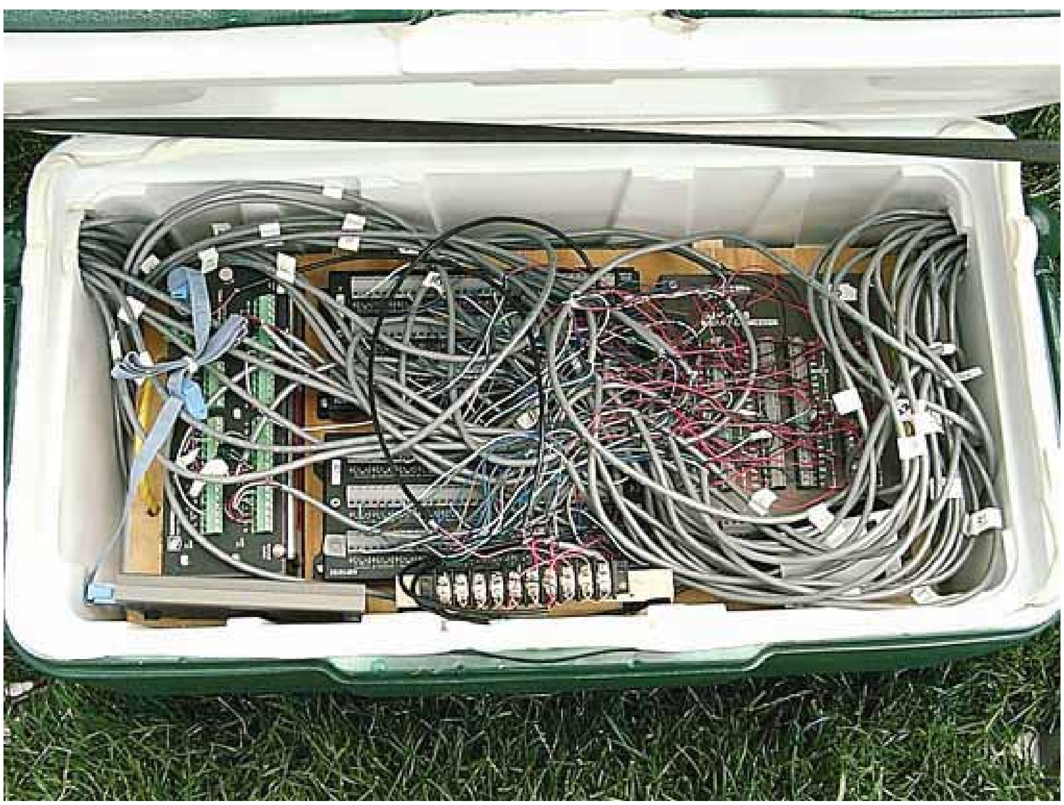


Figure 4. Data acquisition system used to log soil moisture data.
The system included a datalogger and three multiplexors and was capable of controlling 32 dual-probe heat-capacity sensors.

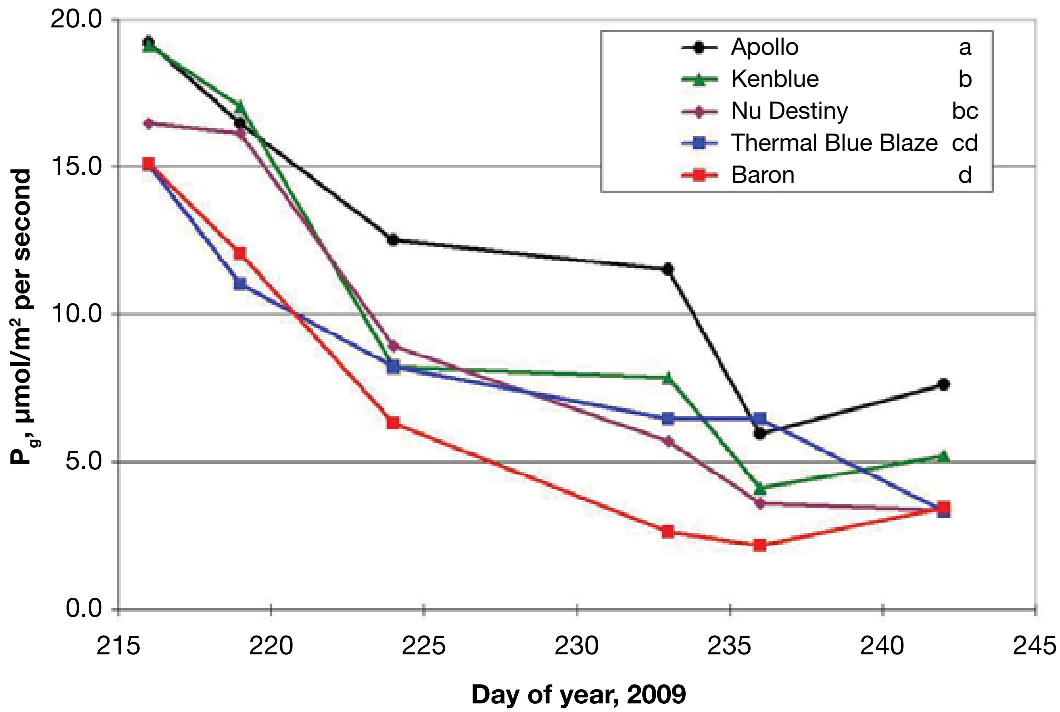


Figure 5. Estimates of gross photosynthesis (P_g) during a 26-day drydown for four Kentucky bluegrasses and a hybrid bluegrass (Thermal Blue Blaze).
In legend, cultivar names followed by the same letter were not significantly different in terms of cumulative P_g during the drydown.

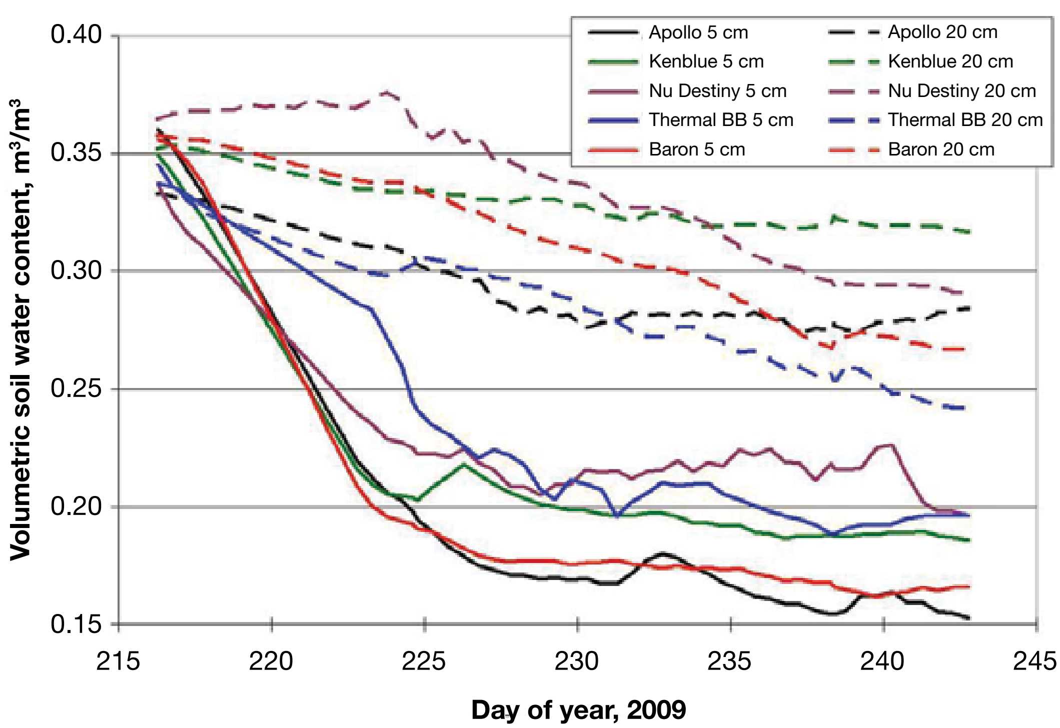


Figure 6. Measurements of volumetric soil water content at 2 in. (5 cm) and 8 in. (20 cm) during the 26-day drydown among four Kentucky bluegrasses and a hybrid bluegrass (Thermal Blue Blaze).

Potential for Slow-Release Polymer-Coated and Organic Nitrogen Fertilizers to Mitigate Greenhouse Gas (Nitrous Oxide) Emissions in Turfgrass

Objective: Investigate nitrous oxide (N_2O) emissions from turfgrass fertilized with urea and two controlled-release fertilizers: (1) polymer-coated nitrogen and (2) organic nitrogen.

Investigators: Dale Bremer and Jason Lewis

Sponsors: Agrium, International Plant Nutrition Institute, and Kansas Turfgrass Foundation. Sustane contributed slow-release organic N fertilizer.

Introduction

Nitrous oxide (N_2O) is a major greenhouse gas that has been implicated in global warming and climate change. Furthermore, N_2O is the dominant ozone-depleting substance in the atmosphere and is expected to remain so throughout the 21st century. Agriculture may contribute more than 80% of N_2O emissions into the atmosphere. Nitrogen (N) fertilization typically increases N_2O emissions from croplands, including turfgrass areas. In the United States, 40 to 50 million acres of urbanized land, or up to 18% of the land area in some regions, are covered with turfgrasses (e.g., golf courses, sports fields, parks, home lawns). This represents an area three times larger than that of any irrigated crop.

Because turfgrass is often fertilized with N, urban areas are probably increasingly contributing to atmospheric N_2O. This indicates a need for research to identify best management practices that mitigate N_2O emissions in turfgrass. One such best management practice may be the use of N fertilizers that result in lower N_2O emissions. Controlled-release N fertilizers may reduce greenhouse gas emissions in turfgrass by slowing the nitrification and denitrification processes, which are the main sources for N_2O emissions in fertilized turfgrass.

In this study, we investigated N_2O emissions from turfgrass fertilized with two controlled-release fertilizers and with urea. The first slow-release fertilizer, polymer-coated N, is formulated for only one application per season and designed to release N slowly over the entire season. The second slow-release fertilizer was an organic N source. Consumers' increasing interest in eco-friendly organic products makes organic N fertilizer an attractive alternative to synthetic fertilizers, particularly if it reduces greenhouse gas emissions.

Methods

This research was conducted at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. We investigated the effects of polymer-coated (poly; Agrium, Calgary, Alberta, CA), organic (Sustane, Cannon Falls, MN), and urea N fertilizers on N_2O emissions from bermudagrass (*Cynodon dactylon* L. Pers. X *C. transvaalensis* Burtt-Davy) during the summers of 2007 and 2008. Bermudagrass in all treatments was fertilized annually with 4.0 lb N/1,000 ft^2 according to the schedule in Table 1.

The N_2O emissions were measured weekly by using small surface chambers from May through September in each year and more frequently (i.e., two or three times) during the week following fertilizations. Gas samples collected from the chambers were transported to the laboratory and analyzed with gas chromatography.

In addition to N_2O emissions, soil moisture (0- to 6-in. depth), soil temperature (2-in. depth), and soil nitrate and ammonium concentrations (0- to 4-in. depth) were measured concurrently; these ancillary factors have been shown to affect N_2O emissions. Climatic conditions were monitored with a weather station located at the site. Visual turf quality was assessed in all plots at the beginning of the study and before each fertilization.

Results

Visual quality of all treatments was similar throughout the study. Nitrous oxide emissions consistently increased among treatments after each fertilization, even in poly plots, which were not fertilized on the second, third, and fourth fertilizer treatment dates (Figures 1A and 2A). The increase in N_2O fluxes in poly plots after the second, third, and fourth treatment dates was likely caused by irrigation that was applied to all plots (including poly) after N fertilization to minimize ammonia volatilization of urea and organic N fertilizers. Wetter soils generally increase denitrification rates, which typically causes greater N_2O emissions. Emissions from the urea treatment, however, were often greater than those from either slow-release fertilizer treatment after fertilization. In general, N_2O emissions returned to pre-fertilization levels after 7 to 10 days. Emissions also increased after irrigation or precipitation (Figures 1A-B and 2A-B).

The relationship between soil temperature and N_2O emissions was weaker than that between soil moisture and N_2O emissions, but emissions tended to be lower later in the fall when soils were cooler (Figures 1 and 2). There were no significant correlations between N_2O emissions and soil ammonium and nitrate levels. However, N_2O emissions from turfgrasses are complex and likely were affected by all factors including fertilizer type, soil moisture, soil temperature, and soil N level (i.e., ammonium and nitrate).

When averaged over the entire study, N_2O-N fluxes in the urea treatment increased to more than three times the background levels during the first week after N fertilization (Table 2). Although not as pronounced as in urea, fluxes in the organic treatment increased by 93% of background levels during the first week after N fertilization. In the poly treatment, N_2O-N fluxes were similar before and after the single annual fertilization (Table 1), revealing no direct response to N fertilization in N_2O-N fluxes in either the first or second week after fertilization.

Nitrous oxide fluxes in the urea treatment decreased between the first and second week after N fertilization but remained about 93% greater than background levels (Table 2). Fluxes in the organic treatment also decreased from the first to the second week after fertilization and became statistically intermediate to fluxes from the first week and background fluxes. These data clearly indicate that N_2O-N fluxes increased in the urea and organic treatments during the first week after N fertilization. Effects of N fertilization on N_2O-N fluxes carried over strongly into the second week in the urea treatment but were subtler in the organic treatment during the second week.

Overall background fluxes of N_2O-N from the poly treatment were 44% higher than those from the urea treatment during the 2-year study (Table 2). The reason for this is uncertain but may be related to levels of soil NH_4^+, which were higher in the poly treatment than in the urea or organic treatments (data not shown). Polymer-coated urea is formulated to release N slowly during the growing season, which may have caused the greater average soil NH_4^+ during the study. Soil NO_3^-, however, was similar between the poly and urea treatments in both years.

Despite the varied, transient responses of N_2O-N fluxes to N fertilization (Figures 1 and 2), cumulative N_2O emissions during the 2-year study were similar among N sources. Cumulative N_2O-N emissions over the 295-day study were 8.38, 7.97, and 6.91 kg N_2O-N/ha (0.17, 0.16, and 0.14 lb N/ 1,000 ft^2) in the poly, organic, and urea treatments, respectively (Figure 3). Thus, over the entire study, the percentages of total N fertilizer volatilized as N_2O-N were 2.1%, 2.0%, and 1.7% in the poly, organic, and urea treatments, respectively.

Compared with traditional urea fertilizer application, controlled-release polymer-coated urea and organic N may not be effective measures for mitigating N_2O-N emissions from turfgrass systems.

Table 1. Dates of nitrogen fertilizer application to bermudagrass plots

Day of year	Poly	Organic	Urea
	--------------------lb N/1,000 ft^2--------------------		
2007			
165	4	1	1
185	—	1	1
213	—	1	1
255	—	1	1
2008			
162	4	1	1
189	—	1	1
224	—	1	1
243	—	1	1

Table 2. Average fluxes of N_2O-N in the first and second weeks after nitrogen fertilization and at all other times (background)

Timing	Poly	Organic	Urea
	------------------ µg N_2O-N/m^2 per hour------------------		
Background	187 aA	143 abB	105 bC
First week[1]	186 bA	276 abA	333 aA
Second week[2]	136 aA	211 aAB	203 aB

Within a row, means followed by the same lowercase letter are not statistically different according to LSD (0.05). Within a column, means followed by the same uppercase letter are not statistically different according to LSD (0.05).

[1] Average fluxes from 1 to 7 days after N application.

[2] Average fluxes from 8 to 14 days after N application.

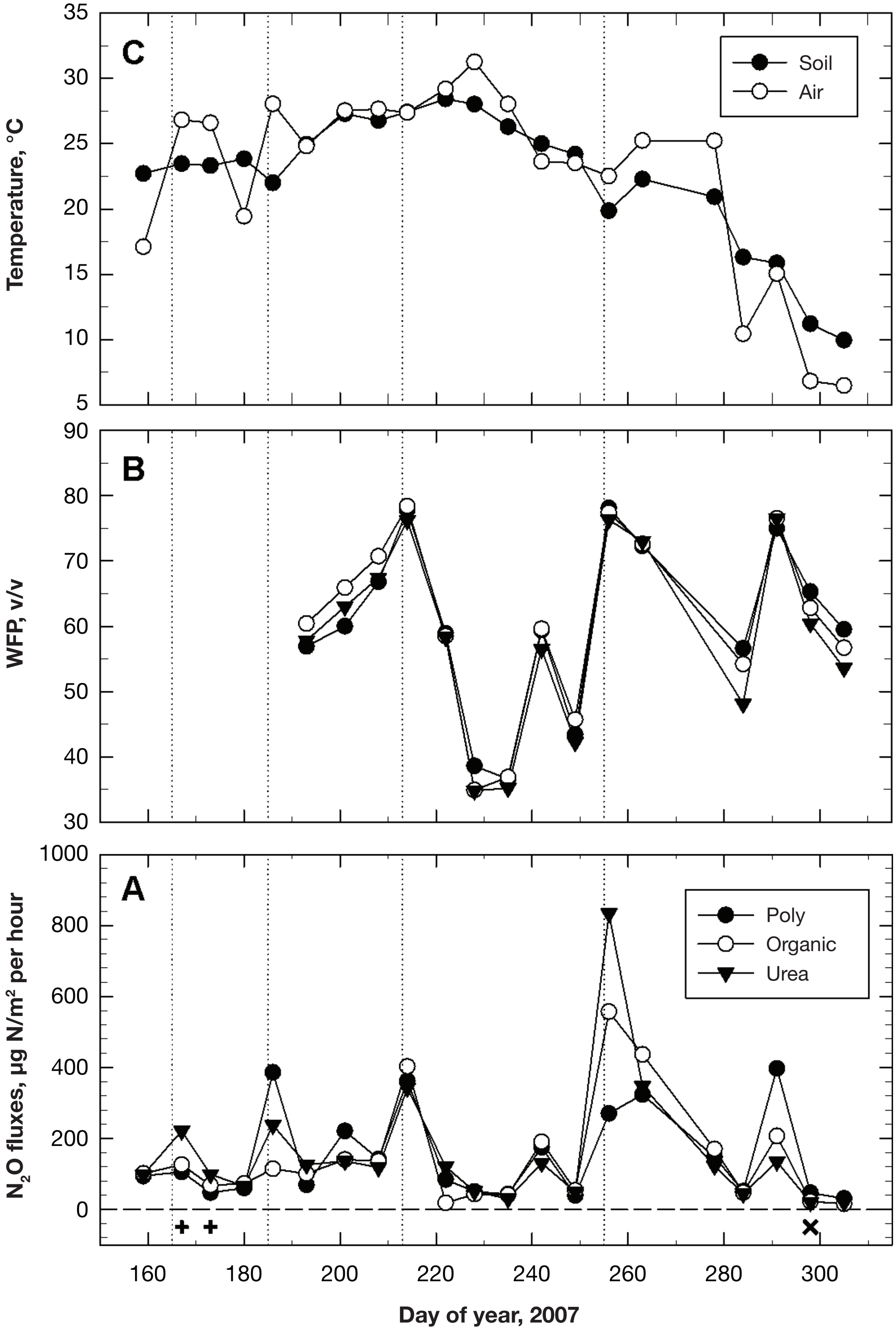


Figure 1. (A) Fluxes of N_2O-N from plots fertilized with polymer-coated urea (poly), organic nitrogen, and urea; (B) water-filled porosity (WFP) in the 0- to 6-in. profile; (C) average soil temperature at 2 in. among treatments and air temperature at 6.5 ft during sampling periods.

Vertical dashed lines represent fertilizer application dates. Plus symbol (+) indicates significant differences between one and the other two treatments on a given date.

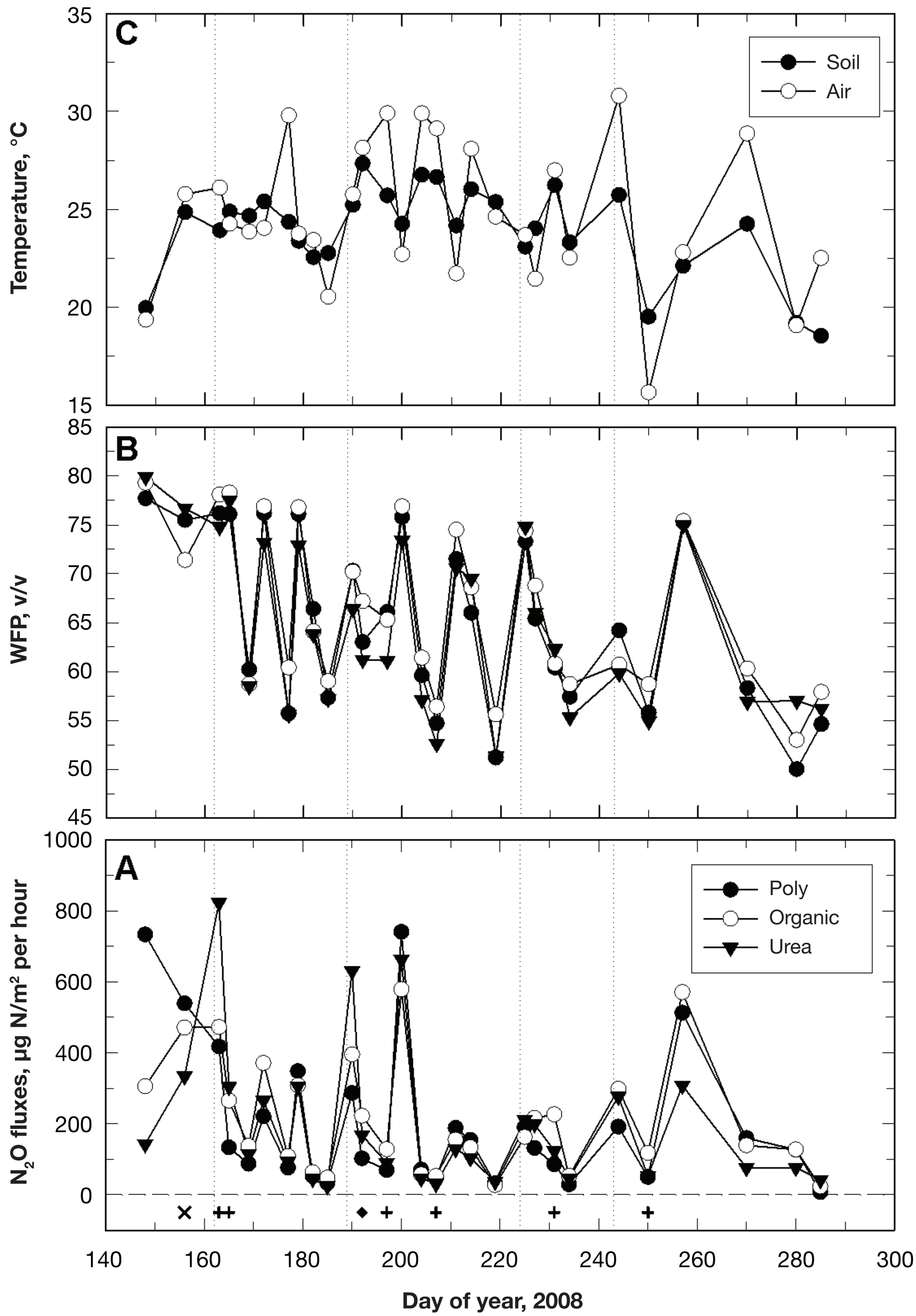


Figure 2. (A) Fluxes of N_2O-N from plots fertilized with polymer-coated urea (poly), organic nitrogen, and urea; (B) water-filled porosity (WFP) in the 0- to 6-in. profile; (C) average soil temperature at 2 in. among treatments and air temperature at 6.5 ft at sampling.

Vertical dashed lines represent fertilizer application dates. Multiplication symbol (×) along the abscissa in panel A indicate significant differences between at least 2 treatments ($P < 0.05$), plus symbol (+) indicates significant differences between one and the other two treatments, and diamond symbol (◆) indicates differences between all three treatments on a given date.

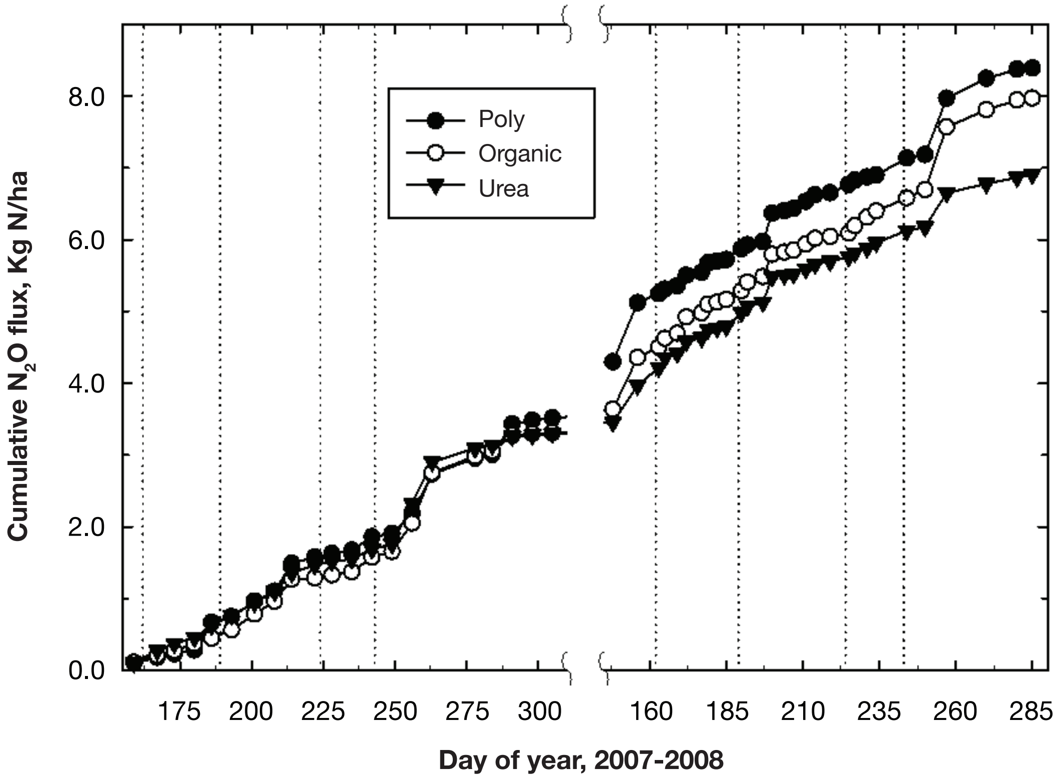


Figure 3. Cumulative fluxes of N_2O-N from plots fertilized with polymer-coated urea (poly), organic nitrogen, and urea.
Vertical dashed lines represent fertilizer application dates. There were no significant differences in cumulative N_2O emissions among treatments.

Relationships Between Spectral Reflectance and Visual Quality in Turfgrasses: Effects of Mowing Height

Objective: Evaluate effects of mowing height on relationships between visual quality ratings of individual turfgrass plots and corresponding measurements of spectral reflectance by using multispectral radiometry.

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

Sponsor: Kansas Turfgrass Foundation

Introduction

Turfgrass quality is typically evaluated by visual observations of color, uniformity, density, and texture, but visual evaluations are subjective and vary among people. The normalized difference vegetation index (NDVI) may provide quantitative, objective evaluations of turfgrass quality and responses to various stresses by measuring spectral reflectance of turfgrasses in the visible and near-infrared parts of the spectrum. However, cultural practices such as mowing may confound attempts to evaluate turfgrass quality with NDVI. This study investigated the effects of mowing height on relationships between turfgrass quality and NDVI.

Methods

This research was conducted under an automated rainout shelter from June 20 to Sept. 30, 2005, and Apr. 26 to July 28, 2006, at the Rocky Ford Turfgrass Research Center near Manhattan, Kan. Visual ratings and reflectance measurements were made on the same days in turfgrass plots of Kentucky bluegrass ('Apollo') and a hybrid bluegrass ('Thermal Blue'). Two irrigation treatments were used to impose water stress: well watered and irrigation deficit (60% evapotranspiration replacement). Plots were mowed at 3 in. (high mowing height) and 1.5 in. (low mowing height).

Visual quality of each plot 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 turf) by the same person. Spectral reflectance of the canopy was measured with a handheld multispectral radiometer that provided estimates of the NDVI. Measurements were taken between noon and 2:30 p.m. CST on days with no cloud cover. All turfgrass plots were fully vegetated; thus, soil background effects were negligible. Estimates of visual quality were then compared with NDVI.

To measure green leaf area index (LAI) and aboveground biomass, turfgrasses were clipped at ground level at the end of the study in 2006 from three areas within three plots each of Kentucky bluegrass and the hybrid bluegrass at each mowing height.

In the laboratory, green and dead leaves and shoots were separated, and green LAI was measured with an image analysis system. Biomass samples were then dried in a forced-air oven and weighed to determine dry biomass.

Results

Effects of Mowing Height on Normalized Difference Vegetation Index

With the exception of Kentucky bluegrass in 2005, NDVI averaged 4.5% to 7% greater in high-mown than in low-mown plots in both years (Table 1). In 2006, NDVI was greater in high-mown than in low-mown plots on 4 out of 9 measurement days in Kentucky bluegrass and 7 out of 9 days in hybrid bluegrass (Figure 1). The greater NDVI in high-mown plots may indicate greater green LAI or biomass compared with low-mown plots. Indeed, measurements at the end of 2006 indicated greater green LAI and aboveground biomass at the high mowing height, particularly in Kentucky bluegrass (Figure 2).

In 2006, measurements were collected on 3 days before initiation of the mowing treatment. It is interesting that NDVI in the hybrid bluegrass was greater on the first 2 days in plots that had been mown low in the previous year (2005) than in plots that had been mown high; a similar trend was observed in Kentucky bluegrass, but differences were not significant (Figure 1). The greater NDVI in previously low-mown plots was likely caused by a combination of less dead litter from the previous year and a greater amount of exposed, actively growing biomass compared with high-mown plots. After mowing treatments began, the trend reversed and NDVI became lower in low-mown than in high-mown plots. This pattern reveals a strong mowing height effect on NDVI. Visual quality remained similar between mowing treatments during the period from before to after initiation of the mowing treatment (data not shown).

General Relationships Between Normalized Difference Vegetation Index and Visual Quality

When data were pooled among mowing heights and turfgrass species, correlations between NDVI and visual quality were strong ($P < .0001$ with coefficients of determination (r^2) of 0.78 in 2005 and 0.54 in 2006). Relationships between NDVI and visual quality were stronger in 2005, probably because 2005 experienced greater heat and drought stress than 2006. The greater stress in 2005 generally expanded the range of turf quality among plots and provided a broader base for comparing NDVI with quality.

Mowing Height Effects in 2005 and 2006

When data were pooled by mowing height, r^2 values were greater at the high than at the low mowing height in both years (Table 2). The reason for this is uncertain, but this result suggests that green LAI and biomass play important roles in the relationship between NDVI and quality. Presumably, higher mowing height corresponds with greater overall green leaf area (Figure 2) and, therefore, greater chlorophyll content in the canopy. And chlorophyll content has been shown to be strongly related to NDVI. An additional factor that may weaken relationships between NDVI and quality at low mowing heights is visible soil. Because soils have different optical properties than leaves, bare soil would adversely affect NDVI.

Analyses of covariance indicated distinct relationships (i.e., models) between visual quality and NDVI at each mowing height (Table 2; Figure 3). The models varied between mowing heights and between years. In 2005, there was no interaction between models at the high and low mowing heights, but the models were significantly distinct (i.e., models had equal slopes at but different intercepts). In 2006, the models had significant interaction (i.e., different slopes). As illustrated in Figure 3, models with equal slopes but different intercepts indicate that for the same NDVI value, mean turf quality will differ between mowing heights and differences in turf quality between mowing heights will remain constant with changes in NDVI. In models with different slopes, however, differences in mean turf quality between mowing heights will vary as NDVI changes.

A second significant observation is that models at each mowing height also varied between years. At the high mowing height, the models had no interaction (i.e., equal slopes) in either year but different intercepts. At the low mowing height, there was interaction between models (i.e., different slopes) between years. This interannual variability among models may have been related to the previously described differences in heat and drought stress between 2005 and 2006. This variability in models between mowing heights and years suggests that separate models may need to be developed at each mowing height and in each year, making use of NDVI for turfgrass visual quality determinations more cumbersome.

The 95% confidence intervals surrounding predictions of visual quality from NDVI ranged from ±1.34 to 2.75 (Table 2). Therefore, the confidence intervals overlapped between high and low mowing heights, which indicates these models were not precise enough for practical detection of differences in quality with NDVI among models. Further research, perhaps with several evaluators, may be required to determine whether the models can be refined further. Nevertheless, the 95% confidence intervals were 17% to 30% smaller at high than at low mowing heights, meaning the predictive strength of the models increased with mowing height.

Table 1. Average normalized difference vegetation index (NDVI) in high-mown (3 in.) and low-mown (1.5 in.) plots of Kentucky bluegrass (Apollo) and a hybrid bluegrass (Thermal Blue) during 2005 (n = 96) and 2006 (n = 72)

		NDVI		
Year	Turfgrass	High	Low	P value[1]
2005	Kentucky bluegrass	0.804	0.790	0.23
	Hybrid bluegrass	0.760	0.727	0.02
2006	Kentucky bluegrass	0.795	0.744	0.009
	Hybrid bluegrass	0.808	0.755	0.0005

Data are from 100% evapotranspiration plots.
[1] Indicates level of significance of differences between high- and low-mown plots in each turfgrass in each year.

Table 2. Models from Kentucky bluegrass (KBG; Apollo) and a hybrid bluegrass (HBG; Thermal Blue) in 2005 (n = 192) and 2006 (n = 144), 95% confidence intervals (CI), coefficients of determination (r^2) between VQ and NDVI, and probability (P) values

					P value[1]	
Year	Mowing height	Pooled models KBG and HBG	CI: Predicting VQ from NDVI[2]	r^2	Mowing height	Year
2005	Low	NDVI=0.063*VQ+0.337	±1.66	0.75	0.053[3]	
	High	NDVI=0.068*VQ+0.316	±1.34	0.81		
2006	Low	NDVI=0.051*VQ+0.437	±2.75	0.40	0.044[4]	0.025[5]
	High	NDVI=0.064*VQ+0.380	±1.81	0.66		<.00016[6]

All coefficients of determination were significant at $P < .0001$.
[1] Determined with analysis of covariance; indicates level of significance of differences between models, either in slope or intercept.
[2] VQ, visual quality; NDVI, normalized difference vegetation index.
[3] In 2005, equal slopes but different intercepts between mowing heights.
[4] In 2006, different slopes between mowing heights.
[5] At low mowing height, different slopes between years.
[6] At high mowing height, equal slopes but different intercepts between years.

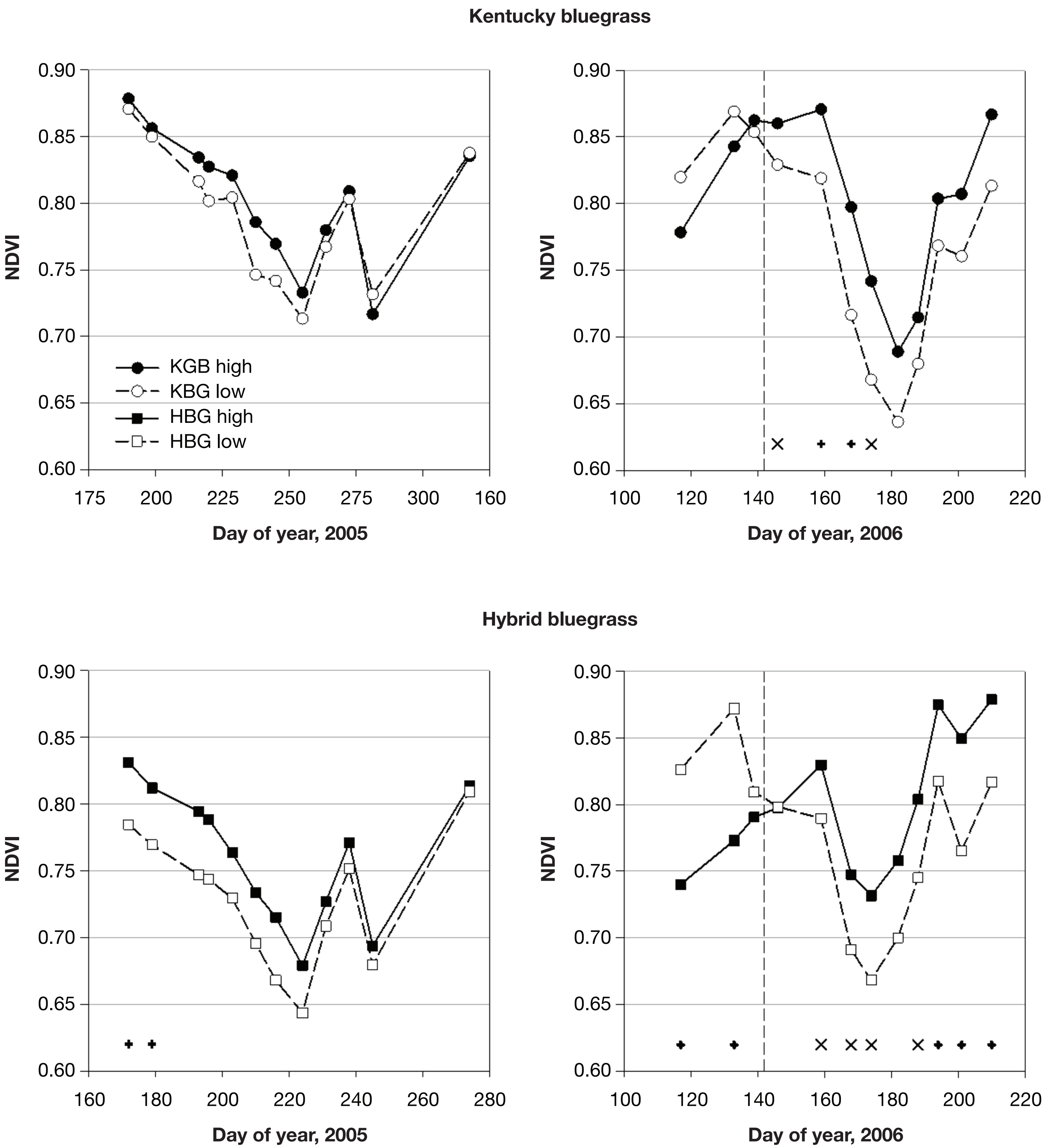


Figure 1. Normalized difference vegetation index (NDVI) in high-mown (3 in.) and low-mown (1.5 in.) plots of Kentucky bluegrass (Apollo) and a hybrid bluegrass (Thermal Blue) during 2005 and 2006.
Data are from 100% evapotranspiration plots. Significant differences between mowing treatments on a given date are denoted along the abscissa by "+" ($P < 0.05$) or "×" ($P < 0.1$). Dashed line on day-of-year 142 in 2006 indicates the beginning of the low mowing treatment.

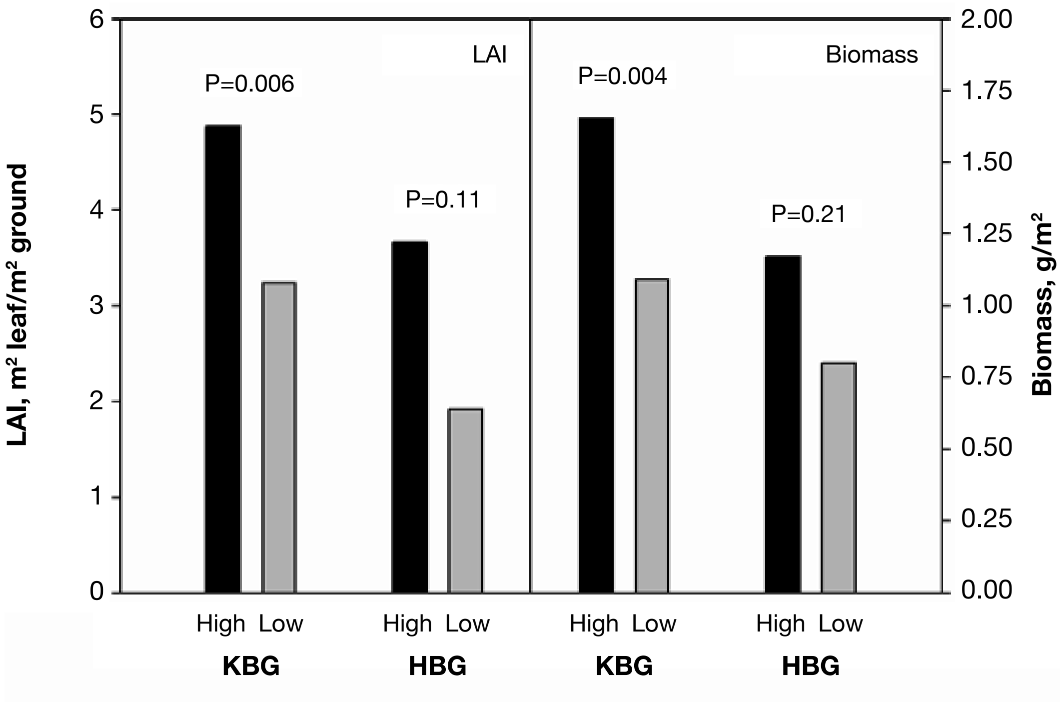


Figure 2. Green leaf area index (LAI) and biomass in high-mown (3 in.) and low-mown (1.5 in.) plots of Kentucky bluegrass (KBG; Apollo) and a hybrid bluegrass (HBG; Thermal Blue).
Values above paired bars indicate the level of significance of differences between high and low mowing heights.

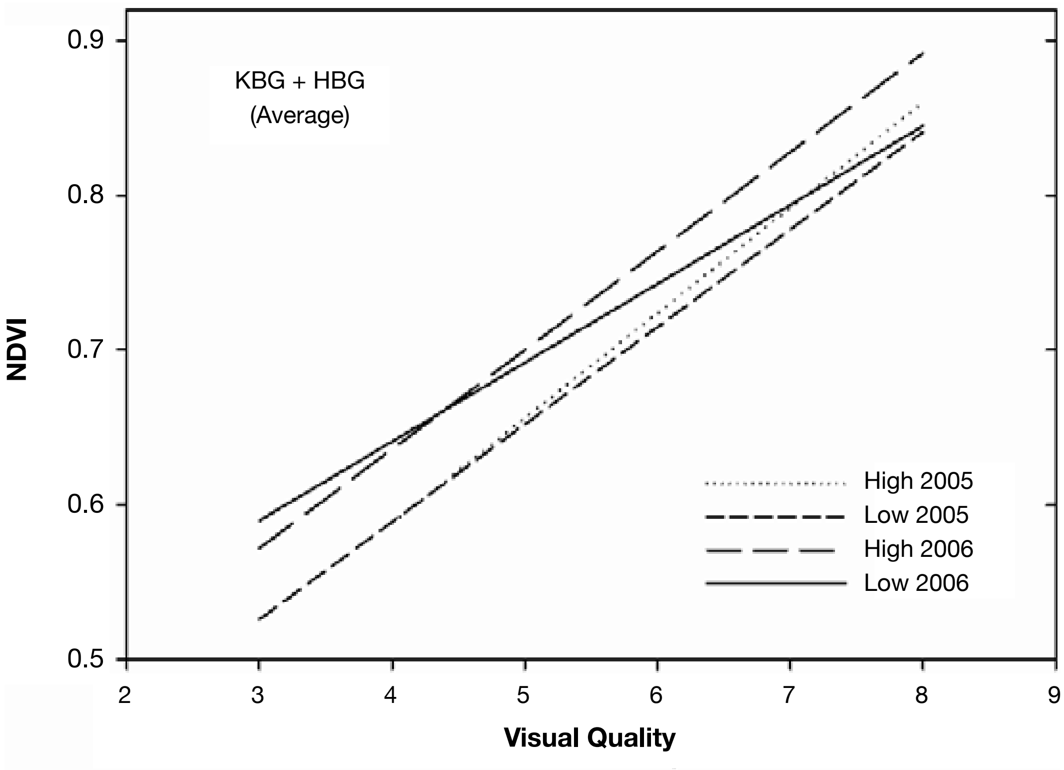


Figure 3. Relationships between normalized difference vegetation index (NDVI) and visual quality.
Scale: 1 to 9, 9 = greatest quality. Models are presented for high- and low-mown treatments in 2005 (n = 192) and 2006 (n = 144). Data are pooled between turfgrasses at each mowing height and in each year.

Moss Control in Creeping Bentgrass Putting Greens Using Conventional and Alternative Practices at Two Mowing Heights

Investigators: Megan Kennelly, Jack Fry, Andrew Lance, Derek Settle, and Tim Todd

Sponsor: Kansas Turfgrass Foundation, Chicago District Golf Association

Introduction

Mosses are common weeds on putting greens; they disrupt the aesthetic appearance and interrupt surface uniformity and ball roll. Silvery-thread moss (*Bryum argenteum*) is the most common moss species, but others can be present. Numerous products have been tested for moss control including conventional herbicide and fungicide products as well as soaps, oils, and other alternative materials. However, more information is needed on chemical control of moss. There is anecdotal evidence that lower mowing heights can lead to more severe moss, but controlled studies on this topic are lacking. The goal of this study was to examine conventional and alternative products and fertility regimes managed at two mowing heights.

Methods

Moss suppression was evaluated in 2008 in standard and alternative putting green management regimes in Manhattan, Kan., and Lemont, Ill. The standard approach included spring and fall broadcast applications of Quicksilver at 6 oz/acre (i.e., carfentrazone-ethyl at 101 g ai/ha) for moss control, applications of urea (46-0-0 N-P-K) every 2 weeks to deliver N at 0.3 lb/1,000 ft^2 (15 kg N/ha), and applications of Daconil Ultrex at 3.2 oz/1,000 ft^2 (i.e., chlorothalonil at 8.2 kg ai/ha) at 14-day intervals.

The alternative approach included spring and fall spot treatments of baking soda at 6 oz/gal (i.e., sodium bicarbonate at 44.2 g/L) for moss control, applications of a natural organic fertilizer (Sustane; 8-1-3 N-P-K) every 2 weeks to provide N at 0.3 lb/1,000 ft^2 (15 kg N/ha), and applications of Daconil Ultrex at the same rate used in the standard approach only when dollar spot reached 5% severity.

Standard and alternative regimes were compared at 0.125- and 0.156-in. (3.2 and 4.0 mm) mowing heights. Synthetic and organic fertilizers applied alone without pest control approaches were included as controls.

Results

At both sites, moss coverage on greens managed using the alternative management regime was not significantly different from that on greens managed using the standard regime. Figure 1 shows the trends in Kansas, and overall trends were similar in Illinois. In Kansas, moss severity at the lower mowing height was 1.6-fold higher than at the higher mowing height. In Illinois, baking soda suppressed moss equivalently to the Quicksilver treatment. In the fertilizer-only controls, mowing at the lower height led to more moss coverage.

These studies demonstrate that spot applications of baking soda can effectively suppress moss on greens and that reduced moss encroachment is possible with higher mowing heights. Temporary phytotoxicity (tip burn) was noted in the turf immediately adjacent to the treated moss colonies after one of the four baking soda treatments at each site.

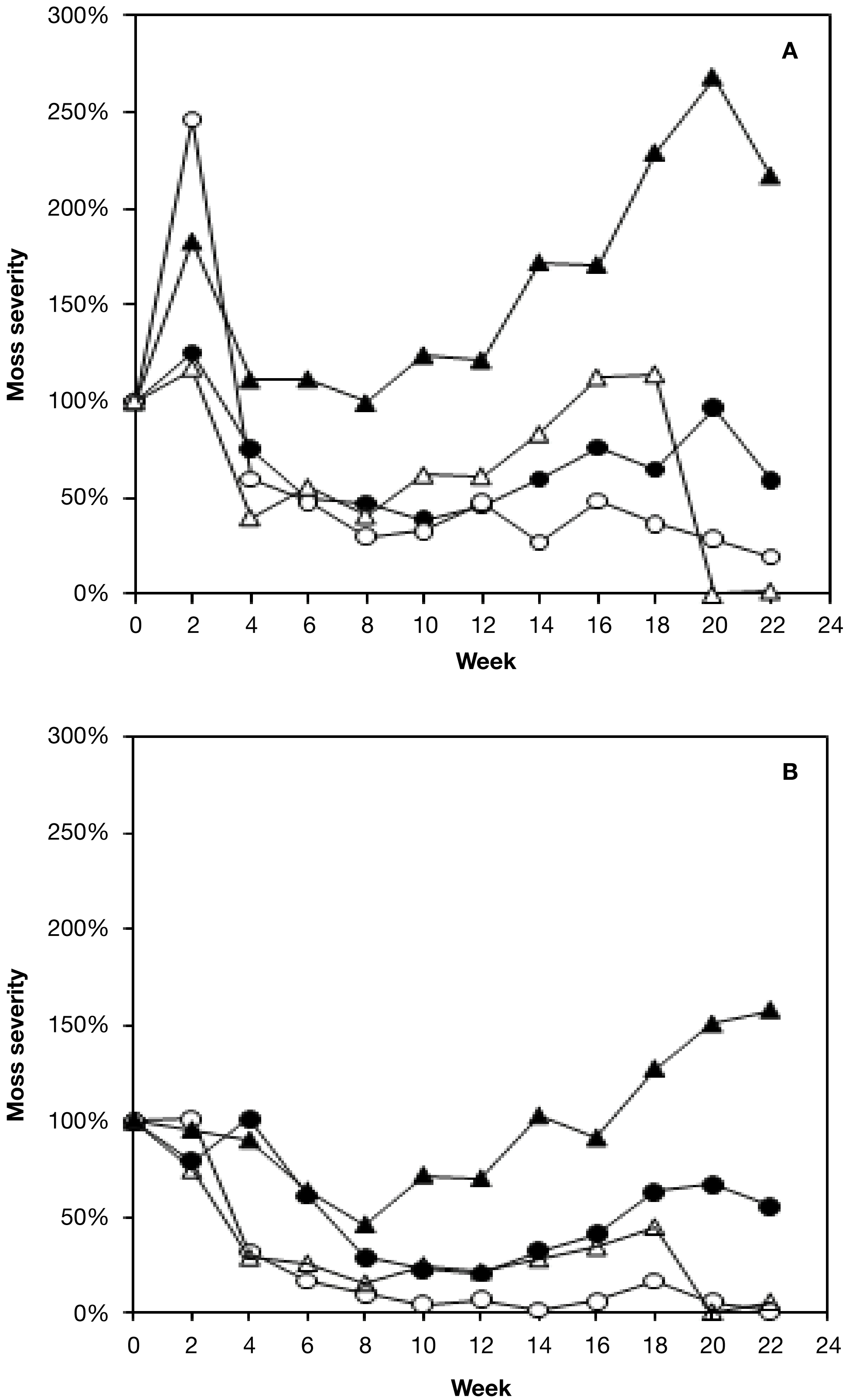


Figure 1. Influence of management systems on moss severity in creeping bentgrass mowed at 0.125 in. (A) or 0.156 in. (B) in Manhattan, Kan., in 2008.
Closed circles and closed triangles represent organic and synthetic fertilizer only, respectively. Open circles represent the alternative management regime, and open triangles represent the standard management regime. Moss severity was determined by visually estimating the percentage of each plot covered by green moss. Moss coverage at week 0 was set to 100%, and severity on subsequent dates was scaled accordingly for each plot.

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

Moss is a nonvascular plant that commonly occurs on creeping bentgrass putting greens. Though there are many species of moss, silvery-thread moss is the species 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 a herbicide commonly used by golf course superintendents to control moss. Alternative products such as sodium bicarbonate (baking soda) may also be used to control moss and are worth investigating.

Methods

This study was conducted on a putting green constructed to United States Golf Association specifications at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. At the beginning of the study, the green was tested for percentages of sand and organic matter, pH, and levels of phosphorous and potassium. The soil medium at the root zone contained 95% sand and 5% organic matter with a pH of 8.1. Phosphorous and potassium levels were 8 and 22 ppm, respectively. The putting green had a natural infestation of silvery-thread moss.

Plots were arranged in a randomized complete block design with four replications. The entire study area measured 18 ft × 24 ft, and individual plots measured 3 ft × 3 ft. The green was mowed 6 days/week at 0.125 in. with a triplex reel mower and irrigated at 100% evapotranspiration replacement. Granular urea (46-0-0 N-P-K) was dissolved in water and applied foliarly at 0.5 lb N/1,000 ft^2 every other week during the growing season in 2009.

Treatments were applied using either a spot or broadcast spray application method. For spot spray treatments, solution was applied with a handheld trigger-spray bottle until moss colonies were visibly wet. Broadcast spray treatments were applied with a handheld CO_2-powered sprayer with a two-nozzle boom at 30 psi. To cover the plot area (3 ft × 3 ft), one of the nozzle assemblies was plugged, and the other was fitted with an even-spray TeeJet nozzle.

Eleven treatments and one untreated control were applied in the spring and fall of 2009. Spring applications began on May 21 and ended with a subsequent application 2 weeks later on June 4. Fall application dates were September 11 and 24. Four sodium bicarbonate (baking soda) treatments were applied: two spot spray applications at 3 and 6 oz/gal and two broadcast spray treatments at 18 and 36 oz/1,000 ft^2. Five potassium bicarbonate (Armicarb) treatments were applied: two trigger-bottle treatments at 3 and 6 oz/gal and three broadcast treatments at 1.84, 4.4, and 36 oz/1,000 ft^2. One Mossbuster treatment was applied following the spot spray application method. Mossbuster is a ready-to-use product (1% essential oil). One carfentrazone-ethyl (Quicksilver) treatment was applied at 6 oz/acre (0.14 oz/1,000 ft^2).

Plots were rated every 2 weeks in 2009 (before treatment application if applicable) for percentage of moss coverage, moss color, and creeping bentgrass quality. The percentage of moss cover was rated visually. Moss severity differed in each plot at the beginning of the study. For this reason, moss severity was considered to be 100% at the time of the initial rating and scaled accordingly for later rating dates. Moss color was rated on a scale of 0 to 5 (0 = black, 1 = black/brown, 2 = red/brown, 3 = between 15% and 50% green, 4 = at least 50% green, and 5 = fully green). Turfgrass color was rated on a scale of 1 to 9 (1 = completely brown, 6 = minimum acceptable greenness, and 9 = optimum green color/no phytotoxicity). Means were separated using Fisher's LSD with the GLIMMIX procedure of SAS.

Results

Moss Severity

Differences in moss severity were significant on three dates in 2009 (Table 1). All plots experienced a natural decline in moss in mid-July. Untreated plots recovered from the decline experienced in midsummer and had moss severity ratings of 127.7 and 122.9 on September 11 and 23, respectively.

The low-rate broadcast treatments of sodium bicarbonate (18 oz/1,000 ft^2) and potassium bicarbonate (4.4 oz/1,000 ft^2) were similar to untreated plots and never had moss severity ratings below 70 to 80. The lowest broadcast rate of potassium bicarbonate (1.84 oz/1,000 ft^2) was significantly different from untreated plots on September 23, as were the highest broadcast treatments of sodium bicarbonate and potassium bicarbonate (36 oz/1,000 ft^2). Quicksilver was significantly different from untreated plots on September 11 and 23 and had a moss severity rating of 40.0 on September 23, which is less than half of the moss severity ratings at the beginning of the season. Mossbuster and the high-concentration spot spray application of sodium bicarbonate (6 oz/gal) were significantly different from untreated plots on September 11 and 23. Both treatments offered control similar to that of Quicksilver, as did the high-concentration spot spray application of potassium bicarbonate (6 oz/gal), which was the only treatment that was significantly different from untreated plots on July 17 and September 11 and 23. Low-rate spot spray applications of sodium bicarbonate and potassium bicarbonate (3 oz/gal) were not as effective as the high rates but still reduced moss compared with untreated plots on September 23.

Moss Color

Moss color in untreated plots was 4.5 or greater on 10 of 14 rating dates (Table 2). All treatments reduced moss color below 5.0 after the first application on May 21. Moss showed little recovery before the second spring treatment on June 4. Moss color ratings again declined for all treatments and then slowly recovered until only Mossbuster plots had poorer moss color than untreated plots on July 17 and 30. Ratings declined again after the September 11 application with little recovery before the final application of the year on September 24. Moss color ratings then further declined with little to no recovery before the end of the 2009 season.

Mossbuster was significantly different from untreated plots on all 14 rating dates and was the only treatment to differ from untreated plots on July 17 and 30. Moss color in Quicksilver-treated plots was lower than that in untreated plots on 12 of 14 rating dates. Both high- and low-concentration spot spray applications of sodium bicarbonate (3 and 6 oz/1,000 ft^2) and the high-concentration spot spray application of potassium bicarbonate (6 oz/1,000 ft^2) reduced moss color compared with untreated plots on 10 of 14 rating dates. Similarly, moss color in potassium bicarbonate (6 oz/gal) plots was greater than 2.0 on eight of 14 rating dates. The low-concentration spot spray application of potassium bicarbonate (3 oz/gal) differed from untreated plots on only four of 14 rating dates and never had a moss color rating lower than 3.3. Broadcast treatments of sodium bicarbonate and potassium bicarbonate did not greatly affect moss color. Effects of treatments on moss and creeping bentgrass phytotoxicity are shown in Figures 1 to 4.

Treatment Effects on Creeping Bentgrass Quality

Turf quality in untreated plots was acceptable on all rating dates (Table 3). Quicksilver plots never received an unacceptable turf quality rating. Mossbuster and high-concentration spot spray applications of sodium bicarbonate and potassium bicarbonate (6 oz/gal) were the most phytotoxic to creeping bentgrass and differed from untreated plots on 10 of 13 dates. In contrast, creeping bentgrass treated with the low-concentration spot spray applications of sodium bicarbonate and potassium bicarbonate (3 oz/gal) differed from untreated plots on three of 13 dates. The highest broadcast rates of sodium bicarbonate and potassium bicarbonate (36 oz/1,000 ft^2) resulted in unacceptable quality on three dates. Creeping bentgrass treated with sodium bicarbonate at 18 oz/1,000 ft^2 differed from untreated plots on three of 13 dates and was unacceptable on one date. Treatments of potassium bicarbonate at 1.83 and 4.4 oz/1,000 ft^2 resulted in relatively high turf quality ratings, and each treatment differed from untreated plots on only one date; neither treatment received a turf quality rating below 7.3.

Creeping Bentgrass Recovery

Of the 12 treatments, only high-concentration spot spray applications of sodium bicarbonate and potassium bicarbonate (6 oz/gal), Mossbuster, and the highest broadcast application rates of sodium bicarbonate and potassium bicarbonate (36 oz/1,000 ft^2) lowered turf quality below an acceptable level for more than 1 day after at least one of the four applications (Table 4).

Table 1. Effect of treatments on moss severity in 2009

	Moss severity[1]		
Treatment and rate[2]	July 17	Sept. 11	Sept. 23
Untreated control (N/A)	78.1 ab	127.7 ab	122.9 a
Sodium bicarbonate (6 oz/gal)[3]	28.2 bc	51.3 cd	31.7 c
Sodium bicarbonate (3 oz/gal)[3]	36.3 bc	81.3 abcd	63.8 bc
Potassium bicarbonate (6 oz/gal)[3]	17.9 c	37.4 cd	26.7 c
Potassium bicarbonate (3 oz/gal)[3]	51.0 bc	82.6 abcd	63.8 bc
Mossbuster (Ready-to-use)[3]	24.2 bc	21.9 d	34.6 c
Sodium bicarbonate (36 oz/1,000 ft^2)	48.3 bc	73.6 bcd	63.0 bc
Sodium bicarbonate (18 oz/1,000 ft^2)	116.7 a	139.6 a	85.8 ab
Potassium bicarbonate (1.84 oz/1,000 ft^2)	58.2 bc	91.2 abc	68.4 bc
Potassium bicarbonate (4.4 oz/1,000 ft^2)	72.0 abc	101.5 abc	88.8 ab
Potassium bicarbonate (36 oz/1,000 ft^2)	49.2 bc	84.2 abcd	70.0 bc
Quicksilver (0.14 oz/1,000 ft^2)	27.0 bc	45.6 cd	40.0 bc

Values displayed are means across four replications.
Within a column, means followed by the same letter are not significantly different ($P \leq 0.05$) according to LSD.
[1] Moss severity is a visual estimate of the percentage of each research plot 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 = [percentage of moss on rating date / percentage of moss on May 12] × 100).
[2] Application dates were May 21, June 4, September 11, and September 24.
[3] Treatments were applied to plots with a handheld trigger bottle until moss colonies were visibly wet.

Table 2. Effect of treatments on moss color in 2009

	Moss color[1]													
Treatment and rate[2]	May 22	May 28	June 4	June 10	June 18	July 2	July 17	July 30	Sept. 12	Sept. 23	Sept. 25	Oct. 5	Oct. 7	Oct. 20
Untreated control (N/A)	5.0 a	5.0 a	5.0 a	5.0 a	3.8 a	5.0 a	5.0 a	5.0 a	4.3 abc	4.8 a	4.8 a	3.0 abcd	3.5 ab	4.5 a
Sodium bicarbonate (6 oz/gal)[3]	2.3 e	2.0 e	2.1 ef	1.5 cd	1.5 de	3.8 bc	4.8 a	4.8 a	2.0 f	1.8 d	1.3 de	1.8 cdef	2.0 bc	2.0 cd
Sodium bicarbonate (3 oz/gal)[3]	2.0 e	3.5 c	2.6 de	2.5 c	2.8 abcd	4.0 b	4.8 a	5.0 a	2.0 f	3.0 c	1.5 de	1.3 def	1.5 cd	2.8 bcd
Potassium bicarbonate (6 oz/gal)[3]	2.3 e	2.8 d	2.1 ef	2.0 cd	1.8 cde	3.0 c	4.5 a	5.0 a	3.0 e	4.3 ab	2.0 de	2.0 bcde	1.8 c	1.8 de
Potassium bicarbonate (3 oz/gal)[3]	3.3 d	4.5 ab	3.8 c	4.0 ab	3.5 ab	5.0 a	4.5 a	4.8 a	3.5 de	4.5 ab	3.3 c	3.5 abc	3.8 a	4.5 a
Mossbuster (Ready-to-use)[3]	1.9 e	2.0 e	1.0 g	1.0 de	1.3 e	1.0 d	2.5 b	3.8 b	2.0 f	1.5 d	1.0 e	1.0 ef	1.3 cd	1.5 de
Sodium bicarbonate (36 oz/1,000 ft^2)	3.4 cd	4.0 bc	3.9 bc	4.0 ab	2.8 abcd	5.0 a	5.0 a	5.0 a	4.0 bcd	4.3 ab	4.3 ab	3.0 abcd	4.0 a	4.0 ab
Sodium bicarbonate (18 oz/1,000 ft^2)	3.0 d	3.8 c	3.8 c	4.5 ab	2.3 bcde	4.5 ab	4.5 a	5.0 a	4.8 a	4.5 ab	4.3 ab	2.8 abcde	3.8 a	3.3 abc
Potassium bicarbonate (1.84 oz/1,000 ft^2)	4.0 b	4.8 a	4.1 bc	5.0 a	4.0 a	5.0 a	5.0 a	5.0 a	4.5 ab	5.0 a	4.3 ab	2.8 abcde	3.5 ab	4.3 a
Potassium bicarbonate (4.4 oz/1,000 ft^2)	3.8 bc	4.0 bc	4.5 ab	4.8 ab	3.5 ab	5.0 a	5.0 a	5.0 a	4.5 ab	4.8 a	4.5 ab	4.0 a	4.3 a	4.3 a
Potassium bicarbonate (36 oz/1,000 ft^2)	4 b	4.0 bc	2.9 d	3.8 b	3.0 abc	4.5 ab	4.5 a	5.0 a	3.8 cd	3.8 bc	3.8 bc	3.8 ab	3.8 a	3.8 ab
Quicksilver (0.14 oz/1,000 ft^2)	1.0 f	0.8 f	1.9 f	0.0 e	1.3 e	3.0 c	5.0 a	5.0 a	0.3 g	1.0 d	0.0 f	0.0 f	0.0 d	0.5 e

Within a column, means followed by the same letter are not significantly different ($P \leq 0.05$) according to LSD.

[1] Scale: 0 to 5 (0 = black, 1 = black/brown, 2 = red/brown, 3 = between 15% and 50% green, 4 = at least 50% green, and 5 = fully green).

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

[3] Treatments were applied to plots with a handheld trigger bottle until moss colonies were visibly wet.

Table 3. Effect of treatments on creeping bentgrass quality in 2009

	Quality[1]												
Treatment and rate[2]	May 22	May 28	June 4	June 5	June 10	June 18	July 2	Sept. 12	Sept. 23	Sept. 25	Oct. 2	Oct. 7	Oct. 20
Untreated control (N/A)	7.9 a	8.8 a	8.4 a	8.0 a	8.3 a	8.3 ab	8.8 ab	8.8 a	8.0 a	7.8 a	7.8 ab	7.5 ab	8.0 a
Sodium bicarbonate (6 oz/gal)[3]	7.6 ab	7.3 b	3.9 f	3.8 f	5.8 d	7.5 dce	8.5 ab	5.8 c	6.2 cd	6.0 bc	6.5 bc	6.3 c	7.3 b
Sodium bicarbonate (3 oz/gal)[3]	7.8 ab	7.8 b	7.5 abc	7.3 ab	8.3 a	8.5 a	8.8 ab	6.5 bc	6.8 bcd	7.0 abc	7.3 ab	7.3 abc	7.5 ab
Potassium bicarbonate (6 oz/gal)[3]	7.0 b	7.3 b	6.4 de	5.5 de	5.3 d	7.0 e	8.3 b	7.0 b	7.3 abc	6.3 bc	5.5 c	6.3 c	7.5 ab
Potassium bicarbonate (3 oz/gal)[3]	7.9 a	7.3 b	7.3 bcd	7.0abc	7.8 ab	7.8 bcd	8.3 b	6.8 bc	7.8 ab	7.0 abc	7.3 ab	7.8 ab	7.8 ab
Mossbuster (Ready-to-use)[3]	2.9 d	5.0 c	6.9 cd	6.8 bc	5.3 d	7.0 e	9.0 a	3.3 e	5.8 d	7.0 abc	7.0 ab	6.3 c	7.3 b
Sodium bicarbonate (36 oz/1,000 ft^2)	6.0 c	8.0 ab	3.6 f	3.8 f	7.0 bc	8.0 abc	8.8 ab	6.5 bc	7.5 abc	5.8 cd	6.5 bc	7.0 abc	7.3 b
Sodium bicarbonate (18 oz/1,000 ft^2)	7.5 ab	7.3 b	5.6 e	6.0 cd	7.8 ab	8.0 abc	8.5 ab	8.5 a	8.3 a	6.8 abc	8.0 a	8.0 a	7.8 ab
Potassium bicarbonate (1.84 oz/1,000 ft^2)	7.8 ab	7.5 b	7.8 abc	7.8 ab	8.3 a	7.8 bcd	8.5 ab	8.8 a	8.0 a	7.3 ab	7.8 ab	7.5 ab	8.0 a
Potassium bicarbonate (4.4 oz/1,000 ft^2)	7.6 ab	7.5 b	7.9 ab	7.8 ab	8.5 a	8.0 abc	8.3 b	8.5 a	8.0 a	7.8 a	7.8 ab	7.5 ab	8.0 a
Potassium bicarbonate (36 oz/1,000 ft^2)	7.6 ab	7.8 b	4.1 f	4.5 ef	6.3 cd	7.3 de	8.8 ab	4.5 d	7.3 abc	4.5 d	7.0 ab	6.8 bc	7.5 ab
Quicksilver (0.14 oz/1,000 ft^2)	7.6 ab	7.8 b	7.9ab	8.0 a	8.0 ab	7.8 bcd	8.8 ab	8.8 a	7.8 ab	8.0 a	8.3 a	7.8 ab	7.3 b

Within a column, means followed by the same letter are not significantly different ($P \leq 0.05$) according to LSD.

[1] Scale: 0 to 9 (0 = completely brown, 6 = minimum acceptable greenness, 9 = optimum green color/no phytotoxicity).

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

[3] Treatments were applied to plots with a handheld trigger bottle until moss colonies were visibly wet.

Table 4. Days to acceptable turf quality in 2009

Treatment and rate	Days to acceptable turf quality[1]			
	May 21	June 4	Sept. 11	Sept. 24
Untreated control (N/A)	1	1	1	1
Sodium bicarbonate (6 oz/gal)[2]	1	14	12	1
Sodium bicarbonate (3 oz/gal)[2]	1	1	1	1
Potassium bicarbonate (6 oz/gal)[2]	1	14	1	1
Potassium bicarbonate (3 oz/gal)[2]	1	1	1	1
Mossbuster (Ready-to-use)[2]	14	1	14	1
Sodium bicarbonate (36 oz/1,000 ft^2)	1	6	1	8
Sodium bicarbonate (18 oz/1,000 ft^2)	1	1	1	1
Potassium bicarbonate (1.84 oz/1,000 ft^2)	1	1	1	1
Potassium bicarbonate (4.4 oz/1,000 ft^2)	1	1	1	1
Potassium bicarbonate (36 oz/1,000 ft^2)	1	6	12	13
Quicksilver (0.14 oz/1,000 ft^2)	1	1	1	1

[1] Days to acceptable quality after treatments were applied. Application dates were May 21, June 4, September 11, and September 24. Values were determined using creeping bentgrass quality data taken on 13 dates from May 22 to October 20.

[2] Treatments were applied to plots with a handheld trigger bottle until moss colonies were visibly wet.

Figure 1. Untreated plot 5 days after the first application on May 21, 2009.

Figure 2. Research plot 5 days after being treated with Mossbuster on May 21, 2009.

Figure 3. Research plot 5 days after being treated with Quicksilver on May 21, 2009.

Figure 4. Research plots on June 3, 13 days after the first application on May 21, 2009.

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

Introduction

Mosses are nonvascular plants that are commonly considered weeds when found in creeping bentgrass putting greens. Silvery-thread moss is the most common moss species found on putting greens. Though ultra-low mowing heights and the absence of mercury-based fungicides in today's pesticide programs are major factors in the current state of moss as an invasive weed, fertility is also though to have a role. Nitrogen deficiencies cause turf to grow less vigorously and allow an avenue for moss encroachment. Earlier research at Kansas State University indicated that soluble nitrogen 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 nitrogen sources.

Methods

This study is being conducted on a push-up green at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. Fifteen research plots were laid out on May 5, 2009. We used a 3 ft × 3 ft square cardboard frame to help lay out plots. The cardboard frame was placed where moss was present on the putting green, and corners were marked. The process was repeated 15 times, yielding three replications with five plots each. Treatments were then randomly assigned to plots. The putting green was mowed 6 days/week at 0.125 in. with a triplex reel mower.

Fertility treatments were applied every 2 weeks in 2009. Four treatments of different nitrogen sources were used to deliver 0.333 lb N/1,000 ft^2 on 13 dates beginning on May 14 and ending on October 30. Urea (46-0-0 N-P-K) was applied foliarly to research plots by dissolving granular urea in water and using a handheld CO_2-powered sprayer with a two-nozzle boom at 30 psi in 2.5 gal water/1,000 ft^2. Granular urea (46-0-0 N-P-K), isobutydine diurea (IBDU; 31-0-0 N-P-K, a slow-release nitrogen source), and Sustane (8-2-4 N-P-K, an organic fertilizer), were applied using a shaker jar. Sustane was the only fertilizer that contained phosphorous and potassium in addition to nitrogen. To ensure that any observed effects were due to a nitrogen response, superphosphate and sulfate of potash were applied with the other three nitrogen sources at a rate equal to the amount of phosphorus and potassium applied with Sustane.

Plots were rated for moss severity every 2 weeks from May 5 to October 30 and for bentgrass color every week from June 4 to October 30. Moss severity was a visual estimate of the percentage of moss in each plot. Moss severity differed in each plot at the beginning of the study. For this reason, moss severity was considered to be 100% at the time of the initial rating scaled accordingly for later rating dates. Bentgrass color was rated on scale of 1 to 9 (1 = completely brown, 6 = minimum acceptable green color, and 9 = optimum dark green color). Tissue samples of creeping bentgrass and from moss colonies were taken on May 11, 2009, to determine nitrogen content of foliage. Creeping bentgrass tissue samples were collected from clippings after mowing. One-inch moss plugs were removed with a soil probe, and the top 0.10 in. of the moss plugs was then removed for tissue analysis. Means were separated using Fisher's LSD with the GLIMMIX procedure of SAS.

Results

Treatment Effects on Moss Severity

Moss severity declined during the warm summer months regardless of fertility treatment. Severity then slowly increased with cooling temperatures in the fall, and no treatments reached severity levels equal to those on first rating date of May 5 (Table 1). Treatments were not significantly different from one another or from untreated plots on any date in 2009. Tissue samples collected from creeping bentgrass and moss colonies on May 11, 2009, indicated 1.9% N in bentgrass and 1.8% N in moss.

Creeping Bentgrass Color

Granular and foliar applications of urea generally yielded higher turfgrass color ratings than other fertility treatments (Table 2). The two were in the same significance level on 13 dates and significantly greater than untreated plots on all16 rating dates. Urea treatments differed from plots treated with Sustane on 12 dates. Color ratings in plots treated with IBDU were similar to those in at least one urea treatment on 12 dates and significantly greater than untreated plots and plots treated with Sustane on 15 and five dates, respectively. Sustane consistently had lower turf color ratings than other treatments and produced color ratings better than untreated plots on only five dates. Creeping bentgrass treated with urea never received a color rating below an acceptable level in 2009. Untreated plots and plots treated with Sustane and IBDU received unacceptable color ratings on 14, 8, and 1 rating dates, respectively.

Table 1. Moss response to nitrogen source in 2009

	Moss severity[1]		
Treatment[2]	May 5	August 7	October 30
Untreated	100	47.5	56.2
Urea (46-0-0)			
Foliar	100	62.5	76.8
Granular[3]	100	35.0	74.8
IBDU (31-0-0)	100	55.6	94.8
Sustane (8-2-4)	100	58.6	80.1

Values displayed are means across three replications.

[1] Moss severity is a visual estimate of the percentage of each research plot 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 5. Subsequent estimates were then scaled accordingly. (Moss severity in each plot = [percentage of moss on rating date / percentage of moss on 5 May] × 100).

[2] Data from three dates are shown although there were no significant differences between treatments on any date in 2009.

[3] Granular urea was dissolved in water and applied foliarly with a CO_2-powered handheld boom.

Table 2. Effect of treatments on creeping bentgrass color

	Turfgrass color[1]				
Treatment	June 4	July 9	Aug. 7	Sept. 30	Oct. 30
Untreated	6.0 c	3.7 c	4.3 b	4.7 c	5.0 c
Urea (46-0-0)					
Foliar	7.7 ab	8.0 a	7.7 a	8.0 a	7.7 a
Granular[2]	8.0 a	6.7 b	7.7 a	7.7 a	7.7 a
IBDU (31-0-0)	6.7 bc	6.7 b	7.3 a	6.7 b	7.0 ab
Sustane (8-2-4)	6.7 bc	4.3 c	5.0 b	6.7 b	6.0 bc

Within a column, means followed by the same letter are not significantly different ($P \leq 0.05$) according to LSD.

[1] Scale: 1 to 9 (1 = completely brown, 6 = minimum acceptable color, and 9 = optimum dark green color). Data were taken on 16 dates, and data from five dates are shown.

[2] Granular urea was dissolved in water and applied foliarly with a CO_2-powered handheld boom.

Figure 1. Research plots after the first fertility treatment on May 14, 2009.

Figure 2. Research plots on June 18, 2009, after three fertility treatments.

Figure 3. Research plot after being treated with isobutydine diurea on Sept. 30, 2009.

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 is one of the most important diseases of creeping bentgrass. Increasing fungicide resistance as well as increasing regulations on chemical use requires 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

This study is being conducted at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. Similar studies are being conducted at universities throughout the north central region of the United States. Fifteen creeping bentgrass cultivars were established in September 2008 on a native soil fairway (Figure 1) and a putting green constructed to United States Golf Association standards (Figure 2). The putting green and fairway were mowed with a triplex reel mower at 0.125 and 0.5 in., respectively. The putting green was mowed 6 days/week, and the fairway was only mowed 3 days/week.

Green and fairway studies were fertilized with urea (46-0-0 N-P-K) at 0.5 lb N/1,000 ft^2 every other week in the spring and summer of 2009. When fungicide applications began, urea fertilization ceased and Professional Fertilizer (18-0-24 N-P-K, Global Seed and Fertilizer, Jackson, Wis.) was applied once monthly at 0.5 lb N/1,000 ft^2 to the fairway and 1 lb N/1,000 ft^2 to the putting green. The fairway was irrigated at 75% evapotranspiration 3 days/week, and the green was irrigated daily at 100% evapotranspiration. Core aerification was performed to the putting green in the spring and fall of 2009 and to the fairway in the fall of 2009.

Each cultivar was established in three 4 ft × 10 ft plots in both fairway and green study areas, yielding two plot areas with 15 treatments and three replications. Replications were then split to achieve a split block design for fungicide applications. A preventative fungicide application was made at the first sign of dollar spot infection centers in all replications of a susceptible cultivar (‘Crenshaw’). Subsequent applications were to follow when two of three plots of a resistant cultivar (‘Declaration’) had more than 5% dollar spot coverage on the putting green and more than 10% dollar spot coverage under fairway conditions. A tank mix of Emerald (0.18 oz/1,000 ft^2) and Daconil Ultrex (3.2 oz/1,000 ft^2) was applied to both fairway and green studies on July 30, 2009. Subsequent applications were not required in the fairway or green.

Both studies were rated monthly for the percentage of cover and every other week for turfgrass quality. Cover data was a visual estimate, and quality was rated on a scale of 1 to 9 (1 = completely brown, 6 = minimum acceptable quality, and 9 = optimum quality). Dollar spot injury was rated by counting the number of infection centers in each plot weekly (when infection was present). Other diseases were rated by visually estimating the percentage of injury in each plot. Means were separated using Fisher's LSD with the GLIMMIX procedure of SAS.

Results

Establishment

Fairway. There were generally no differences between cultivars in turfgrass cover in the fairway study from establishment in September 2008 through the 2009 season. All cultivars achieved cover ratings of 70% to 85% by Nov. 12, 2008, and cover ratings were between 95% and 100% on June 10, 2009 (data not shown). A decrease in coverage on July 9, 2009, occurred because of a pythium outbreak on July 8, 2009. With the exception of Crenshaw, all cultivars recovered and remained around 100% cover for the rest of 2009. Crenshaw received a significantly lower cover rating than all other cultivars on September 30, likely because of dollar spot pressure (Table 1).

Putting Green. The 15 creeping bentgrass cultivars established at generally the same rate from September 2008 to September 2009 (data not shown). All cultivars had between 90% and 100% coverage on July 9, and cover ratings remained around 100% for the rest of 2009.

Dollar Spot Resistance

Fairway. All creeping bentgrass cultivars performed better than Crenshaw and generally had significantly fewer dollar spot infection centers (Table 1). An area-under-the-curve analysis indicated that Crenshaw had significantly more dollar spot injury through the 2009 season than any other cultivar evaluated. Declaration had the lowest area-under-curve value but was significantly more resistant to dollar spot than only Crenshaw and 'Bengal'. All other cultivars were similar to Bengal.

Putting Green. All cultivars performed better than Crenshaw and had significantly less dollar spot injury (Table 2). As in the fairway study, Crenshaw had the greatest area-under-curve value and was significantly more susceptible to dollar spot than any other cultivar. There were no other significant differences in area-under-curve values among cultivars. Photos of selected cultivars are shown in Figures 3 to 6.

Creeping Bentgrass Quality

Fairway. No one cultivar consistently performed better than any other in 2009 (Table 3). All cultivars received quality ratings between 6.7 and 8.0 on May 14 and then steadily increased in quality; all were rated 9.0 on June 10. Quality declined in all cultivars during summer months and slowly improved until the final rating date on October 16, when only Crenshaw received a rating below 7.0. Declaration received significantly lower quality ratings than other cultivars on July 23, August 7, August 18, and September 4 and had unacceptable quality on July 23. Crenshaw was the only other cultivar to receive an unacceptable quality rating; on September 30, its quality was significantly lower than that of all other cultivars. Crenshaw also received a quality rating significantly lower than that of other cultivars on Oct. 16. Reduction in quality on both dates was due to dollar spot injury.

Putting Green. As in the fairway study, no one cultivar consistently outperformed the rest (Table 4). All cultivars had acceptable quality on Nov. 12, 2008, which was 2 months after seeding. All cultivars were rated as unacceptable on the first rating date in 2009 (May 14) but greened up quickly; all cultivars had acceptable quality 2 weeks later (quality ratings ranged from 6.7 to 8.0). In general, cultivars performed similarly in 2009, and ratings regularly exceeded 7.0. No cultivar had a quality rating below an acceptable level during the rest of the season.

Table 1. Dollar spot severity at fairway height in 2009

	Dollar spot severity[1]			
Cultivar	Sept. 9	Sept. 30	Oct. 21	AUC[2]
L-93	14.3 bcde	51.0 bc	43.2 b	289.8 bc
T-1	20.2 bc	68.3 bc	48.3 b	341.7 bc
Alpha	15.5 bcde	64.5 bc	46.0 b	353.7 bc
Kingpin	8.0 de	30.0 bc	23.2 b	191.1 bc
Crenshaw	57.8 a	178.0 a	152.3 a	1018.2 a
Penncross	12.8 dce	52.7 bc	39.3 b	308.5 bc
A-4	29.0 b	71.0 bc	47.7 b	393.8 bc
Crystal Bluelinks	9.3 de	44.2 bc	28.3 b	252.3 bc
007	12.5 cde	21.2 bc	13.8 b	151.1 bc
Mackenzie	8.8 de	49.3 bc	36.3 b	270.5 bc
Memorial	10.3 de	33.7 bc	26.0 b	214.2 bc
Independence	20.2 bcd	78.3 b	60.7 b	413.83 bc
Declaration	2.5 e	16.5 c	10.2 b	110.6 c
LS-44	20.2 bcd	71.0 bc	50.0 b	383.3 bc
Bengal	26.3 bc	79.2 b	55.7 b	430.8 b

Within a column, means followed by the same letter are not significantly different ($P \leq 0.05$) according to LSD.

[1] Severity = number of dollar spot infection centers. Data were taken on eight dates, and three of the seven significant dates are shown.

[2] AUC, area under the curve; summarizes all eight rating dates in 2009.

Table 2. Dollar spot severity at putting green height in 2009

	Dollar spot severity[1]			
Cultivar	Sept. 9	Sept. 30	Oct. 21	AUC[2]
L-93	7.0 bc	3.0 b	1.2 b	30.8 b
T-1	41.0 bc	23.0 b	14.2 b	217.6 b
Alpha	24.3 bc	16.0 b	8.3 b	130.0 b
Kingpin	1.8 c	0.0 b	0.0 b	4.8 b
Crenshaw	84.8 a	87.2 a	71.7 a	588.5 a
Penncross	7.0 bc	2.3 b	0.5 b	25.4 b
A-4	22.8 bc	15.2 b	8.2 b	120.8 b
Crystal Bluelinks	4.5 bc	2.5 b	1.2 b	19.3 b
007	25.2 bc	17.3 b	7.8 b	140.3 b
Mackenzie	26.3 bc	17.2 b	8.8 b	129.3 b
Memorial	1.2 c	0.3 b	0.0 b	3.0 b
Independence	47.0 ab	32.7 b	21.2 b	243.9 b
Declaration	3.2 c	1.5 b	0.2 b	15.1 b
LS-44	19.5 bc	9.8 b	5.7 b	87.2 b
Bengal	21.7 bc	18.0 b	10.2 b	137.8 b

Within a column, means followed by the same letter are not significantly different ($P \leq 0.05$) according to LSD.
[1] Severity = number of dollar spot infection centers. Data were taken on eight dates, and three of the seven significant dates are shown.
[2] AUC, area under the curve; summarizes all eight rating dates in 2009.

Table 3. Creeping bentgrass quality at fairway height in 2009

	Turfgrass quality[1]			
Cultivar	May 14	July 23	Sept. 30	Oct. 16
L-93	7.0 cd	7.0 cd	7.5 abc	8.2 abc
T-1	7.7 ab	6.3 e	7.0 bc	8.2 abc
Alpha	7.3 bc	6.7 de	7.2 abc	7.8 abc
Kingpin	7.7 ab	7.7 ab	7.7 ab	8.3 ab
Crenshaw	6.7 d	7.3 bc	5.7 d	6.7 d
Penncross	7.0 cd	8.0 a	7.3 abc	8.7 a
A-4	7.3 bc	6.3 e	6.7 c	7.8 abc
Crystal Bluelinks	7.3 bc	7.3 bc	7.5 abc	8.3 ab
007	8.0 a	7.0 cd	8.0 a	8.0 abc
Mackenzie	7.7 ab	7.3 bc	7.3 abc	8.2 abc
Memorial	8.0 a	7.3 bc	7.8 ab	8.2 abc
Independence	7.3 bc	6.7 de	6.7 c	7.5 bcd
Declaration	7.7 ab	5.7 f	7.8 ab	8.0 abc
LS-44	7.7 ab	7.3 bc	7.3 abc	8.0 abc
Bengal	8.0 a	7.7 ab	6.7 c	7.3 cd

Within a column, means followed by the same letter are not significantly different ($P \leq 0.05$) according to LSD.
[1] Scale: 1 to 9 (1 = completely brown, 6 = minimum acceptable quality, and 9 = optimum quality). Data were taken on 12 dates, and four of the eight significant dates are shown.

Table 4. Creeping bentgrass quality at green height in 2009

	Turfgrass quality[1]			
Cultivar	May 14	July 23	Sept. 30	Oct. 16
L-93	6.7 d	8.3 ab	8.3 bcd	6.7 c
T-1	7.7 ab	9.0 a	8.8 ab	7.5 a
Alpha	8.0 a	8.7 a	8.5 abc	6.8 bc
Kingpin	7.3 bc	8.7 a	9.0 a	7.3 ab
Crenshaw	7.0 cd	8.7 a	8.7 abc	6.7 c
Penncross	7.3 bc	8.7 a	8.2 cd	7.2 abc
A-4	7.0 cd	8.7 a	8.7 abc	7.0 abc
Crystal Bluelinks	7.3 bc	8.7 a	8.5 abc	7.0 abc
007	7.7 ab	7.7 b	7.8 d	7.3 ab
Mackenzie	6.7 d	8.3 ab	8.3 bcd	7.0 abc
Memorial	7.3 bc	9.0 a	8.3 bcd	6.7 c
Independence	7.7 ab	8.7 a	8.5 abc	7.2 abc
Declaration	7.3 bc	9.0 a	8.7 abc	7.5 a
LS-44	7.7 ab	8.7 a	9.0 a	7.3 ab
Bengal	7.0 cd	9.0 a	9.0 a	7.2 abc

Within a column, means followed by the same letter are not significantly different ($P \leq 0.05$) according to LSD.
[1] Scale: 1 to 9 (1 = completely brown, 6 = minimum acceptable quality, and 9 = optimum quality). Data were taken on 12 dates, and four of the six significant dates are shown.

Figure 1. Fairway study area on June 11, 2009 (8 months after being seeded in September 2008).

Figure 2. Putting green study area on June 11, 2009 (8 months after being seeded in September 2008).

Figure 3. Crenshaw creeping bentgrass, not treated with fungicide, at green height on Sept. 30, 2009.

Figure 4. Declaration creeping bentgrass, not treated with fungicide, at green height on Sept. 30, 2009.

Figure 5. L-93 creeping bentgrass, not treated with fungicide, at green height on Sept. 30, 2009.

Figure 6. Penncross creeping bentgrass, not treated with fungicide, at green height on Sept. 30, 2009.

Evaluation of Fungicide Applications for Control of Spring Dead Spot in Bermudagrass

Investigator: Megan Kennelly

Sponsor: Cleary Chemical, Gowan Company, Kansas Turfgrass Foundation

Introduction

Spring dead spot, caused by several fungi in the genus *Ophiosphaerella*, is the most common and serious disease of bermudagrass in Kansas. It causes large, sunken areas several feet across that take a long time to recover. These dead patches are frequently colonized by weeds. Information on products and application timing is needed for improved control.

Methods

Fungicides were evaluated on an established stand of 'Yukon' bermudagrass at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. All materials were applied with a handheld CO_2-powered boom sprayer equipped with three XR TeeJet 8003VS nozzles at 30 psi in water equivalent to 2.0 gal/1,000 ft^2. Plots were 5 ft × 8 ft and arranged in a randomized complete block design with four replications. Rubigan applications were made on Sept. 9 and/or Oct. 2, 2008. CX-09 was applied on Sept. 9, 2008, and 3336 Plus and Protect were applied on May 8, 2009. Plots were irrigated with 0.5-in. of water immediately following the September and October applications. In mid-May and early June, we rated plots by visually estimating the percentage of each plot affected by spring dead spot symptoms.

Results

See Table 1 for full results. Spring dead spot symptoms became visible in mid-May as the bermudagrass greened up. Diseased areas appeared tan and sunken with weed encroachment. No treatment reduced disease compared with the untreated control, and there were no significant differences among treatments on either rating date. This is consistent with prior tests in Kansas in which fungicides were not effective. There were no differences in green-up, and no phytotoxic effects were observed.

Table 1. Spring dead spot severity as influenced by fungicide treatment

		Disease severity	
Treatment and rate/1,000 ft^2	Application timing	May 22	June 5
Untreated	n/a	15.8 a	12.5 a
Rubigan 1AS 6.0 fl oz	Sept. 9, 2008	5.5 a	7.0 a
Rubigan 1AS 6.0 fl oz	Oct. 2, 2008	33.8 a	22.0 a
Rubigan 1AS 4.0 fl oz	Sept. 9 + Oct. 2, 2008	20.0 a	14.8 a
CX-09 2.5 oz + 3336 Plus 2F 4.0 fl oz + Protect 75DF 8.0 oz	Sept. 9, 2008 + May 8, 2009[1]	30.0 a	18.8 a

Values represent means of four replications. Values were square root transformed before analysis.
Within columns, means followed by the same letter are not significantly different according to Tukey's pairwise comparisons (family error rate P = 0.05).
[1] CX-09 was applied on Sept. 9, and 3336 Plus and Protect were applied on May 8.

Preventative Fungicide Applications for Control of Dollar Spot and Brown Patch on Creeping Bentgrass in Kansas

Investigators: Megan Kennelly and Cole Thompson

Sponsors: BASF, Kansas Turfgrass Foundation

Introduction

Dollar spot is caused by the fungus *Sclerotinia homoeocarpa*. It is a common disease, appearing 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. Brown patch, caused by the fungus *Rhizoctonia solani*, also causes blighting in hot, humid weather. Many fungicides are labeled for dollar spot and brown patch suppression in golf courses. This study was conducted to evaluate several fungicides for dollar spot and brown patch control.

Methods

Fungicides were evaluated on an established stand of a 'Crenshaw-Cato' blend of creeping bentgrass on a sand-based putting green at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. The turf was mowed to a height of 0.156-in. and irrigated daily for 15 minutes. The area was fertilized every 2 weeks with 0.5 lb N/1,000 ft^2 during March through June and 0.33 lb N/1,000 ft^2 during July through November. Fungicide applications were made at 14- or 21-day intervals beginning on May 28 with the final application on August 20. Fungicides were applied with a CO_2-powered boom sprayer equipped with two XR TeeJet 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. We periodically rated plots by visually estimating the percentage of each plot affected by dollar spot or brown patch symptoms.

Results

See Table 1 for full results. Dollar spot severity remained less than 10% from late June through early August then steadily increased from mid-August into September. All materials studied reduced dollar spot to zero, except a trace amount of dollar spot remained in the Emerald 0.18 oz treatment on June 19. Brown patch symptoms were visible on only one rating date at low levels, and all fungicides reduced disease to zero. No phytotoxic effects were observed.

Table 1. Dollar spot and brown patch severity as influenced by fungicides

Treatment[1] and rate/1,000 ft^2	Spray interval (days)	Dollar spot severity (%)					Brown patch severity
		June 19	July 17	Aug. 12	Aug. 28	Sept. 10	July 17
Untreated control		7.0 a	4.3 a	14.5 a	20.0 a	42.5 a	2.3 a
Honor 28WG 0.55 oz	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Insignia 20WG 0.5 oz + Trinity 1.69SC 1.0 fl oz	14	0.0 b	0.0 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	0.0 b
Emerald 70WG 0.18 oz	21	1.0 b	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	0.0 b
Honor 28WG 1.1 oz	21	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b

Values represent the average percentage of plot area blighted by dollar spot or brown patch symptoms.
Within columns, means followed by the same letter are not significantly different according to Tukey's pairwise comparisons (family error rate P = 0.05).
[1] 14-day interval application calendar dates were May 28, June 10 and 25, July 7 and 21, and August 5 and 20. 21-day interval application calendar dates were May 28, June 17, July 7 and 29, and August 20.

Preventative Demethylation Inhibitor Fungicide Applications for Control of Dollar Spot and Brown Patch on Creeping Bentgrass in Kansas

Investigators: Megan Kennelly and Cole Thompson

Sponsors: Bayer, Kansas Turfgrass Foundation

Introduction

Dollar spot is caused by the fungus *Sclerotinia homoeocarpa*. It is a common disease, appearing 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. Brown patch, caused by the fungus *Rhizoctonia solani*, also causes blighting in hot, humid weather. Many fungicides are labeled for dollar spot and brown patch suppression in golf courses. This study was conducted to evaluate several demethylation inhibitor (DMI) fungicides for dollar spot and brown patch control.

Methods

Fungicides were evaluated on an established stand of 'A4' creeping bentgrass on a sand-based putting green at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. The turf was mowed to a height of 0.156 in. and irrigated daily for 15 minutes. The area was fertilized every 2 weeks with 0.5 lb N/1,000 ft^2 during March through June and 0.33 lb N/1,000 ft^2 during July through November. Fungicide applications were made at 14-day intervals beginning on May 28 with the final application on August 20. Fungicides were applied with a CO_2-powered boom sprayer equipped with two XR TeeJet 8004VS nozzles at 30 psi in water equivalent to 2.0 gal/1,000 ft^2. Plots were 4 ft × 10 ft and arranged in a randomized complete block design with four replications. We periodically rated plots by visually estimating the percentage of each plot affected by dollar spot or brown patch symptoms.

Results

See Table 1 for full results. Dollar spot was present on several rating dates but never exceeded 10% severity. All materials studied reduced dollar spot to zero, except a trace of dollar spot remained in the Reserve 2.8 fl oz treatment on July 17 and August 12. Brown patch symptoms were visible on only one rating date, and all fungicides reduced brown patch to zero. A slight blue-green color typical of DMI fungicide growth-regulator effects was visible in the Banner Maxx and Concert treatments on most rating dates.

Table 1. Dollar spot and brown patch severity as influenced by fungicides

Treatment[1] and rate/1,000 ft²	Spray interval (days)	Dollar spot severity (%) June 19	July 17	Aug. 12	Aug. 27	Brown patch severity July 17
Untreated control		5.5 a	4.8 a	7.8 a	8.8 a	5.8 a
Triton Flo 3.1SC 0.5 fl oz	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Triton Flo 3.1SC 0.75 fl oz	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Triton Flo 1.0 fl oz	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Banner Maxx 2.0 fl oz	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Reserve 4.8SC 2.8 fl oz	14	0.0 b	0.3 b	0.3 b	0.0 b	0.0 b
Reserve 4.8SC 3.2 fl oz	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Reserve 4.8SC 3.6 fl oz	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Reserve 4.8SC 4.5 fl oz	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Concert 4.3SE 5.0 fl oz	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b

Values represent the average percentage of plot area blighted by dollar spot or brown patch symptoms.
Within columns, means followed by the same letter are not significantly different according to Tukey's pairwise comparisons (family error rate P = 0.05).
[1] Application calendar dates were May 28, June 10 and 25, July 7 and 21, and August 20.

Efficacy of DuPont Imprelis Granular Formulation and Granular Combination Formulation for Clover Control

Objective: Evaluate various application rates and granular formulations of a new herbicide from DuPont for control of clover in tall fescue.

Investigator: Rodney St. John

Methods

This study was conducted at the Horticulture Research and Extension Center in Olathe, Kan. The study area is a tall fescue field that was seeded in September 2007. The field has considerable clover (Photo 1).

The products were applied on May 27, 2009, at about 9:00 a.m. No dew was present on the grass at the time of application. The study site had not received rain since May 13, 2009, and it did not rain again until June 2. It rained quite regularly before and after this time, and the grass and weeds were not drought stressed. No supplemental irrigation was applied to this area throughout the study.

The experimental design was a randomized complete block design with four replications. Individual plots were 5 ft × 5 ft in size. All of the products were weighed and distributed by hand using paper shaking cups. The experimental design and treatments are shown in Figure 1 and Table 1, respectively.

A tenth treatment, Drive 75DF, was added to the original nine treatments for comparison purposes.

Results

All of the Imprelis products provided excellent clover control with no phytotoxicity (Tables 2 and 3). Momentum Force and DriveDF also controlled clover. There was considerable phytotoxicity in plots treated with Drive 75DF (Tables 2 and 3). Treatment 6 seemed to provide the quickest knockdown of the clover. There was little clover left in any plot by 21 days after treatment.

All of the products were formulated on a fertilizer carrier except the treatment containing Drive 75DF. Untreated control plots and plots treated with Drive 75DF that did not receive any extra fertilizer typically had the lowest visual rating on all rating dates (Table 4). Treatments 1, 2, and 3 had the highest rating on many rating dates. Visual quality was assessed by looking at overall density, color, and weed population of the plot. Because all treated plots were relatively weed free, the quality differences are likely a result of differences in color caused by differences in amount and source of nitrogen. The only exception was that plots treated with Drive had some reduction in quality due to some phytotoxicity in the first few weeks after treatment.

Weekly results are shown in photos 2 through 6 (and the related data tables). No photos were taken after 30 days after treatment because most of the treated plots had an equivalent percentage of clover control by that time. Overall, the granular Imprelis product performed very well; it provided excellent clover control with no phytotoxicity.

Table 1. Treatments and rates

Treatment	Product	Active ingredient	Formulation	lb ai/acre	Product/ acre	Product/ 1,000 ft^2
1	Imprelis	aminocyclopyrachlor	0.05GF-S	0.075	150 lb	3.44 lb
2	Imprelis	aminocyclopyrachlor	0.05GF-S	0.087	175 lb	4.0 lb
3	Imprelis	aminocyclopyrachlor	0.05GF-S	0.1	200 lb	4.6 lb
4	Imprelis	aminocyclopyrachlor	0.05GF-E	0.075	150 lb	3.44 lb
5	Imprelis	aminocyclopyrachlor	0.05GF-E	0.087	175 lb	4.0 lb
6	Imprelis	aminocyclopyrachlor	0.05GF-E	0.1	200 lb	4.6 lb
7	Momentum Force	2,4-D; MCPA; Dicamba	GF-E	2.72	156.8 lb	3.6 lb
8	DPX-Q9T28-001	E2Y45/MAT28	0.067/0.067GF-E	0.1/0.1	150 lb	3.44 lb
9	Untreated					
10	Drive 75DF	Quinclorac	Sprayable	0.75	1 lb	0.367 oz

6	9	2	4	10	**Rep 1**
5	8	7	1	3	
8	9	10	5	3	**Rep 2**
6	7	4	1	2	
6	4	7	10	2	**Rep 3**
9	8	1	5	3	
1	4	9	2	5	**Rep 4**
8	6	10	7	3	

N

Figure 1. Map of experimental area.
Overall plot dimensions: 25 ft × 40 ft; Diagonal 47 ft, 2 in.

Table 2. Average percentage of clover coverage in tall fescue plots

Treatment	Rate (lb ai/acre)	Clover coverage[1] June 3 7 DAT[2]	June 11 14 DAT	June 17 21 DAT	June 26 30 DAT	July 8 42 DAT	July 29 60 DAT	August 26 90 DAT
		---------------------------------	-----------------	----------------	%	----------------	----------------	----------------
Imprelis	0.075	45.0 bc	27.5 b	5.3 b	0.0 b	0.0 b	0.0 b	0.0 b
Imprelis	0.087	47.5 b	22.5 bc	3.5 bc	0.0 b	0.0 b	0.0 b	0.0 b
Imprelis	0.1	47.5 b	27.5 b	3.0 bcd	0.0 b	0.0 b	0.0 b	0.0 b
Imprelis	0.075	40.0 bc	22.5 bc	2.8 bcd	0.0 b	0.0 b	0.0 b	0.0 b
Imprelis	0.087	45.0 bc	20.0 bc	1.5 cd	0.0 b	0.0 b	0.0 b	0.0 b
Imprelis	0.1	40.0 bc	12.5 c	0.5 d	0.0 b	0.0 b	0.0 b	0.0 b
Momentum Force	2.72	35.0 bc	20.0 bc	2.5 bcd	0.5 b	0.3 b	0.0 b	0.0 b
DPX-Q9T28-001	0.1/0.1	42.5 bc	15.0 bc	0.3 d	0.0 b	0.0 b	0.0 b	0.0 b
Untreated		65.0 a	85.0 a	88.8 a	82.5 a	85.0 a	86.25a	82.5 a
Drive 75DF	0.75	32.5 c	12.5 c	1.0 cd	0.0b	0.0 b	0.0 b	0.0 b
$LSD_{0.05}$		13.6	13.0	2.8	3.0	4.6	2.2	2.3

On a date, means followed by the same letter are not significantly different (P < 0.05).
[1] Rating: 0 = no clover found in plots, 100 = plot is completely covered by clover.
[2] DAT, days after treatment.

Table 3. Average phytotoxicity of tall fescue in plots treated with various herbicides

Treatment	Rate (lb ai/acre)	Phytotoxicity[1] June 3 7 DAT[2]	June 11 14 DAT	June 17 21 DAT	June 26 30 DAT	July 8 42 DAT	July 29 60 DAT	August 26 90 DAT
Imprelis	0.075	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a
Imprelis	0.087	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a
Imprelis	0.1	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a
Imprelis	0.075	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a
Imprelis	0.087	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a
Imprelis	0.1	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a
Momentum Force	2.72	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a
DPX-Q9T28-001	0.1/0.1	8.8 b	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a
Untreated		9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a
Drive 75DF	0.75	5.0 c	6.0 b	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a
$LSD_{0.05}$		0.2	0.0	0.0	0.0	0.0	0.0	0.0

On a date, means followed by the same letter are not significantly different (P < 0.05).
[1] 0 = complete death, 9 = no phytotoxicity.
[2] DAT, days after treatment.

Table 4. Average visual quality of tall fescue plots receiving various herbicides and fertilizers

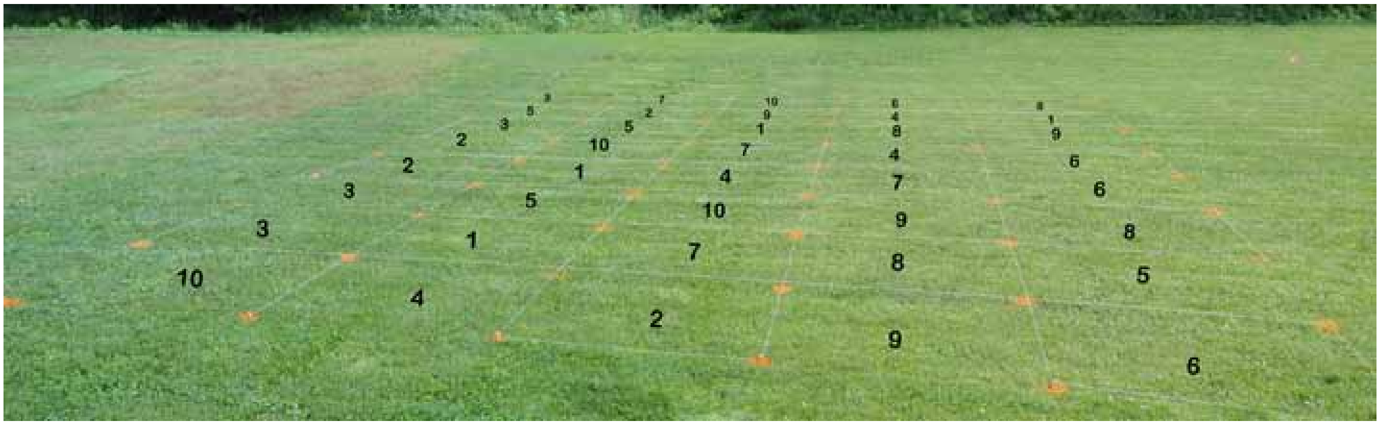
		Quality[1]						
Treatment	Rate (lb ai/acre)	June 3 7 DAT[2]	June 11 14 DAT	June 17 21 DAT	June 26 30 DAT	July 8 42 DAT	July 29 60 DAT	August 26 90 DAT
Imprelis	0.075	8.8 ab	9.0 a	8.8 ab	8.3 a	8.8 a	7.8 a	9.0 a
Imprelis	0.087	8.5 ab	8.8 ab	8.5 ab	8.3 a	8.8 a	7.5 a	8.8 ab
Imprelis	0.1	9.0 a	8.8 ab	9.0 a	8.3 a	8.8 a	7.5 a	8.3 b
Imprelis	0.075	8.0 bcd	8.0 cd	7.5 cde	8.0 a	8.3 ab	7.3 abc	7.3 c
Imprelis	0.087	7.8 cd	7.5 d	8.3 abc	8.3 a	8.5 ab	7.0 bc	7.5 c
Imprelis	0.1	7.8 cd	8.0 cd	7.0 e	8.0 a	8.3 ab	7.5 ab	7.3 c
Momentum Force	2.72	8.3 abcd	8.3 bc	8.0 bcd	8.5 a	8.3 ab	7.0 bc	7.5 c
DPX-Q9T28-001	0.1/0.1	7.5 d	8.0 cd	7.3 de	8.0 a	8.3 ab	7.3 abc	7.0 c
Untreated		9.0 a	5.0 f	6.0 f	7.0 b	7.0 c	6.0 d	6.0 d
Drive 75DF	0.75	5.0 e	6.0 e	6.8 ef	7.8 ab	8.0 b	6.8 c	7.5 c
$LSD_{0.05}$		1.0	0.6	0.8	0.9	0.7	0.7	0.7

On a date, means followed by the same letter are not significantly different ($P < 0.05$).

[1] Scale: 1 to 9 (1 = lowest quality, 6 = lowest acceptable quality, and 9 = best quality).

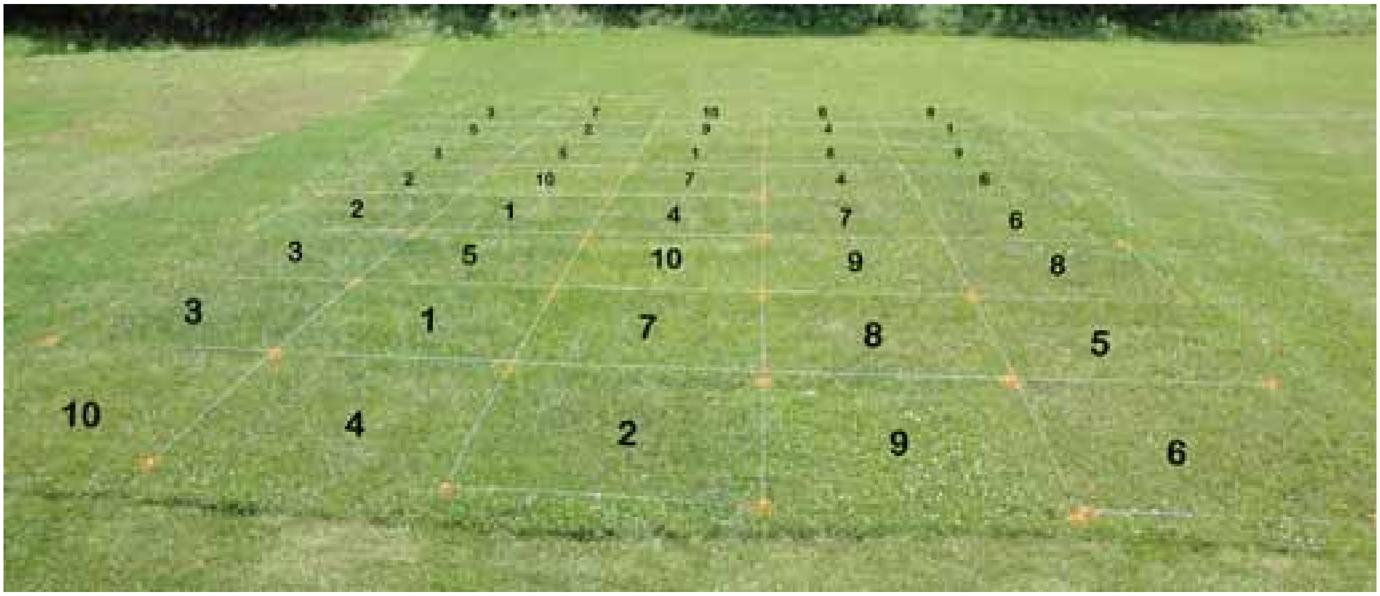
[2] DAT, days after treatment.

Photo 1. Study area on May 27, 2009, before mowing and applications.



Treatment	Product	Rate (lb/1,000 ft^2)
1	MAT28-70	3.4
2	MAT28-70	4.0
3	MAT28-70	4.6
4	MAT28-71	3.4
5	MAT28-71	4.0
6	MAT28-71	4.6
7	Momentum Force	3.6
8	Q9T28-001	3.4
9	Untreated	0
10	Drive	0.37 oz

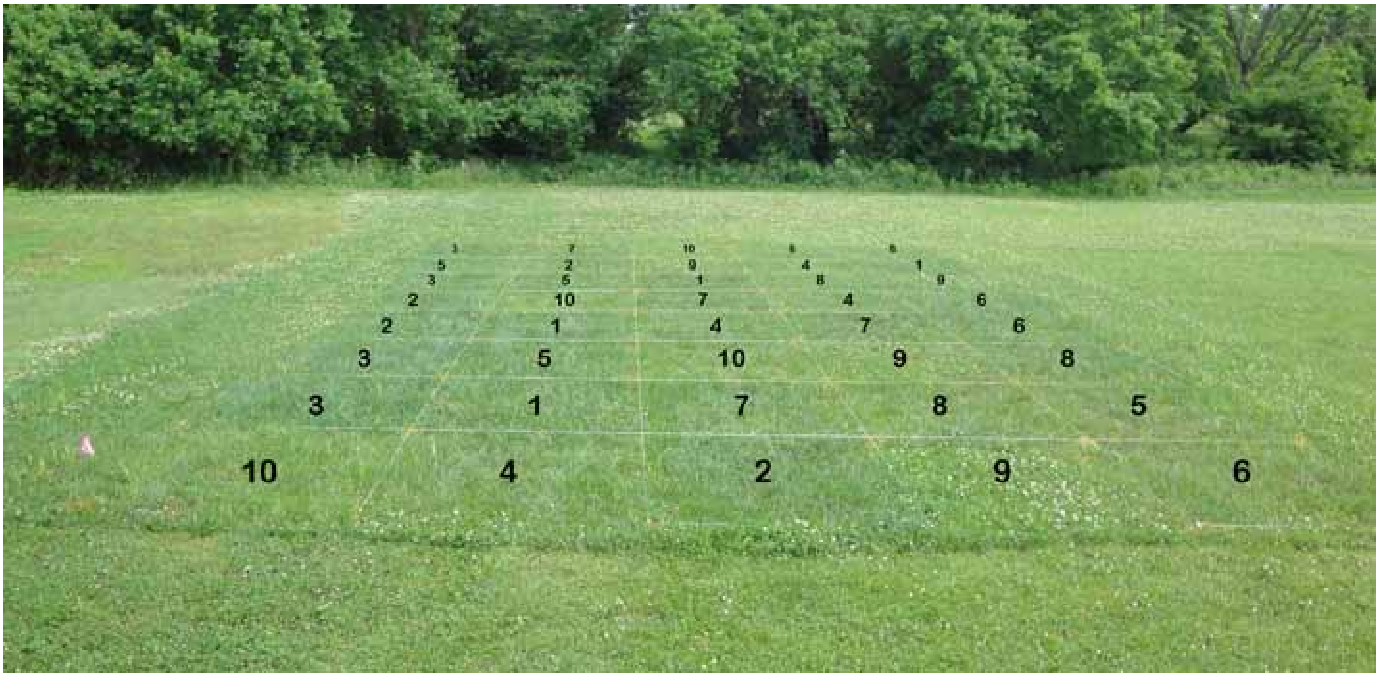
Photo 2. Study area on May 27, 2009; 0 days after treatment.



Treatment	Clover[1]	Treatment	Turf quality[2]	Treatment	Phytotoxicity[3]	Treatment	Product	Rate (lb/1,000 ft^2)
10	33	3	9	1	9	1	MAT28-70	3.4
7	35	9	9	2	9	2	MAT28-70	4.0
4	40	1	8.8	3	9	3	MAT28-70	4.6
6	40	2	8.5	4	9	4	MAT28-71	3.4
8	43	7	8.3	5	9	5	MAT28-71	4.0
1	45	4	8	6	9	6	MAT28-71	4.6
5	45	5	7.8	7	9	7	Momentum Force	3.6
2	48	6	7.8	9	9	8	Q9T28-001	3.4
3	48	8	7.5	8	8.8	9	Untreated	0
9	65	10	5	10	5	10	Drive	0.37 oz
LSD 0.05	13.6		1.0		0.2			

[1] Percentage of clover coverage in plot.
[2] Quality scale: 1 to 9 (1 = poor quality, 9 = best quality).
[3] Phytotoxicity scale: 1 to 9 (1 = complete damage, 9 = no phytotoxicity).

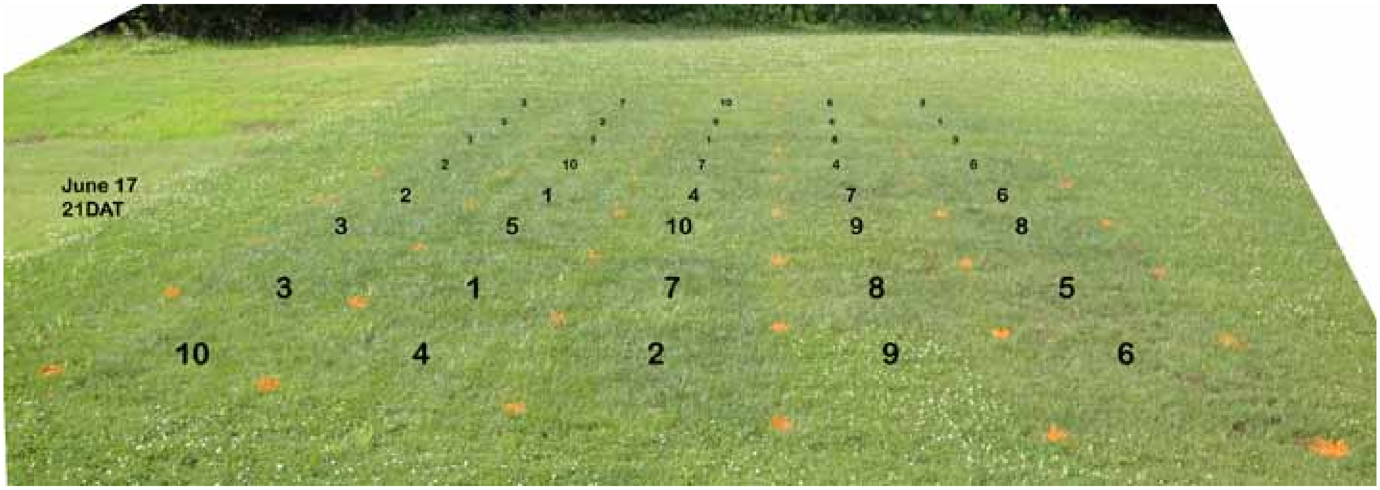
Photo 3. Study area on June 3, 2009; 7 days after treatment.



Treatment	Clover[1]	Treatment	Turf quality[2]	Treatment	Phytotoxicity[3]	Treatment	Product	Rate (lb/1,000 ft²)
6	13	1	9	1	9	1	MAT28-70	3.4
10	13	2	8.8	2	9	2	MAT28-70	4.0
8	15	3	8.8	3	9	3	MAT28-70	4.6
5	20	7	8.3	4	9	4	MAT28-71	3.4
7	20	4	8	5	9	5	MAT28-71	4.0
2	23	6	8	6	9	6	MAT28-71	4.6
4	23	8	8	7	9	7	Momentum Force	3.6
1	28	5	7.5	8	9	8	Q9T28-001	3.4
3	28	10	6	9	9	9	Untreated	0
9	85	9	5	10	6	10	Drive	0.37 oz
LSD 0.05	13.0		0.6		0.0			

[1] Percentage of clover coverage in plot.
[2] Quality scale: 1 to 9 (1 = poor quality, 9 = best quality).
[3] Phytotoxicity scale: 1 to 9 (1 = complete damage, 9 = no phytotoxicity).

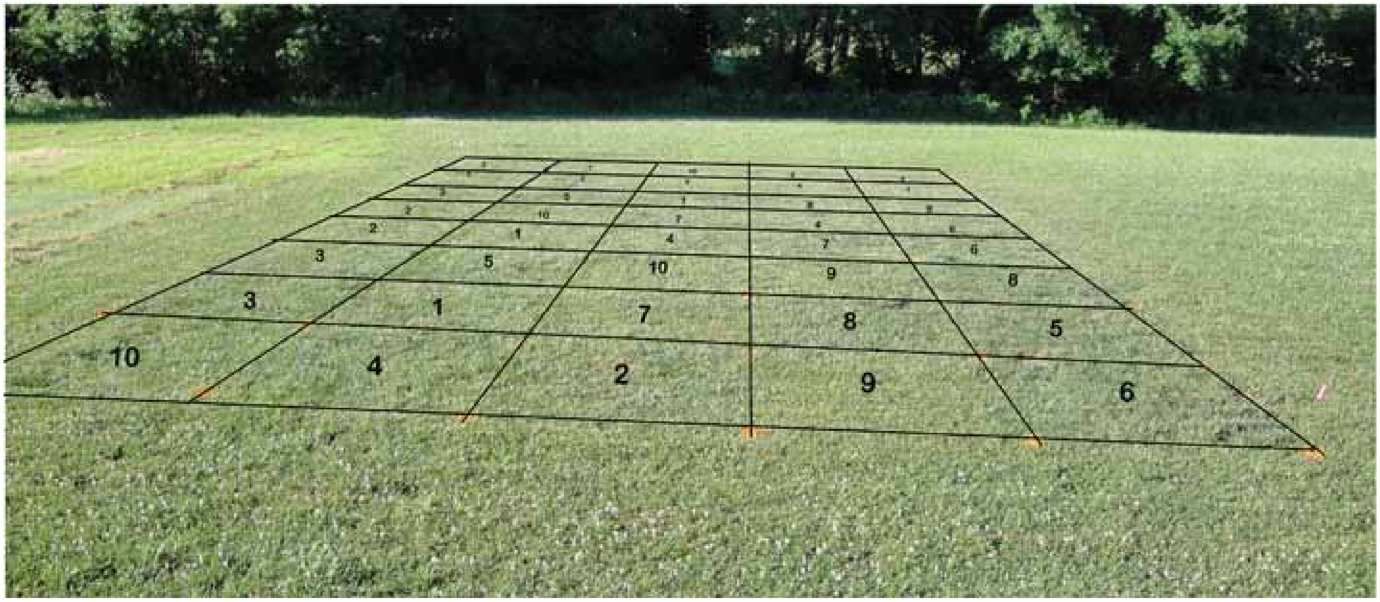
Photo 4. Study area on June 11, 2009; 14 days after treatment.



Treatment	Clover[1]	Treatment	Turf quality[2]	Treatment	Phytotoxicity[3]	Treatment	Product	Rate (lb/1,000 ft^2)
8	0.3	3	9.0	1	9	1	MAT28-70	3.4
6	0.5	1	8.8	2	9	2	MAT28-70	4.0
10	1.0	2	8.5	3	9	3	MAT28-70	4.6
5	1.5	5	8.3	4	9	4	MAT28-71	3.4
7	2.5	7	8.0	5	9	5	MAT28-71	4.0
4	2.8	4	7.5	6	9	6	MAT28-71	4.6
3	3.0	8	7.3	7	9	7	Momentum Force	3.6
2	3.5	6	7.0	8	9	8	Q9T28-001	3.4
1	5.3	10	6.8	9	9	9	Untreated	0
9	88.8	9	6.0	10	9	10	Drive	0.37 oz
LSD 0.05	2.8		0.8		0.0			

[1] Percentage of clover coverage in plot.
[2] Quality scale: 1 to 9 (1 = poor quality, 9 = best quality).
[3] Phytotoxicity scale: 1 to 9 (1 = complete damage, 9 = no phytotoxicity).

Photo 5. Study area on June 17, 2009; 21 days after treatment.



Treatment	Clover[1]	Treatment	Turf quality[2]	Treatment	Phytotoxicity[3]	Treatment	Product	Rate (lb/1,000 ft^2)
1	0	7	8.5	1	9	1	MAT28-70	3.4
2	0	1	8.3	2	9	2	MAT28-70	4.0
3	0	2	8.3	3	9	3	MAT28-70	4.6
4	0	3	8.3	4	9	4	MAT28-71	3.4
5	0	5	8.3	5	9	5	MAT28-71	4.0
6	0	4	8.0	6	9	6	MAT28-71	4.6
8	0	6	8.0	7	9	7	Momentum Force	3.6
10	0	8	8.0	8	9	8	Q9T28-001	3.4
7	0.5	10	7.8	9	9	9	Untreated	0
9	82.5	9	7.0	10	9	10	Drive	0.37 oz
LSD 0.05	3.0		0.9		0.0			

[1] Percentage of clover coverage in plot.
[2] Quality scale: 1 to 9 (1 = poor quality, 9 = best quality).
[3] Phytotoxicity scale: 1 to 9 (1 = complete damage, 9 = no phytotoxicity).

Photo 6. Study area on June 26, 2009; 30 days after treatment.

National Turfgrass Evaluation Program Tall Fescue Evaluation

Objective: Evaluate tall fescue cultivars under Kansas conditions and submit data collected 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. However, tall fescue possesses a rather coarse leaf texture, 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 Sept. 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 N/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 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. The cultivars are rated visually on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum).

Results

During the 2009 growing season, we collected data on turf genetic color, texture, quality, and fall color retention. We rated the turf for 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. BAR Fa 6235, PSG-TTRH, 'Reunion' (LS-03), 'Braveheart' (DP 50-9407), MVS-1107, and 'Talladega' (RP 3) performed best overall (Table 1). When we evaluated genetic color and texture, RNP, AST 7001, and 'AST9003' (AST-1) were the darkest green, and SC-1, 'Shenandoah III' (SH 3), 'Cochise IV' (RKCL), 'Falcon V' (ATM), 'Firecracker LS' (MVS-MST), and RK 5 had the finest texture. On November 13, we rated the turf for fall color retention; 'Faith' (K06-WA), 'Firecracker LS' (MVS-MST), and SC-1 were the greenest.

More information on NTEP and the nationwide 2006 National Tall Fescue Test results are available online at *http://www.ntep.org*

Table 1. 2009 performance of tall fescue cultivars, Wichita[1]

Cultivar/experimental number[2]	Genetic color	Leaf texture	Fall color retention	Quality Apr.	May	June	July	Aug.	Sept.	Avg.
BAR Fa 6235	6.3	4.7	6.0	4.7	5.0	5.7	5.3	6.7	6.7	5.7
PSG-TTRH	6.0	4.7	6.3	4.7	5.3	5.3	6.0	6.3	6.3	5.7
Reunion (LS-03)*	7.0	5.7	5.0	5.3	6.7	5.3	5.3	5.3	6.0	5.7
Braveheart (DP 50-9407)	7.3	5.7	6.0	5.0	5.0	5.0	5.7	6.3	6.3	5.6
MVS-1107	6.0	5.3	6.3	4.3	5.0	5.3	5.7	6.3	6.7	5.6
Talladega (RP 3)*	6.0	5.7	5.7	5.0	6.0	5.3	5.3	5.7	6.0	5.6
SC-1	6.3	7.0	6.7	5.7	4.7	5.0	5.3	6.0	6.3	5.5
Hunter*	7.3	5.0	6.0	4.7	5.0	5.0	5.0	6.3	6.7	5.4
Crossfire 3 (Col-J)	6.3	5.0	5.3	4.3	5.7	5.0	5.0	6.0	6.3	5.4
SR 8650 (STR-8LMM)*	6.3	4.7	5.0	4.7	5.3	5.0	5.7	5.7	6.0	5.4
Speedway (STR-8BPDX)*	5.7	5.7	4.7	5.0	5.7	5.0	5.7	5.3	5.7	5.4
PSG-82BR	5.7	5.3	6.0	4.0	5.3	5.0	5.7	6.0	6.3	5.4
PSG-85QR	6.0	5.3	6.0	4.3	5.0	5.0	5.3	6.0	6.3	5.3
STR-8GRQR	6.0	5.3	6.3	4.7	5.3	5.3	5.7	5.0	6.0	5.3
Wolfpack II (PST-5WMB)*	6.0	5.7	6.3	5.3	5.3	4.7	5.0	5.3	6.3	5.3
Pedigree (ATF-1199)	5.7	5.3	5.3	4.7	5.3	5.0	5.3	5.7	5.7	5.3
Raptor II (MVS-TF-158)*	6.3	5.3	5.0	5.0	5.7	5.3	4.3	5.7	5.7	5.3
Einstein*	6.0	4.7	6.0	4.3	4.7	5.3	5.3	6.0	6.0	5.3
Firecracker LS (MVS-MST)*	5.7	6.3	6.7	4.7	5.3	4.7	5.0	6.0	6.0	5.3
AST 7001*	7.7	5.0	5.7	4.7	5.0	5.0	5.3	5.7	5.7	5.2
Finelawn Xpress (RP 2)	6.0	6.0	6.0	5.0	4.3	4.7	5.0	6.3	6.0	5.2
JT-33	6.3	5.3	5.7	4.3	4.7	5.0	5.3	5.7	6.3	5.2
Rebel IV*	6.0	5.3	5.7	4.3	5.0	4.7	5.0	6.0	6.3	5.2
STR-8BB5	5.3	5.0	5.7	5.0	5.7	4.3	4.3	6.0	6.0	5.2
Sidewinder (IS-TF-138)	6.3	6.0	5.7	4.7	5.3	5.0	5.0	6.0	5.3	5.2
Titanium LS (MVS-BB-1)*	6.0	5.3	6.0	4.7	6.0	4.7	4.7	5.7	5.7	5.2
ATF 1328	6.3	5.0	4.7	4.3	5.0	5.0	5.0	5.7	6.0	5.2
JT-36	6.3	4.7	5.7	4.3	5.3	5.3	4.7	5.3	6.0	5.2
Terrier (IS-TF-135)	6.3	5.3	5.0	5.0	4.0	5.0	5.7	5.3	6.0	5.2
Tulsa Time (Tulsa III)*	6.0	5.7	5.7	4.3	4.7	4.7	5.3	5.7	6.3	5.2
Umbrella (DP 50-9411)	7.3	4.7	5.3	4.7	5.3	4.7	4.7	5.7	6.0	5.2
Greenbrooks (TG 50-9460)	6.0	5.3	5.7	4.3	4.7	5.3	5.0	6.0	5.3	5.1
GWTF	6.7	5.0	5.7	4.3	4.7	4.7	5.3	5.7	6.0	5.1
KZ-2	7.0	5.0	5.0	4.0	6.0	4.7	4.7	5.7	5.7	5.1
3rd Millennium SRP*	6.0	5.0	5.7	4.3	5.0	4.7	4.7	5.7	6.0	5.1
Catelyst (NA-BT-1)	5.7	5.7	5.3	4.7	4.7	4.0	5.3	5.7	6.0	5.1
Corona (Col-M)	7.0	5.0	5.3	4.7	4.3	5.0	5.0	5.3	6.0	5.1
Honky Tonk (RAD-TF17)*	5.7	5.3	5.3	4.3	4.7	5.0	5.3	5.3	5.7	5.1
RNP	8.0	4.3	4.7	4.3	5.3	4.3	4.7	6.0	5.7	5.1
Faith (K06-WA)*	6.7	6.0	6.7	4.7	5.0	4.7	4.7	5.3	6.0	5.1

Table 1. 2009 performance of tall fescue cultivars, Wichita[1]

Cultivar/experimental number[2]	Genetic color	Leaf texture	Fall color retention	Quality						
				Apr.	May	June	July	Aug.	Sept.	Avg.
Rembrandt*	5.3	4.3	5.7	4.3	5.7	4.7	4.7	5.7	5.3	5.1
Col-1	6.3	5.0	6.0	4.3	5.3	4.3	5.0	5.3	6.0	5.1
GE-1	6.0	4.7	5.0	4.3	5.0	5.0	4.7	5.7	5.7	5.1
Lindbergh*	6.0	4.7	6.0	4.3	4.0	4.7	5.3	6.3	5.7	5.1
Cochise IV (RKCL)	6.0	6.3	5.7	5.3	4.3	5.3	4.3	5.3	5.3	5.0
Falcon NG (CE 1)	5.7	5.0	5.0	4.3	4.7	4.0	5.3	5.7	6.0	5.0
Gazelle II (PST-5HP)*	5.7	5.0	5.7	4.3	5.3	4.0	5.0	5.7	5.7	5.0
J-140	6.0	5.7	5.3	4.7	5.3	4.0	4.7	5.3	6.0	5.0
JT-41	6.0	5.0	4.7	5.0	5.0	4.3	5.0	5.0	5.7	5.0
JT-45	6.3	5.0	4.7	4.0	5.3	4.7	5.3	5.3	5.3	5.0
RK 5	5.7	6.3	6.0	4.7	5.0	4.7	4.7	5.7	5.3	5.0
Turbo*	6.0	5.7	6.0	4.7	4.7	4.3	5.0	5.3	6.0	5.0
AST 7003*	7.0	5.3	5.3	4.7	4.7	4.7	4.7	5.7	5.3	4.9
Hudson (DKS)*	6.3	4.7	4.7	4.3	5.0	4.7	4.7	5.7	5.3	4.9
Biltmore*	6.3	4.3	5.7	4.0	4.7	5.0	5.0	5.3	5.7	4.9
Escalade*	5.7	5.3	5.0	4.0	5.7	4.3	4.3	5.7	5.7	4.9
Padre*	6.0	4.0	5.0	4.3	5.0	4.7	5.3	5.3	5.0	4.9
06-WALK	6.3	5.0	5.0	4.3	4.7	5.0	5.0	5.3	5.3	4.9
Rhambler SRP (Rhambler)*	5.7	6.0	6.3	4.0	5.0	3.7	5.0	6.0	6.0	4.9
Renovate (LS-11)*	7.3	5.3	5.3	4.0	4.3	4.3	5.3	5.3	6.0	4.9
Shenandoah Elite (RK 6)	6.0	5.7	5.0	5.0	5.0	3.7	4.3	5.7	5.7	4.9
RK 4	6.0	5.7	5.0	4.0	6.3	3.7	4.7	5.3	5.3	4.9
Skyline*	5.3	4.7	5.0	4.0	5.0	4.7	4.7	5.3	5.7	4.9
BGR-TF1	6.7	5.0	5.0	4.3	4.3	4.7	5.0	5.0	5.7	4.8
Cannavaro (DP 50-9440)	5.3	6.0	4.3	4.3	6.0	4.3	4.7	5.0	4.7	4.8
Firenza*	6.0	6.0	5.0	4.7	5.7	4.3	4.3	5.0	5.0	4.8
Shenandoah III (SH 3)	5.7	6.7	5.7	4.7	5.3	4.0	4.7	5.3	5.0	4.8
Trio (IS-TF-152)	6.3	5.0	5.7	4.7	4.0	4.7	4.7	5.3	5.7	4.8
Van Gogh (LTP-RK2)*	6.0	5.7	5.7	4.3	4.3	4.3	5.0	5.7	5.3	4.8
Darlington (CS-TF1)*	7.0	4.3	5.0	4.0	5.3	4.0	4.3	5.7	5.3	4.8
AST9003 (AST-1)*	7.7	5.3	5.3	4.0	4.7	4.0	4.7	5.3	5.7	4.7
BGR-TF2	7.0	5.3	4.7	4.0	5.0	4.0	4.7	5.0	5.7	4.7
Jamboree (IS-TF-128)	5.7	5.7	4.3	4.3	5.0	4.0	5.0	5.0	5.0	4.7
MVS-341	5.7	4.7	5.3	4.7	4.7	4.3	4.7	5.0	5.0	4.7
Mustang 4 (M4)*	6.3	6.0	5.3	4.0	4.7	3.7	4.3	5.7	6.0	4.7
Rocket (IS-TF-147)	6.3	5.0	5.3	4.0	5.0	4.0	4.3	5.3	5.7	4.7
AST9001 (AST-3)*	7.0	4.7	5.0	3.7	4.7	4.0	4.3	5.7	6.0	4.7
Tahoe II*	6.0	4.3	5.7	4.0	5.0	4.3	4.3	5.3	5.3	4.7
0312	6.3	5.3	4.7	3.7	4.7	4.0	5.0	5.3	5.3	4.7
06-DUST	6.0	5.3	5.0	4.0	4.3	4.0	5.0	5.0	5.7	4.7

Table 1. 2009 performance of tall fescue cultivars, Wichita[1]

				Quality						
Cultivar/experimental number[2]	Genetic color	Leaf texture	Fall color retention	Apr.	May	June	July	Aug.	Sept.	Avg.
Aristotle*	6.7	4.0	5.0	3.7	4.7	4.7	4.7	5.0	5.3	4.7
Bullseye*	5.7	5.7	4.7	5.0	5.3	3.7	4.7	5.0	4.3	4.7
Essential (IS-TF-154)*	6.0	5.3	5.7	4.3	5.0	4.3	4.3	5.3	4.7	4.7
Hemi*	6.0	5.0	5.3	4.0	4.7	3.7	4.7	5.7	5.3	4.7
J-130	5.7	4.7	4.3	4.0	5.0	3.7	5.0	5.0	5.3	4.7
PSG-RNDR	6.0	4.3	5.3	3.7	4.3	4.3	4.3	5.7	5.7	4.7
Spyder LS (Z-2000)*	6.0	5.0	5.0	5.0	2.0	4.7	5.3	5.7	5.3	4.7
Toccoa (IS-TF-151)*	6.7	5.7	5.0	3.7	4.7	4.0	4.7	5.7	5.3	4.7
Magellan*	5.7	4.3	5.0	4.3	4.7	3.7	4.7	5.3	5.0	4.6
Ninja 3 (ATF 1247)	6.3	4.3	5.0	4.0	5.0	4.3	4.0	5.3	5.0	4.6
Traverse SPR (RK-1)*	6.0	6.0	6.0	4.7	4.3	3.7	4.0	5.3	5.7	4.6
Compete (LS-06)*	6.7	4.7	5.0	3.7	5.0	4.3	4.0	5.0	5.3	4.6
PSG-TTST	5.3	5.0	4.7	4.0	4.3	4.0	5.3	5.0	4.7	4.6
Plato*	5.7	5.3	4.7	4.0	5.7	4.0	4.7	4.7	4.3	4.6
Turbo RZ (Burl-TF8)*	6.3	5.3	5.7	3.7	4.0	4.0	5.0	5.3	5.3	4.6
Falcon IV*	5.7	4.7	4.7	4.0	4.3	4.0	4.3	5.0	5.3	4.5
AST9002 (AST-2)*	7.0	5.0	5.3	4.0	5.0	3.7	4.3	5.0	5.0	4.5
Cezanne Rz (LTP-CRL)*	5.7	5.0	5.3	4.3	5.0	4.0	4.0	5.0	4.7	4.5
Falcon V (ATM)	5.7	6.3	5.0	5.0	4.7	3.3	4.3	4.7	5.0	4.5
AST1001 (AST-4)	7.3	5.0	4.3	4.0	4.3	4.0	4.3	5.0	5.0	4.4
Monet (LTP-610 CL)*	5.7	6.0	4.7	5.0	3.0	4.3	4.0	5.3	5.0	4.4
JT-42	6.7	4.7	5.0	3.3	5.0	4.0	4.3	4.7	5.3	4.4
BAR Fa 6363	5.7	4.0	4.7	4.0	5.3	3.7	4.0	4.7	4.7	4.4
GO-1BFD	5.7	5.3	5.7	3.7	4.3	4.0	4.0	5.0	5.3	4.4
Justice*	5.7	5.3	4.3	4.0	5.0	4.0	4.0	4.7	4.3	4.3
Stetson II (NA-SS)	6.7	5.0	4.7	4.0	4.7	4.3	3.7	4.7	4.7	4.3
Aggressor (IS-TF-153)	5.7	5.3	4.7	4.0	4.0	4.0	4.3	4.7	4.7	4.3
Fat Cat (IS-TF-161)	6.3	5.0	4.7	3.7	4.7	4.0	4.0	4.7	4.7	4.3
AST 7002*	6.0	4.3	5.0	3.3	4.0	4.0	4.3	5.3	4.3	4.2
KZ-1	6.3	4.3	4.0	4.3	5.3	3.7	4.0	4.0	4.0	4.2
IS-TF-159	5.7	6.0	5.0	3.7	4.7	3.7	3.7	4.3	4.0	4.0
Silverado*	4.0	3.7	4.3	3.3	5.3	3.0	3.7	4.3	3.7	3.9
Ky-31*	3.0	3.0	4.3	2.3	4.7	3.0	2.3	3.0	3.0	3.1
Least significant difference (LSD)[3]	1.0	1.0	4.3	1.6	2.7	3.2	2.4	4.5	4.6	2.4

[1] Visual ratings based on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum).
[2] Cultivars marked with "*" will be 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.

Irrigation Requirements of 28 Kentucky Bluegrass Cultivars and Two Texas Bluegrass Hybrids in the Transition Zone

Objective: Compare the irrigation requirements of 30 turfgrass cultivars by using a large rainout facility at Kansas State University.

Investigators: Jason Lewis, Dale Bremer, Steve Keeley, and Jack Fry.

Sponsors: United States Golf Association, Turfgrass Producers International, Kansas Turfgrass Foundation (KTF).

Introduction

One of the most important challenges facing the turfgrass industry is the increasingly limited supply of water for irrigation. Consequently, water conservation and improving the resistance of turfgrasses to drought stresses have become topics of major importance. Turf managers commonly face drought, and drought can occur anywhere in the United States. In 2004, a task force of the Environmental Institute for Golf concluded that future water availability is a *serious* issue in the western United States and that there is a lack of data on water use in many states. The task force also noted that state and local drought restrictions may be imposed on turf managers with no regard for damage to turfgrasses. Nevertheless, clients and the public (for example, golfers at private and public facilities, participants at outdoor sporting events, and lawn owners) express displeasure when turfgrass managed with restricted irrigation is not the quality they've come to expect.

Because turfgrass acreage is increasing with urban expansion, the demand for water for the irrigation of turfgrass will also likely continue to increase. A NASA study conducted in 2005 determined that turfgrass in the United States already covered an area three times greater than that of any other irrigated crop. And urban expansion in the United States is projected to increase by nearly 80% by 2025. One strategy to mitigate the irrigation demands for turfgrass may be the identification of cultivars that use less water and tolerate drought better. Kentucky bluegrass is commonly used on golf course roughs and fairways, in sports fields, and in home and commercial lawns. Consequently, information is needed about Kentucky bluegrass cultivars that conserve water while maintaining acceptable quality.

A large, fully automated rainout shelter (40 ft × 40 ft) at Kansas State University near Manhattan, Kan., offers a unique opportunity to compare the irrigation requirements of multiple turfgrass cultivars in the stressful climate of the U.S. transition zone, which is located between the northern regions where cool-season grasses are adapted and the southern regions where warm-season grasses are adapted. The shelter shields plots during rainfall, and plots can be irrigated individually as needed to determine their respective irrigation requirements under identical field conditions. Turfgrasses with similar visual qualities but with lower irrigation requirements may offer significant water savings to turfgrass managers. In this study, we are investigating water use and performance of 28 cultivars of Kentucky bluegrasses and two Texas bluegrass hybrids by using the rainout shelter.

Cultivars, Turfgrass Management, Experimental Design

The study includes 28 Kentucky bluegrass cultivars and two Texas bluegrass hybrids (Table 1). The selected cultivars represent major groups (based on phenotypic characteristics) of Kentucky bluegrasses, and most were best performers in National Turfgrass Evaluation Program trials. Four standard entries were included in the mix: 'Midnight', 'Baron', 'Eagleton', and 'Kenblue'.

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 Sept. 19, 2006, at approximately 2 lb/1,000 ft^2 pure live seed in a randomized block design; cultivars were replicated three times each for a total of 90 plots (Figure 1). 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 irrigated several times daily to maintain a wet seedbed during germination. Plots were mowed once in the fall of 2006 at approximately 2 in. and were mowed weekly or as needed at the same height during 2007, 2008, and 2009. A moderate billbug infestation in 2008 delayed the study's completion until 2009. In May, September, and November of 2007, 2008, and 2009, plots were fertilized with 1 lb N/1,000 ft^2.

Methods

Plots were well watered until June 1, 2007 (Figure 2) and then allowed to dry down without irrigation or precipitation until turfgrasses showed signs of wilt. Individual plots were evaluated daily for wilt and irrigated with approximately 1 in. of water when about 50% of the plot exhibited visual symptoms of wilt. Each plot was irrigated manually, and irrigation quantity and date were recorded for each plot. This experiment continued (Figure 3) through the end of September 2007. Total irrigation requirements of each cultivar for the 4-month study period were then summarized. This project was repeated in 2009.

We evaluated general turf performance daily by visually rating turf quality on a scale of 1 to 9 (1 = dead, brown turf, 6 = minimum acceptable quality for a home lawn, and 9 = optimum quality).

Results

The total amount of water applied, averaged over the two summers, varied significantly among cultivars and ranged from 8 to 20 in. during the 4-month period. Visual quality also varied substantially among cultivars. In terms of visual quality and water requirement, cultivars in the Compact America and Mid-Atlantic phenotypic groups performed better (higher quality, lesser water requirements) and Common types performed poorer (lower quality, greater water requirements), but there was significant variability among cultivars in each group.

The same cultivars used in the field study were evaluated for rooting characteristics including maximum root length extension, surface area, mean root diameter, and root biomass in a greenhouse at Kansas State University by using root tubes. Briefly, turfgrasses were planted in clear polyethylene root tubes that were filled with fritted clay and then inserted into opaque PVC pipe (sleeves). Root growth was monitored periodically along the side of the clear root tubes. When roots in the first tube reached the bottom of the container, we harvested and analyzed the roots with a scanner and computer software. For a more complete report of results from the greenhouse portion of this study, see Kansas State University's 2009 turfgrass research report.[1]

There were broad ranges in rooting characteristics among cultivars at each depth. Several cultivars had maximum rooting depths below 90 cm. Differences among phenotypic groups were less pronounced, but root surface area was less in Mid-Atlantic and Compact America groups than in Common types. There was no correlation between water applied in the field study and any rooting characteristic measured in the greenhouse study.

We anticipate that this research will result in a list of National Turfgrass Evaluation Program best-performing cultivars of Kentucky bluegrasses separated into categories with high, medium, and low irrigation requirements. Such a list would provide guidance to turfgrass managers who are interested in cultivars of Kentucky bluegrass that may conserve water without significantly compromising quality and who may be faced with irrigation restrictions that could affect their turfgrasses. The list will also provide information on rooting potential and relative drought resistance among cultivars.

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[1] See, *Genetic Rooting Potential of 28 Kentucky Bluegrass Cultivars and Two Texas Bluegrass Hybrids*, pp. 33-37 in Turfgrass Research 2009, Report of Progress 1015, Kansas State University. Available at: *www.ksre.ksu.edu/library*

Table 1. Kentucky bluegrass cultivars and Texas bluegrass hybrids selected for the 2-year study under the rainout shelter at Kansas State University

Group[1]	Cultivar[2]
Aggressive	Limousine
	Touchdown
BVMG	Baron
	Envicta
	Abbey
Common	Kenblue
	Wellington
	Park
Compact	Diva
	Skye
	Moonlight
Compact America	Langara
	Bedazzled
	Apollo
	Unique
	Kingfisher
Compact Midnight	Midnight
	Midnight II
	Blue Velvet
	Nu Destiny
	Award
European	Blue Knight
	Bartitia
Julia	Julia
Mid-Atlantic	Eagleton
	Preakness
	Cabernet
Shamrock	Shamrock
Texas bluegrass hybrids	Thermal Blue Blaze
	Longhorn

[1] Groups are cultivars with similar phenotypic characteristics.
[2] Shaded boxes indicate the four standard entries.

Block 1			Block 2			Block 3		
Midnight II	Thermal Blue Blaze	Diva	Shamrock	Bedazzled	Langara	Kingfisher	Envicta	Bartitia
Julia	Blue Velvet	Longhorn	Moonlight	Bartitia	Touchdown	Unique	Eagleton	Nu Destiny
Baron	Shamrock	Wellington	Park	Cabernet	Skye	Bedazzled	Limousine	Abbey
Unique	Skye	Touchdown	Kenblue	Baron	Unique	Blue Knight	Baron	Blue Velvet
Kenblue	Preakness	Bartitia	Limousine	Midnight	Nu Destiny	Midnight	Preakness	Midnight II
Cabernet	Apollo	Envicta	Wellington	Award	Blue Velvet	Shamrock	Touchdown	Diva
Blue Knight	Midnight	Moonlight	Apollo	Preakness	Longhorn	Award	Kenblue	Longhorn
Langara	Park	Abbey	Envicta	Abbey	Thermal Blue Blaze	Cabernet	Langara	Park
Eagleton	Nu Destiny	Limousine	Julia	Diva	Kingfisher	Moonlight	Skye	Apollo
Award	Kingfisher	Bedazzled	Blue Knight	Eagleton	Midnight II	Thermal Blue Blaze	Wellington	Julia

Figure 1. Schematic of the layout of 90 plots of bluegrasses, which covered an area of 1,550 ft^2 under a rainout shelter at the Rocky Ford Turfgrass Research Center near Manhattan, Kan.

Figure 2. Well-watered plots at the beginning of the study (June 4, 2007) before dry-down experiments were initiated.

Figure 3. Plots at 2 months into the study (Aug. 4, 2007).
Drought or heat stress is evident in some plots of Kentucky bluegrass.

Zoysiagrass Growth Under Tree Shade

Objective: Evaluate new zoysiagrasses for stolon growth and tillering under shade.

Investigators: David Okeyo and Jack Fry

Cooperators: Ambika Chandra and Dennis Genovesi, Texas A&M University

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

Introduction

Susceptibility to freezing temperatures limits the use of more zoysiagrass cultivars in the transition zone. We have identified several improved zoysiagrass progeny that have potential for use in Kansas. 'Meyer' zoysiagrass, the most commonly used cultivar in our region, is cold hardy but has poor shade tolerance. Identification of a cultivar with good hardiness and improved shade tolerance would be valuable for zoysiagrass managers.

Methods

This study was conducted at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. Meyer, 'Zorro', 'Emerald', 'Diamond', 'Cavalier', 'DALZ 0102', and 12 experimental progeny from Emerald × *Z. japonica* and *Z. japonica* × *Z. matrella* were evaluated under silver maple (*Acer saccharinum* L.) shade and in full sun in 2008 and 2009. A single 6-cm-diameter plug of each cultivar was planted in the center of 1.2 m × 1.2 m plots that were arranged in a randomized complete block design with six replicates. Data on number of stolons, stolon elongation, and number of stolon branches were collected weekly, and aboveground biomass was determined at the end of the study. Tiller number was collected at the start and end of the study.

Results

Photosynthetically active radiation in the shaded plots was reduced between 64% and 76% across months and years. It is difficult for zoysiagrass turf to recover from injury under even moderate shade. Zoysiagrasses growing under tree shade exhibited reductions of 38% to 95% in stolon number, 9% to 70% in stolon length, 10% to 93% in branching, and 56% to 98% in total aboveground biomass compared with turf in full sun (Tables 1 and 2). In addition, tillering declined from the beginning to the end of the study period for seven of the 10 grasses in 2008 and six of the 10 grasses in 2009 (Table 3). These reductions in growth in response to shade demonstrate why zoysiagrass quality often declines in shade and how zoysiagrass recovery in moderate shade is inhibited.

Table 1. Stolon number, length, and branching and total biomass of shade-grown zoysiagrasses and reduction in growth compared with zoysiagrasses grown in full sun at Manhattan, Kan., in 2008

	Stolon characteristics							
	Number[1]		Length[2] (mm)		Branches[3] (no./stolon)		Total biomass[4] (g)	
Cultivar or experimental progeny	Shade	Reduction in shade vs. sun (%)	Shade	Reduction in shade vs. sun (%)	Shade	Reduction in shade vs. sun (%)	Shade	Reduction in shade vs. sun (%)
Emerald (*Z. japonica* × *Z. tenuifolia*)	12.3 abcd	78.4 b	184 de	18.6 a	16.5 abc	66.1 bcd	33.0 abc	67.0 a
Z. japonica								
Meyer	3.8 f	95.0 a	162 de	30.6 a	7.8 cd	82.9 ab	26.7 abcd	73.4 a
Chinese Common	6.8 ef	78.0 b	319 abc	20.8 a	15.1 abc	59.5 bcd	29.3 abcd	70.7 a
Z. matrella								
Diamond	3.2 f	94.5 a	95 e	31.4 a	3.1 d	92.5 a	34.4 ab	65.6 a
Cavalier	10.7 bcde	85.1 ab	243 bcd	18.0 a	11.6 bcd	68.2 abcd	17.8 bcd	82.2 a
Zorro	14.8 ab	86.0 ab	303 abc	29.3 a	19.6 ab	72.2 abcd	6.1 d	93.9 a
Cavalier × C. Common								
5311-22	17.5 a	79.5 b	309 abc	28.7 a	13.3 abc	61.1 bcd	15.4 bcd	84.6 a
5311-27	12.0 bcde	75.0 b	213 cde	44.3 a	10.9 bcd	73.8 abc	43.9 a	56.2 a
Zorro × C. Common								
5312-49	9.2 cde	81.9 ab	336 ab	37.7 a	15.2 abc	52.8 cd	17.2 bcd	82.8 a
Emerald × Meyer								
5321-3	13.0 abc	86.9 ab	383 a	8.7 a	19.9 ab	57.1 bcd	9.98 cd	90.0 a
5327-19	9.7 bcde	80.2 b	348 ab	13.6 a	21.3 a	46.6 d	18.8 bcd	81.2 a
5321-18	—		—	—	—	—	—	—

Grasses were planted in tree shade and full sun as 6-cm-diameter plugs with six replicates on June 30, 2008.
Within column, means followed by the same letter are not significantly different according to the REGWQ test at $P < 0.05$.
[1] Average number of stolons per plug over six replicates on Sept. 29, 2008.
[2] Average total length of three stolons per plug over six replicates on Sept. 29, 2008.
[3] Average number of branches on three stolons per plug over six replicates on Sept. 29, 2008.
[4] Average dry weight of all plant parts except roots over six replicates after harvest on Sept. 29, 2008.

Table 2. Stolon number, length, and branching and total biomass of shade-grown zoysiagrasses and reduction in growth compared with zoysiagrasses grown in full sun at Manhattan, Kan., in 2009

	Stolon characteristics						Total biomass[4] (g)	
	Number[1]		Length[2] (mm)		Branches[3] (no./stolon)			
Cultivar or experimental progeny	Shade	Reduction in shade vs. sun (%)	Shade	Reduction in shade vs. sun (%)	Shade	Reduction in shade vs. sun (%)	Shade	Reduction in shade vs. sun (%)
Emerald (*Z. japonica* × *Z. tenuifolia*)	25.8 abc	76.0 ab	407 bc	70.1 a	12.1 c	58.1 a	32.0 ab	89.1 a
Z. japonica								
Meyer	5.8 d	85.3 a	336 c	56.9 ab	14.2 bc	50.0 a	13.17 b	97.2 a
Chinese Common	9.7 cd	89.2 a	545 abc	44.4 bc	16.4 bc	24.3 a	29.3 ab	97.9 a
Z. matrella								
Diamond	14.3 abcd	57.4 bc	379 bc	65.1 ab	15.8 bc	20.4 a	14.0 b	90.5 a
Cavalier	21.2 abcd	76.0 ab	454 bc	64.6 ab	15.4 bc	48.7 a	17.7 ab	97.0 a
Zorro	28.2 ab	38.0 c	520 abc	68.6 a	20.5 abc	47.5 a	26.2 ab	96.8 a
Cavalier × C. Common								
5311-22	30.2 a	65.3 abc	770 a	63.9 ab	31.9 a	10.4 a	41.3 ab	97.9 a
5311-27	20.7 abcd	74.0 ab	482 bc	67.9 a	23.1 abc	51.5 a	34.2 ab	96.2 a
Zorro × C. Common								
5312-49	22.5 abc	72.8 ab	638 ab	59.4 ab	25.8 ab	8.5 a	54.7 a	92.8 a
Emerald × Meyer								
5321-3	21.8 abcd	80.2 a	601 abc	56.8 ab	24.9 ab	19.1 a	25.3 ab	96.0 a
5327-19	19.5 abcd	43.9 bc	515 abc	52.7 abc	16.1 bc	44.1 a	20.7 ab	85.7 a
5321-18	22.5 abcd	59.3 abc	470 bc	63.0 ab	16.8 bc	33.7 a	29.0 ab	91.2 a

Grasses were planted in tree shade and full sun as 6-cm-diameter plugs with six replicates on June 26, 2009.
Within column, means followed by the same letter are not significantly different according to the REGWQ test at $P < 0.05$.
[1] Average number of stolons per plug over six replicates on Sept. 24, 2009.
[2] Average total length of three stolons per plug over six replicates on Sept. 24, 2009.
[3] Average number of branches on three stolons per plug over six replicates on Sept. 24, 2009.
[4] Average dry weight of all plant parts except roots over six replicates after harvest on Sept. 29, 2008.

Table 3. Changes in tiller number of shade-grown zoysiagrasses from July 14 to Sept. 27, 2008, and from July 1 to Sept. 23, 2009, at Manhattan, Kan.

	Tillers[1] (no./20 cm²)					
	2008			2009		
Cultivar or experimental progeny	July 14	Sept. 17	Change (%)	July 1	Sept. 23	Change (%)
Emerald (*Z. japonica* × *Z. tenuifolia*)	68.3 bc	76.2 b	+ 22.4 a	78.8 bcd	83.8 b	+ 17.4 a
Z. japonica						
Meyer	72.2 bc	56.3 bcde	- 18.7 abc	53.3 cde	50.7 de	+0.7 ab
Chinese Common	29.3 c	34.5 e	+ 21.1 ab	33.2 e	36.2 f	+ 18.3 a
Z. matrella						
Diamond	189.7 a	114.2 a	- 39.2 bc	131.3 a	139.5 a	+19.4 a
Cavalier	89.5 b	65.8 bcd	- 8.4 abc	82.8 bcd	70.8 bc	- 1.9 ab
Zorro	72.2 bc	69.2 bc	- 0.9 abc	91.3 bc	77.0 b	- 13.6 ab
Cavalier × C. Common						
5311-22	47.5 bc	36.2 de	- 22.8 abc	55.8 cde	43.8 ef	- 20.6 ab
5311-27	87.3 b	45.2 cde	- 43.3 c	44.0 de	45.3 ef	+ 4.7 ab
Zorro × C. Common						
5312-49	41.7 c	39.8 cde	- 4.4 abc	49.5 de	56.8 cde	+20.8 a
Emerald × Meyer						
5321-3	42.0 c	45.0 cde	+ 9.9 abc	50.7 de	50.3 de	+6.9 ab
5327-19	31.8 c	32.3 e	+ 6.31 abc	63.7 bcde	48.0 de	-19.6 ab
5321-18	—	—	—	96.7 b	65.7 bcd	-29.8 b

Grasses were planted in tree shade and full sun as 6-cm-diameter plugs with six replicates on June 30, 2008, and June 26, 2009.
Within column, means followed by the same letter are not significantly different according to the REGWQ test at $P < 0.05$.
[1] Average number of tillers counted within the 20-cm² center of the planted plug over six replicates.

Figure 1. The study was conducted just to the north of this line of maple trees in Manhattan, Kan.

Figure 2. David Okeyo counts tillers in the shade.

Stolon Growth Characteristics and Establishment Rates of Zoysiagrass

Objectives: Evaluate new zoysiagrasses for stolon growth characteristics and rate of establishment.

Determine the relationship between stolon growth characteristics and coverage.

Investigators: David Okeyo and Jack Fry

Cooperators: Ambika Chandra and Dennis Genovesi, Texas A&M University

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

Introduction

'Meyer' zoysiagrass, the most commonly used zoysiagrass in the transition zone, has a relatively slow establishment rate. There is interest in evaluating the growth characteristics and rate of establishment of new zoysiagrass progeny that have demonstrated good cold hardiness in trials at Kansas State University since 2004.

Methods

This study was conducted at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. Eighteen freeze-tolerant progeny from crosses of 'Emerald' (*Z. japonica* × *Z. tenuifolia*) or of *Z. matrella* × *Z. japonica* were planted along with Meyer and 'DALZ0102' as 6-cm-diameter plugs on 30.5 cm × 30.5 cm centers in 1.5 m × 1.5 m plots in 2007 and as single 10-cm-diameter plugs in 1.2 m × 1.2 m plots in 2008. Data on stolon number per plug, stolon elongation (Figure 1), and number of stolon branches were collected weekly, and coverage was rated visually by two researchers near the end of each growing season. Correlation analysis was done to evaluate the relationship between stolon growth characteristics and coverage.

Results

The rate of stolon production ranged from 2.2 to 8.6/week (Table 1). Elongation rate ranged from 18.8 to 65.1 mm/week. Seven weeks after planting in 2007, four of 18 progeny had superior coverage compared with Meyer. Nine weeks after planting in 2008, all but five progeny had superior coverage compared with Meyer (Table 2). Stolon number was positively correlated ($P < 0.01$) with coverage in 2007 ($r = 0.66$) and 2008 ($r = 0.94$). Stolon length was also positively correlated with coverage in 2007 ($r = 0.52$, $P < 0.01$) and 2008 ($r = 0.53$, $P < 0.05$). The greater stolon production and elongation of these experimental zoysiagrass progeny indicate that they could establish faster than Meyer.

Table 1. Rates of stolon production, elongation, and branching of zoysiagrasses at Manhattan, Kan., in 2007 and 2008[1]

	Stolons[2] (no./week)		Elongation[3] (mm/week)		Branching[4] (no./week)	
Cultivar or experimental progeny	2007	2008	2007	2008	2007	2008
Meyer (control)	2.91 c	3.40 b	38.0 bc	26.8 cd	5.56 ab	5.64 ab
DALZ0102	2.62 c	7.46 ab	26.4 c	36.3 bc	4.08 b	5.42 ab
Cavalier × Meyer (5283-27)	4.66 b	6.90 ab	35.1 bc	41.9 bc	4.71 ab	6.77 ab
Cavalier × Chinese common						
5311-3	5.61 ab	7.21 ab	53.3 ab	36.7 bc	4.60 ab	1.75 c
5311-8	4.61 b	6.50 ab	46.2 b	35.0 bc	3.75 b	4.39 bc
5311-22	6.26 a	7.62 ab	55.7 ab	46.0 bc	4.71 ab	3.67 bc
5311-26	4.96 ab	5.25 b	34.1 bc	39.6 bc	3.48 b	3.02 c
5311-27	4.84 ab	7.85 ab	43.6 b	46.3 bc	3.23 b	4.45 bc
5311-32	4.65 b	7.74 ab	49.3 ab	46.0 bc	4.23 b	5.13 bc
Zorro × Chinese common						
5312-36	4.07 bc	7.81 ab	58.0 ab	49.1 b	5.21 ab	6.35 ab
5312-49	3.49 bc	5.28 b	61.9 a	65.1 a	3.58 b	6.49 ab
Emerald × Meyer						
5321-3	4.92 ab	8.62 a	39.6 bc	40.3 bc	3.60 b	4.62 bc
5321-24	2.89 c	7.65 ab	21.6 c	30.6 cd	3.44 b	5.06 bc
5321-45	2.41 c	4.59 b	37.4 bc	33.5 c	4.67 ab	5.37 b
5321-48	2.19 c	3.24 b	21.3 c	18.8 d	2.60 b	4.44 bc
8501 × Meyer						
5324-18	5.34 ab	8.38 a	54.8 ab	43.2 bc	6.01 ab	7.66 a
5324-27	4.69 ab	7.76 ab	32.0 bc	37.8 bc	2.33 b	6.71 ab
5324-52	2.58 c	5.48 b	32.5 bc	29.1 cd	3.82 b	6.22 ab
5324-53	4.12 bc	7.06 ab	58.1 ab	39.1 bc	7.09 a	5.32 b
Meyer × Diamond (5327-19)	3.16 bc	4.85 b	46.5 b	29.8 cd	5.13 ab	3.60 bc

In 2007, grasses were planted on June 5 as 6-cm-diameter plugs on 30.5-cm centers in 1.5 × 1.5 m plots, and data were collected on August 1. In 2008, grasses were planted on June 24 as 10-cm-diameter plugs in 1.2 × 1.2 m plots, and data were collected on Sept. 17.

Within columns, means followed by the same letter are not significantly different according to Bonferroni's t-test at $P < 0.05$ (corrected for multiple comparisons).

[1] Rates of stolon production, elongation, and branching were calculated from week 1 to 7 in 2007 and from week 1 to 10 in 2008 by using linear regression analysis to obtain slope estimates.

[2] In 2007: average of three replicates from three randomly selected plugs per plot. In 2008: average of a single plug over three replicates.

[3] In 2007: average of one stolon from three randomly selected plugs per plot over three replicates. In 2008: average of three randomly selected stolons per plug and three replicates.

[4] In 2007: average number of branches on one stolon from three randomly selected plugs per plot and over replicates. In 2008: average of three selected stolons per plug over three replicates.

Table 2. Coverage of zoysiagrasses at Manhattan, Kan., in 2007 and 2008

Cultivar or experimental progeny	Coverage[1] (%)		
	Aug. 24, 2007	Sept. 24, 2007	Sept. 4, 2008
Meyer	55.8 cd	94.7 ab	50.0 d
DALZ0102	66.7 bc	94.7 ab	90.0 ab
Cavalier × Meyer (5283-27)	53.3 cd	85.0 abcd	85.0 ab
Cavalier × Chinese common			
5311-3	54.2 cd	90.0 abc	85.0 ab
5311-8	63.3 bc	95.0 ab	73.3 abc
5311-22	78.3 a	97.7 a	75.0 abc
5311-26	67.5 b	96.0 ab	70.0 bcd
5311-27	65.4 bc	96.3 ab	85.0 ab
5311-32	64.2 bc	94.7 ab	90.0 ab
Zorro × Chinese common			
5312-36	60.0 c	97.7 a	85.0 ab
5312-49	66.7 bc	94.7 ab	75.0 abc
Emerald × Meyer			
5321-3	72.5 ab	99.0 a	95.0 a
5321-24	42.5 e	76.7 cd	75.0 abc
5321-45	51.7 d	85.0 abcd	56.7 cd
5321-48	43.3 e	73.3 d	50.0 d
8501 × Meyer			
5324-18	74.2 ab	97.7 a	90.0 ab
5324-27	44.2 e	81.7 bcd	90.0 ab
5324-52	55.8 cd	86.7 abcd	70.0 bcd
5324-53	56.7 cd	93.3 ab	80.0 ab
Meyer × Diamond (5327-19)	58.3 cd	88.3 abc	70.0 bcd

In 2007, grasses were planted on June 5 as 6-cm-diameter plugs on 30.5-cm centers in 1.5 × 1.5 m plots. In 2008, grasses were planted on June 24 as 10-cm-diameter plugs in 1.2 × 1.2 m plots.
Within a column, means followed by the same letter are not significantly different according to the REGWQ test at $P < 0.05$.
[1] Average of visual evaluations by two researchers and over three replicates.

Figure 1. Measuring stolon growth characteristics in the field.

Freeze Tolerance and Seasonal Color Retention of Zoysiagrasses

Objectives: Evaluate freeze tolerance of 10 zoysiagrass progeny developed from crosses of *Z. matrella* (L.) Merr. × *Z. japonica* or 'Emerald' [*Z. japonica* × *Z. pacifica* (Goudsw.) M. Hotta & Kuroi] × 'Meyer', 'Cavalier' (*Z. matrella*), and 'DALZ 0102' (*Z. japonica*).

Evaluate autumn spring green color of the grasses and determine the relationship between autumn color and freeze tolerance.

Investigators: David Okeyo, Jack Fry, Dale Bremer, and Channa Rajashekar

Cooperators: Ambika Chandra and Dennis Genovesi, Texas A&M University

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

Introduction

Freeze tolerance is the limiting factor preventing use of new zoysiagrass cultivars in the transition zone. In this study, we wanted to evaluate hardiness of several zoysiagrass progeny that we have evaluated in the field since 2004. In addition, it is commonly believed that warm-season grasses that retain green color longer in autumn are more susceptible to freezing injury, so one of our objectives was to evaluate this relationship in zoysiagrasses.

Methods

Grasses were managed under golf course fairway conditions at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. Cores of each grass were sampled from the field in December 2007 and 2008, October 2008, and February 2008 and 2009 and exposed to temperatures between -6°C and -22°C in the laboratory (Figure 1). Then LT_{50} values (i.e., lethal temperatures resulting in 50% loss of tillers) were determined by counting tillers after 6 weeks of recovery in the greenhouse (Figure 2). Fall and spring color were determined by analyzing digital images.

Results

Across sampling dates, LT_{50} ranged from -0.2°C to -12.2°C (Table 1). All grasses were equivalent to Meyer in freeze tolerance except Cavalier on three of five dates and one *Z. matrella* × *Z. japonica* progeny in December 2007. Five progeny were superior to Meyer in autumn color retention, but none of the progeny tested were superior to Meyer in spring color. Autumn color in October and November 2007 was positively correlated (r = 0.40 to 0.58, $P < 0.05$) with LT_{50} in December 2007. In other words, grasses that were greener in autumn 2007 had poorer freeze tolerance in December 2007. In general, experimental progeny originating from the aforementioned crosses demonstrated good freeze tolerance and, in some cases, superior autumn color compared with Meyer.

Table 1. Lethal temperatures resulting in death of 50% of zoysiagrass tillers (LT_{50}) after sampling from the field at Manhattan, Kan., 2007, 2008, and 2009

	LT_{50} (°C)[1]				
Cultivar or experimental progeny	Dec. 15, 2007	Feb. 15, 2008	Oct. 15, 2008	Dec. 15, 2008	Feb., 15 2009
Meyer	-10.7 c	-12.9 b	-5.8 a	-12.0 b	-4.8 a
Cavalier	-0.2 a	-5.2 a	-4.8 a	-5.0 a	-4.8 a
DALZ 0102	—	-10.9 b	-7.3 a	-10.9 ab	-4.8 a
Cavalier × Meyer	-8.6 bc	-8.4 ab	-4.8 a	-9.0 ab	-4.8 a
Cavalier × Chinese common					
5311-3	-9.0 bc	-11.8 b	-4.8 a	-11.6 b	-4.8 a
5311-8	-8.8 bc	-10.0 b	-4.8 a	-6.2 ab	-4.8 a
5311-22	-9.3 c	-10.8 b	-4.8 a	-9.5 ab	-4.8 a
5311-26	-10.3 c	-11.8 b	-4.8 a	-8.4 ab	-4.8 a
5311-27	-10.4 c	-12.2 b	-2.7 a	-8.5 ab	-4.8 a
5311-32	-9.0b c	-10.9 b	-5.5 a	-11.0 ab	-4.8 a
Emerald × Meyer (5321-3)	-10.4 c	-10.8 b	-6.0 a	-9.6 ab	-4.8 a
8501 × Meyer					
5324-18	-8.4 bc	-11.3 b	-7.2 a	-8.8 ab	-4.8 a
5324-53	-3.4 ab	-10.9 b	-7.3 a	-8.2 ab	-4.8 a
CV	-30.5	-24.9	-52.7	-23.5	0

Grasses were randomly sampled as sixteen 6-cm-diameter cores from plots maintained under culture similar to a golf course fairway.
Within columns, means followed by the same letter are not significantly different according to the REGWQ multiple range test at $P < 0.05$.
[1] LT_{50} values were determined by fitting a linear regression of $\log_{10}$ (percentage tiller number plus 0.0001) vs. temperature and then substituting $\log_{10}$ 50% in the generated equation to obtain the corresponding temperature.

Figure 1. Plugs sampled from the field were subjected to freezing temperatures in a chamber.

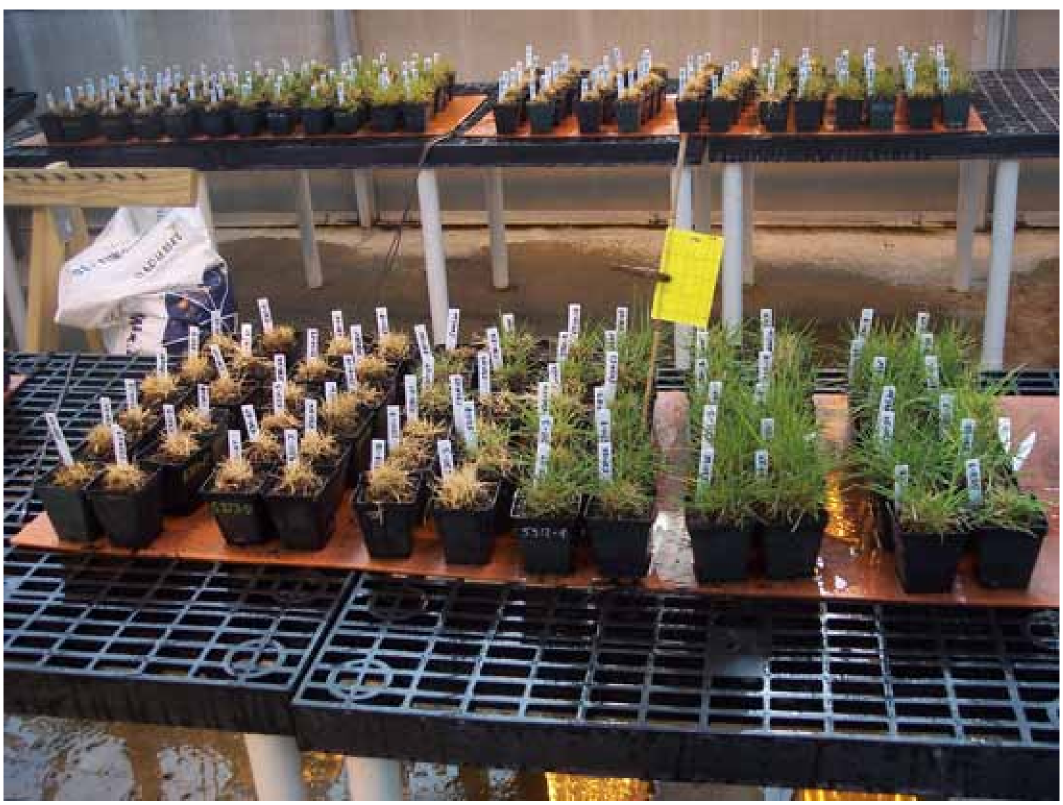

Figure 2. Recovery was evaluated in the greenhouse.

National Turfgrass Evaluation Program Zoysiagrass Evaluation

Objective: Evaluate standard and experimental zoysiagrass cultivars for adaptation to the Midwest.

Investigator: Jack Fry

Sponsor: National Turfgrass Evaluation Program

Introduction

Although 'Meyer' is the predominant zoysiagrass cultivar used in Kansas, there continues to be interest new cultivars. This National Turfgrass Evaluation Program zoysiagrass evaluation is being conducted at several locations across the United States. The most important consideration in our climate is freezing tolerance. High-density, fine-textured cultivars are usually from the *Zoysia matrella* group, but these cultivars are also less hardy.

Methods

Grasses were plugged into 5 ft × 5 ft plots on June 27, 2007. Turf was mowed 3 days weekly at 0.5 in. and irrigated as needed to receive about 0.75 in./week. Turf received two separate summer applications of 1 lb N/1,000 ft^2 from urea. Plots were rated for winterkill, summer coverage, spring greenup, leaf texture, and quality. Winterkill and summer coverage were rated on a scale of 0% to 100%. Other characteristics were rated visually on a scale of 0 to 9 (0 = worst, and 9 = best).

Results

All selections that were from *Z. matrella* experienced poor spring greenup and spring cover (Table 1). These are not recommended for use in the upper transition zone. Once they recovered in midsummer to late summer, these selections had fine leaf texture and very good turf quality. The *Z. japonica* cultivars (Meyer, 29-2, and 'Zenith') exhibited billbug injury, but data were variable and these zoysiagrasses were not different from one another.

Table 1. Zoysiagrass performance at Manhattan, Kan., in 2009[1]

								Turf quality				
Cultivar	Species[2]	Genetic color	Spring greenup	Leaf texture	Spring cover	Fall color	Billbug	May	June	July	Aug.	Mean
380-1	M	8.0	2.0	9.0	65.0	5.3	0.0	4.3	7.0	8.7	8.7	7.2
DALZ 0701	M	7.3		9.0	26.7	7.0	0.0	2.7	8.0	8.0	8.3	6.8
Zorro	M	7.0	1.0	9.0	38.3	6.7	0.0	4.0	6.7	8.0	8.3	6.8
Meyer	J	7.0	2.0	6.7	86.7	6.3	8.3	5.3	6.7	7.0	7.0	6.5
29-2	J	6.7	5.3	7.0	88.3	6.7	13.3	5.7	6.3	6.3	7.0	6.4
240	J	7.7	2.3	7.0	88.3	5.0	0.0	4.7	7.0	7.0	6.7	6.3
DALZ 0702	M	7.0		9.0	18.3	7.0	0.0	1.7	6.7	7.7	8.0	6.0
Zenith	J	7.0	5.0	5.3	90.0	5.0	13.3	6.3	5.3	6.0	6.3	6.0
DALZ 0501	M	7.3		9.0	18.3	6.7	0.0	2.3	5.7	7.3	8.0	5.8
Shadowturf	M	7.0		9.0	3.0	6.7	0.0	1.0	4.0	5.3	7.0	4.3
L1F	M				0.0			1.0	1.0	1.0	1.0	1.0
LSD[3]		0.8	1.0	0.4	18.9	1.1	13.6	1.5	1.2	1.2	1.1	0.1

[1] Genetic color, spring greenup, leaf texture, fall color, and quality were rated visually on scale of 0 to 9 (0 = worst, 9 = best). Spring cover and billbug were rated visually on a scale of 0% to 100%.

[2] M, *Zoysia matrella*; J, *Zoysia japonica*.

[3] To determine statistically significant differences between 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 2008 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

During summer 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 cultivars were plugged on 1-ft centers with 16 plugs per plot, and seeded cultivars 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 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 (i.e., 0.17 g/16 ft^2 of the 75% DF product) in two applications.

After establishment, 2 lb N/1,000 ft^2 was applied to the area (1 lb in June and 1 lb in July). Barricade was applied in the spring to prevent annual weeds. The plots are maintained at 2.0 in. high and irrigated 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. Leaf texture, genetic color, and turf stand density were rated in July 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). Overall quality was recorded monthly during the growing season on a scale of 1 to 9 (6 = lowest acceptable turf quality).

Wichita Results

During 2009, the first full season of this trial, we collected information on quality; spring greenup and cover; absence of seed heads; genetic color; spring, summer, and fall density; and fall color retention. We started the year by evaluating spring greenup on May11; vegetative cultivar NE-BFG07-09 and seeded cultivar NE-BFG07-03 were the greenest (Table 1). All plots were green by the end of May, so after the study's first winter, we visually rated stand cover on a scale of 0% to 100%. Vegetative varieties NE-BFG07-09, 609, and 'Legacy' and seeded varieties NE-BFG07-03 and NE-BFG07-08 exhibited the best cover. We rated the turf for 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. Vegetative cultivars 609, Legacy, and NE-BFG07-09 and seeded cultivars NE-BFG07-03, NE-BFG07-08, and NE-BFG07-02 performed best overall. During the course of the summer, we rated turf for genetic color and absence of seed heads. The seeded cultivar with the best color was 'Bison', and the vegetative cultivar with the best color was Legacy. Of the seeded cultivars, Bison, 'Bowie', and 'Texoka' had the fewest seed heads.

We rated stand density in spring, summer, and fall. Vegetative cultivars 'Prestige' and NE-BFG07-10 and seeded cultivars NE-BFG07-01 and NE-BFG07-03 exhibited the best spring density. Vegetative cultivars 609 and Prestige and seeded cultivars NE-BFG07-03, NE-BFG07-04, and NE-BFG07-08 exhibited the best summer density. Seeded cultivars NE-BFG07-04, NE-BFG07-02, and NE-BFG07-03 and vegetative cultivars NE-BFG07-10 and NE-BFG07-09 exhibited the best fall density.

We ended the season by looking at fall color retention over the course of several weeks. On October 27, vegetative cultivar 609 stood out as still being mostly green; vegetative cultivar NE-BFG07-09 and seeded cultivar Bison and Texoka were still somewhat green. By December 1, cultivar 609 was still somewhat green, whereas all other cultivars were mostly a dull tan.

Olathe Results

Most of the vegetative varieties performed the better than the seeded varieties in terms of color, density, and texture (Table 2). Legacy, Prestige, BFG07-10, and BFG07-12 had the best overall quality. It is interesting to see how the grasses perform differently in Olathe than in Wichita. 609 is performing very well in Wichita, but 609 is doing as well in Olathe. BFG07-10, BFG07-13, BFG07-09, Legacy, and Bison had the darkest genetic color. Legacy, 609, and Prestige had the finest leaf texture. BFG07-10, BFG07-11, 609, and Legacy maintained the greenest fall color.

At both locations, the vegetatively propagated cultivars had few, if any, male flowers and seed heads, but on occasion, Legacy had more seed heads than even the seeded cultivars. Legacy is a female-only clone and should not produce male flowers. In discussions with the cooperators from Nebraska, we learned that under some set of unknown environmental conditions, Legacy may be able to switch sex and change from female only to female and male plants. The Legacy plants that the University of Nebraska was growing changed their sex before they were sent out to all the trial locations in 2008.

Table 1. Performance of buffalograss cultivars in Wichita, Kan., in 2009[1]

Cultivar/ experimental number	Type	Spring greenup	Cover (%)	Genetic color	Seed heads	Spring density	Summer density	Fall density	Fall color	Quality					
										May	June	July	Aug.	Sept.	Avg.
609	V	4.3	80.0	5.3	9.0	4.3	7.0	4.7	8.3	4.7	6.3	6.0	6.0	6.0	5.9
Legacy	V	4.7	75.0	7.0	3.0	4.7	5.3	4.7	3.7	4.0	4.7	5.7	6.7	6.7	5.3
NE-BFG07-09	V	6.0	85.0	6.0	9.0	5.3	5.0	5.0	5.0	4.7	5.7	5.3	5.7	5.7	5.3
NE-BFG07-03	S	5.3	71.7	7.0	5.0	5.0	5.7	5.3	2.0	4.3	5.0	5.7	5.3	5.3	5.1
NE-BFG07-08	S	4.7	70.0	7.0	5.3	4.7	5.7	5.0	2.0	3.7	5.0	5.7	5.3	5.3	4.9
NE-BFG07-02	S	4.0	63.3	7.0	4.7	4.3	5.3	5.3	2.0	3.3	4.7	6.0	5.3	5.3	4.8
NE-BFG07-11	V	4.3	65.0	6.3	8.3	5.3	5.7	4.0	3.7	3.7	5.0	5.7	5.0	5.0	4.7
NE-BFG07-04	S	4.7	61.7	7.0	4.0	4.7	5.7	5.7	2.3	3.7	4.7	5.0	5.0	5.0	4.6
Prestige	V	4.0	60.0	5.0	9.0	6.3	6.0	4.7	3.0	4.0	4.7	4.7	4.7	4.7	4.5
NE-BFG07-01	S	4.0	65.0	7.0	5.3	5.0	5.0	4.3	2.0	3.3	5.0	5.0	4.7	4.7	4.5
NE-BFG07-12	V	4.7	65.0	6.0	9.0	5.3	5.7	4.3	2.0	4.0	4.7	5.0	4.7	4.7	4.5
NE-BFG07-10	V	4.3	63.3	6.0	9.0	5.7	5.3	5.3	3.0	3.3	4.3	4.7	5.3	5.3	4.4
Texoka	S	4.0	66.7	7.0	7.0	4.0	4.7	4.3	4.3	3.0	5.0	4.7	4.0	4.0	4.2
Cody	S	3.7	56.7	7.0	6.7	4.7	4.7	4.3	3.0	2.7	3.7	4.3	5.0	5.0	4.0
Bison	S	2.0	30.0	7.5	7.5	3.5	4.0	4.0	4.5	2.5	3.5	4.0	3.5	3.5	3.5
Bowie	S	2.0	33.3	7.0	7.0	4.0	4.0	5.0	2.3	2.0	3.0	4.0	4.0	4.0	3.4
NE-BFG07-13	V	3.3	40.0	6.0	8.7	4.7	5.0	3.0	1.0	2.3	3.0	3.7	3.0	3.0	3.0
LSD[2]		3.7	26.2	0.4	0.9	2.6	2.3	0.9	1.2	1.6	1.6	2.9	1.5	0.9	1.2

[1] Spring greenup, genetic color, seed heads, density, fall color retention, and quality were rated visually on a scale of 1 to 9 (1 = worst, 9 = best). Cover was rated visually on a scale of 0% to 100%.

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

Table 2. Performance of buffalograss cultivars in Olathe, Kan., in 2009

						Quality						
Cultivar/ experimental number	Type	Genetic color	Summer density	Texture	Fall color	May	June	July	Aug.	Sept.	Oct.	Avg.
NE-BFG07-10	V	8.0	8.7 ab	8.7 ab	8.0 a	6.7 a	8.0 a	8.7 a	9.0 a	9.0 a	8.0 a	8.2 a
Prestige	V	7.0	9.0 a	9.0 a	7.0 cd	5.7 abc	8.0 a	8.7 a	9.0 a	9.0 a	8.0 a	8.1 a
Legacy	V	7.3	8.7 ab	8.7 ab	7.3 bc	6.7 a	8.0 a	8.0 ab	8.3 ab	8.0 bc	7.7 ab	7.8 abc
NE-BFG07-12	V	7.0	7.7 bcd	8.0 c	7.0 cd	6.7 a	7.0 bc	7.7 abc	8.3 ab	8.7 ab	6.7 cde	7.5 bc
NE-BFG07-09	V	7.3	8.0 abc	8.0 c	7.3 bc	6.0 abc	7.3 ab	7.7 abc	8.0 bc	7.7 cd	7.3 abc	7.3 cde
NE-BFG07-03	V	7.0	7.0 cde	8.0 c	6.3 ef	6.0 abc	7.0 bc	7.7 abc	8.0 bc	7.7 cd	7.3 abc	7.3 cde
NE-BFG07-08	S	7.3	7.7 bcd	8.0 c	6.3 ef	6.3 ab	7.3 ab	7.3 bcd	7.7 bcd	8.0 bc	7.0 bcd	7.3 cde
NE-BFG07-11	S	7.3	7.0 cde	8.0 c	7.7 ab	6.7 a	7.0 bc	7.0 bcd	8.0 bc	8.0 bc	7.0 bcd	7.3 cde
NE-BFG07-02	S	7.0	7.0 cde	8.0 c	6.0 f	6.3 ab	7.0 bc	7.7 abc	7.7 bcd	7.3 cd	7.0 bcd	7.2 def
NE-BFG07-04	S	7.3	7.3 cde	8.0 c	6.0 f	6.3 ab	7.3 ab	7.7 abc	7.7 bcd	7.3 cd	6.7 cde	7.2 def
NE-BFG07-01	S	7.0	6.3 e	8.0 c	6.0 f	6.7 a	7.0 bc	7.3 bcd	7.3 cd	7.0 d	6.7 cde	7.0 defg
609	V	7.3	8.7 ab	8.3 ab	7.7 ab	4.3 d	6.3 cd	7.3 bcd	8.0 bc	8.0 bc	8.0 a	7.0 defg
NE-BFG07-13	V	8.0	7.3 cde	8.0 c	6.7 de	4.3 d	7.3 ab	8.0 ab	8.0 bc	7.7 cd	6.0 e	6.9 efgh
Bowie	S	7.3	7.3 cde	8.0 c	6.3 ef	5.0 cd	6.7 bcd	7.3 bcd	7.7 bcd	7.7 cd	6.7 cde	6.8 efgh
Cody	S	7.0	7.0 cde	8.0 c	6.3 ef	5.3 bcd	6.3 bcd	7.0 bcd	7.3 cd	7.7 cd	6.0 e	6.6 fgh
Texoka	S	7.3	6.7 de	8.0 c	6.7 de	5.3 bc	6.3 bcd	6.7 cd	7.0 d	7.3 cd	6.0 e	6.4 gh
Bison	S	7.3	6.3 e	8.0 c	7.0 cd	5.0 cd	6.0 d	6.3 d	7.0 d	7.3 cd	6.3 de	6.3 h
$LSD_{0.05}$		NS	1.1	0.4	0.6	1.1	0.8	1.0	0.8	0.9	1.0	0.6

Within columns, means followed by the same letter are not significantly different ($P < 0.05$).

2007 Ornamental Grass Trial

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

Investigators: Rodney St. John, Robin Dremsa, and Jason Griffin

Overview

Ornamental grasses, sedges, and rushes can be great additions to midwestern landscaping, but little research has been done to evaluate them within a Kansas climate. This project, which is designed to evaluate many species and cultivars of ornamental grasses, will continue for many years. We will record winter and summer survival rates, the rate at which grasses spread, average height, and appearance. Results will also include a photographic record of each grass as it progresses throughout 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. Both forms can be advantageous in different landscape situations. For example, spreading grasses can be used to fill in a large area. One of the purposes of this study is to evaluate the spreadability of these grasses.

This trial will run for several years, and you can find detailed information about each grass on the Kansas State University turfgrass website:
http://ksuturf.com/ornamentalgrasses.html

Methods

Two study sites were established in different regions of Kansas. One site is located at the Kansas State University Horticulture Research and Extension Center in the eastern region of Kansas in Olathe (Johnson County). This trial site has a tree line at the southern edge but is otherwise open and exposed to the sun and wind. In June 2007, we planted 45 grass cultivars obtained from nursery sources in northeastern Kansas. Clusters of three or more plants of each variety were planted randomly in a newly cultivated area. Grasses were watered until they were established, and then no supplemental water was given throughout the duration of the trial. A preemergence herbicide (Treflan) was applied 3 days after planting, and a layer of hardwood mulch was put down for additional weed suppression. In the following 2 years, weeds were controlled with hand pulling and occasional spot applications of herbicides such as glyphosate and halosulfuron. Foliage remained on the plants throughout the winter and was cut to a height of about 4 in. every March.

The second study site is at the John C. Pair Horticultural Center in the south central region of Kansas in Haysville (Sedgwick County). This site is fully exposed to the elements, with no protection from wind or sun. All 45 grass cultivars planted at this site came from Hoffman Nursery (Rougemont, N.C.) and were planted in groups of three; groups were randomly replicated three times in 4 ft × 4 ft plots. The plants were established in May 2007 and received irrigation to prevent water stress during the first summer; no additional water was provided for the rest of the trial period. A preemergence herbicide (Treflan) was applied 3 days after planting. Surflan was applied in the spring of years two and three. Additional weed suppression was obtained by hand weeding and spot herbicide applications of glyphosate, halosulfuron, or both as needed. No fertilizer was applied specifically for the ornamental grasses, but the adjacent turfgrass received annual applications of a fertilizer plus preemergence product. Foliage remained on the plants throughout the winter and was cut to a height of about 4 in. every March.

At the end of each growing season (September), grasses were counted to determine survival and measured for foliage height and flower height. Vigor (growth, strength, and substance of the vegetation) and floriferousness (overall visual impact of the foliage and flowers) were rated on a scale of 1 to 7 to determine the cultivar's suitability for landscape use (1 = almost dead, 4 = acceptable, and 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 3 years, but only the last year's data (which represent mature plants) are presented.

Results

Many grasses had good survival rates and ornamental properties after the 3-year trial period. On the basis of survivability, vigor, and floriferousness, 21 grasses were designated as recommended varieties for Kansas (Table 1).

Some cultivars that have high visual interest did not receive a recommendation for this region because of their invasive growth habit. *Leymus arenarius* 'Blue Dune' had unique spiky blue foliage, but its aggressive spreading growth habit reduced its rating because it would likely invade and take over landscape beds.

Minimal to no reseeding was observed, but this characteristic was not specifically investigated in this study. Further research on the reseeding properties of ornamental grasses may lead to cautions about the use of some cultivars in this region.

Table 1. Recommended ornamental grass varieties for Kansas

		Olathe			Haysville		
Scientific name	Cultivar	Foliage height (in.)	Flower height (in.)	Survival (%)	Foliage height (in.)	Flower height (in.)	Survival (%)
Arundo donax	Variegata	136	152	100	118		100
Calamagrostis × acutiflora	Karl Foerster	22	52	100	18	50	100
Hystrix patula				0	5	19	44
Leymus arenarius	Blue Dune	25	45	100	14	34	100
Miscanthus sinensis	Adagio	35	58	75	36	52	100
Miscanthus sinensis	Little Kitten	33	56	80	34	50	100
Miscanthus sinensis	Little Zebra	45	66	100	39	63	78
Miscanthus sinensis	Silberfeder	59	84	100	56	96	100
Miscanthus sinensis	Silberfeil	59	70	80	44	72	100
Miscanthus sinensis	Strictus	62	87	100	46	78	100
Miscanthus × giganteus		114	131	100		140	100
Molinia arundinacea	Skyracer	30	98	100	11	53	78
Panicum virgatum		42	60	100	51	78	100
Panicum virgatum	Cloud Nine	66	90	100	71	92	100
Panicum virgatum	Dallas Blues	60	83	80	65	84	100
Panicum virgatum	Prairie Sky	35	56	100	43	75	100
Pennisetum alopecuroides	Hameln	19	34	100	10	21	100
Pennisetum orientale	Karley Rose	29	40	100	32	43	100
Saccharum ravennae		70	145	100	74	149	100
Schizachyrium scoparium		36	36	100	10	49	100
Sporobolus heterolepis		14	44	100	14	34	100

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SRP 1035 July 2010

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