K-STATE TURFGRASS RESEARCH

2012

REPORT OF PROGRESS 1071

K-STATE Research and Extension

KANSAS STATE UNIVERSITY
AGRICULTURAL EXPERIMENT
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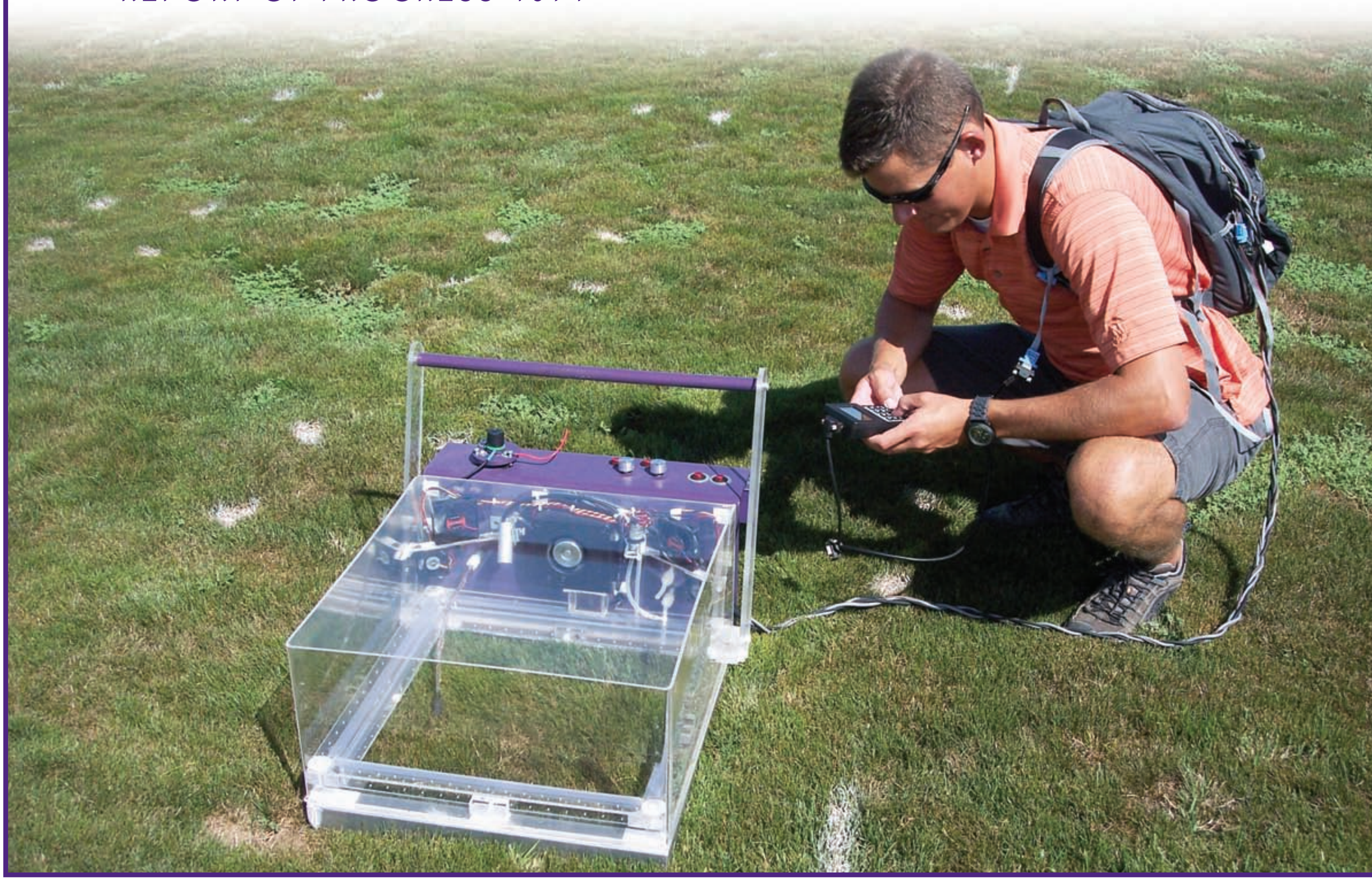

K-STATE TURFGRASS RESEARCH 2012

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Foreword

Turfgrass Research 2012 contains results of projects conducted by K-State faculty and graduate students. Some of these results will be presented at the Kansas Turfgrass Field Day, August 2, 2012, at the Rocky Ford Turfgrass Research Center, Manhattan. Articles included in this Report of Progress present summaries of research projects that were completed recently or will be completed in the next year or two. Specifically, this year's report presents summaries of research on turf establishment and management, variety evaluations, pest management, and water issues and drought.

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

www.ksuturf.org and ***www.ksre.ksu.edu/library/***

Note: Photos were taken by K-State Turfgrass faculty, staff, and students unless otherwise noted.

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Changes in Zoysiagrass Growth and Quality in Shade

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

Investigators: Kenton Peterson, Jack Fry, Dale Bremer

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

Introduction

Zoysiagrass (*Zoysia* Willd.) is used extensively for golf courses throughout the transition zone, and to a more limited extent in the southeastern United States. The lower input requirements of zoysiagrass compared with other available turfgrasses help drive its popularity. Zoysiagrasses vary in shade tolerance. In general, *Z. matrella* cultivars, which are generally finer and more dense, as well as 'Emerald' zoysia (*Z. japonica* x *Z. pacifica*), are considered more shade-tolerant than *Z. japonica* cultivars, including 'Meyer.' This is problematic for golf course superintendents who may have a considerable amount of turf under moderate to heavy shade. Although 'Meyer' is hardy in the transition zone, *Z. matrella* cultivars and 'Emerald' often suffer winter injury and are used only in the southernmost part of this region.

Based on growth from vegetative plugs, previous research has shown that progeny arising from crosses of 'Emerald' x 'Meyer' have improved shade tolerance. In addition, research at Kansas State University has demonstrated these experimental grasses have freezing tolerance comparable to 'Meyer.'

Methods

The study was conducted at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. (Figure 1). Plots measured 61cm × 61cm and were arranged in a randomized complete block design with five replications. Treatment design was a single factor (zoysiagrass genotype). Plots were planted on the north side of a mature line of silver maple (*Acer saccharinum*) trees.

The genotypes selected for this study were 'Zorro' (*Zoysia matrella*), 'Emerald,' 'Meyer,' Chinese common, and experimental progeny 5313-46 ('Zorro' x 'Meyer'), 5321-18 ('Emerald' x 'Meyer'), and 5321-45 ('Emerald' x 'Meyer').

Zoysiagrass was established in the greenhouse from plugs and planted in the field on June 10, 2010. Plots were fertilized at planting with 1 lb N/1,000 ft^2 using an 18-20-0 N-P-K fertilizer. Plots were maintained at 2.75 in. using a rotary mower, and received 1 lb N/1,000 ft^2/yr. Irrigation was applied to prevent severe stress.

Data collected included shoot elongation rate (mm/day), tiller density (tillers/m^2), and leaf width (mm). Visual ratings for genetic color, density, quality, fall color retention, and spring greenup were taken monthly on a 1 to 9 scale (1 = poor, 6 = minimal acceptable, 9 = superior). Beginning in 2011, a lighted camera box was used to evaluate percentage green cover.

Results

Visual quality ratings declined from 2010 to 2011 (Table 1). In 2010, all genotypes maintained acceptable quality, but in 2011, 'Zorro' never achieved minimal acceptable quality, probably because it experienced some winter injury and never fully recovered. Genotype 5321-18 was the only genotype with a quality rating over 8.0 in 2011.

Overall, tiller counts decreased from 2010 to 2011 and varied widely among genotypes in both years (Figure 2). Genotype 5321-18 was superior to all other genotypes in 2011; even though it exhibited a decrease in tiller counts in 2011 compared with 2010, the decrease was not as great as observed from the other genotypes. The superior shade tolerance of *Z. matrella* cultivars and 'Emerald' reported in the literature may be due in part to the fact that they have greater density (more tillers per unit area) than most *Z. japonica* cultivars. Although tiller numbers decline in *Z. matrella* cultivars, they continue to have more tillers over time due to their greater initial number.

Zoysiagrass green cover percentage was evaluated in 2011 (Figure 3). 'Zorro,' 'Emerald,' and 5313-46 were slowest to green up in the spring and to attain 50% green cover. This result may be attributed to winterkill from which grasses had to recover. These three genotypes also retained green color longer in autumn than the others, which is often associated with greater winter injury. Shade greatly slows recovery, because the plant is not able to photosynthesize at the level it does in full sun.

Genotype 5321-18 exhibited the greatest green cover in 2011 (Figure 3). It also exhibited a more rapid spring greenup and entered dormancy at a more rapid rate than the other genotypes. Entering dormancy prior to lethal temperatures results in the turf being less vulnerable to winter injury. As a result, spring greenup may occur more rapidly, the turf may achieve greater quality, and green coverage may be greater than the other genotypes; however, these characteristics must not overshadow the fact that this turf is able to perform at this level under dense shade.

Zoysiagrass turf is greatly affected by dense tree shade, but tolerance is improving. Genotype 5321-18 exhibited superior turfgrass quality, tiller counts, and green cover compared with the other genotypes, including 'Meyer.' Continued breeding efforts to select for shade and cold tolerance will continue to result in improved zoysiagrass genotypes.

Table 1. Mean zoysiagrass visual quality ratings for 2010 and 2011

	2010				2011			
Genotype	June	July	August	September	June	July	August	September
	Quality rating (1–9[1])							
Common	7.0	6.8	6.8	6.6	6.6	6.0	6.6	5.8
Emerald	8.4	7.2	7.6	8.0	4.0	5.2	6.4	5.8
Meyer	7.8	7.4	7.8	7.2	7.0	6.6	7.0	6.8
Zorro	8.8	7.8	8.0	8.0	3.4	4.6	5.8	5.6
5321-45[2]	7.6	6.8	7.4	7.2	6.2	7.0	7.6	7.0
5321-18	8.6	8.0	8.0	8.2	8.2	7.8	8.2	7.8
5313-46	8.2	7.2	7.2	6.8	4.8	5.6	6.0	6.2
LSD ($P < 0.05$)	0.7[3]	0.7	0.5	0.7	1.3	1.3	1.3	1.1

[1] Visual turfgrass quality rated on a 1 to 9 scale (1 = poor, 6 = minimal acceptable, 9 = superior).

[2] Grasses with the 5321 prefix are crosses between 'Emerald' and 'Meyer.' 5313-46 is progeny from 'Zorro' and 'Meyer.'

[3] To determine if one grass is statistically different from another, subtract the LSD value from the mean with the higher value. If that number is higher than the mean of the lower valued turfgrass, they are statistically different.

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

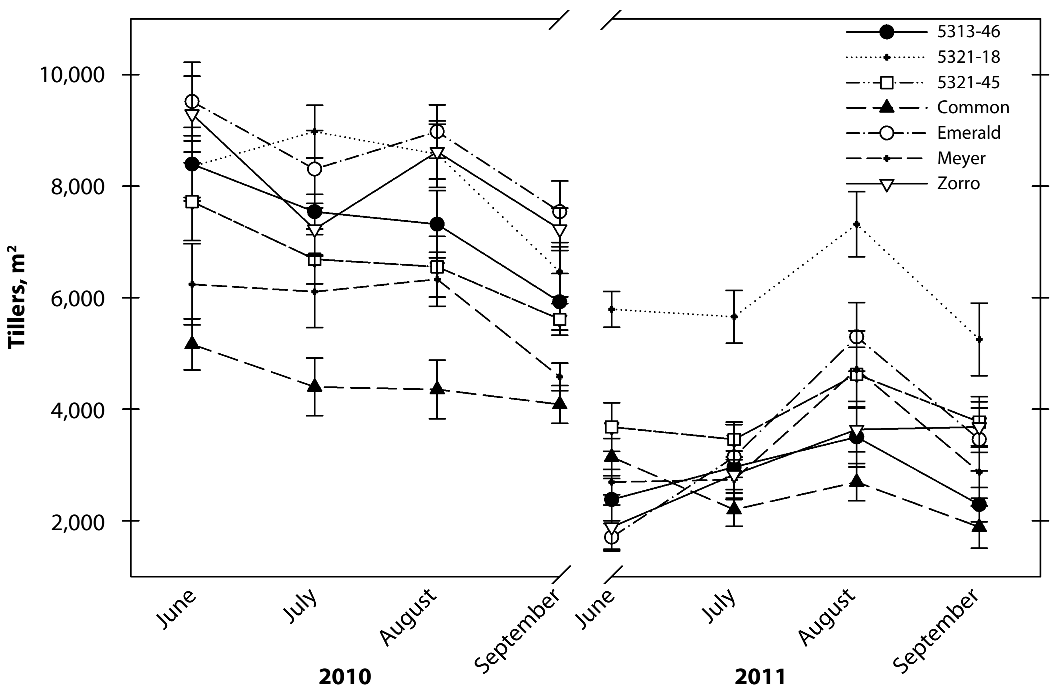

Figure 2. Mean zoysiagrass tiller counts for 2010 and 2011. Bars represent standard error of 5%. Grasses with the 5321 prefix are 'Emerald' x 'Meyer;' 5313-46 is 'Zorro' x 'Meyer.'

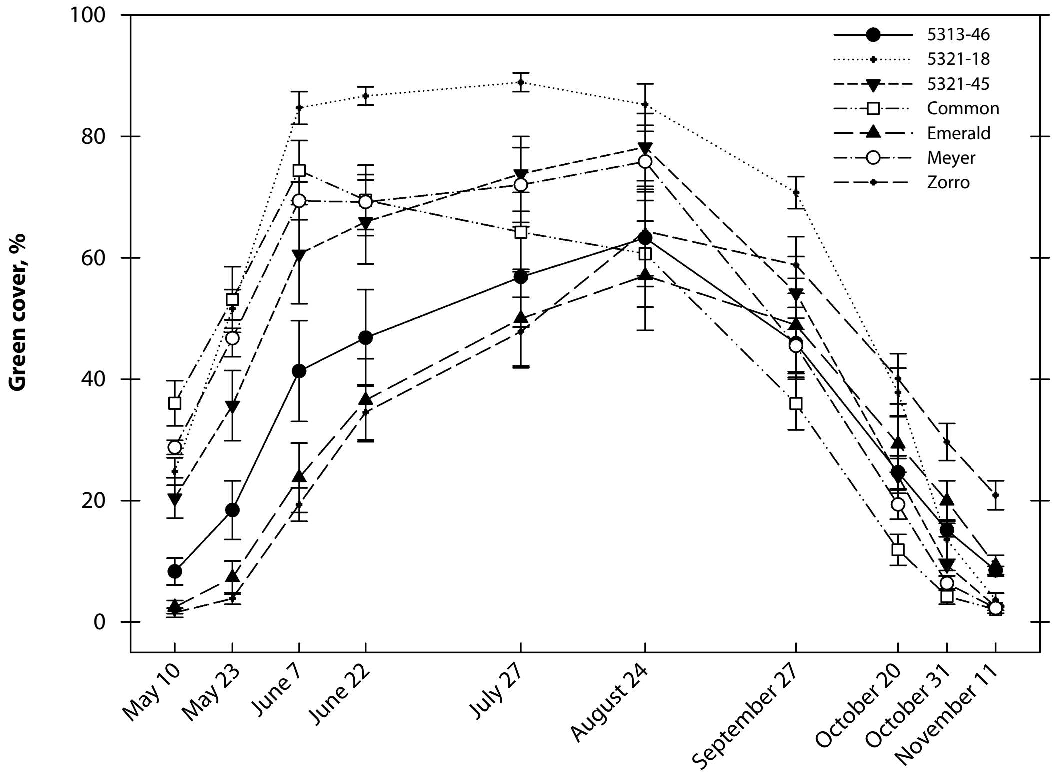

Figure 3. Mean zoysiagrass percentage green cover for 2011. Bars represent standard error of 5%. Grasses with the 5321 prefix are 'Emerald' x 'Meyer;' 5313-46 is 'Zorro' x 'Meyer.'

Recovery of an Experimental Zoysiagrass After Sod Harvest

Objectives: 1) Determine the importance of preemergence herbicide application on the recovery of DALZ 0102 zoysiagrass after harvesting sod, and 2) determine the effects of different nitrogen fertilization regimens on the recovery of DALZ 0102 zoysiagrass after harvesting sod.

Investigators: Cole Thompson and Jack Fry

Introduction

DALZ 0102 zoysiagrass (*Zoysia japonica* Steud.) is an experimental zoysia that exhibits good freezing tolerance, quality, and resistance to damaging bluegrass billbug (*Sphenophorus parvulus* Gyllenhal) infestations. DALZ 0102 will be jointly released by Kansas State University and Texas A&M in the near future, so data pertaining to propagation of DALZ 0102 is of particular interest.

Methods

This study was conducted in 2011 on established DALZ 0102 zoysiagrass at Rocky Ford Turfgrass Research Center in Manhattan, Kan. Turf was stripped to a depth of 1 in. from a 9 ft × 18 ft area on June 8, 2011, with a sod cutter (Ryan Jr. Sod Cutter, Schiller Grounds Care, Inc., Johnson Creek, WI). The study was arranged with a split-plot treatment structure in a randomized complete block design. Whole plots measured 3 ft × 9 ft and were either treated with the preemergence herbicide simazine (Princep; Syngenta Corp., Wilmington, Del.) on June 13, 2011, or left untreated. Fertility was the split-plot treatment factor. Individual subplots measured 3 ft × 3 ft and treatments were 1) untreated, 2) 1 lb N/1,000 ft^2 every other week, and 3) 1 lb N/1,000 ft^2 monthly. Nitrogen was provided from urea (46-0-0 N-P-K) from June 10 through September 1, 2011, until 7 lb and 4 lb N/1,000 ft^2 had been applied to biweekly and monthly N treatment subplots, respectively.

Data Collection

Percentage cover of turf and summer annual weeds was monitored every other week from June 10 through September 28, 2011. Percentage cover data was taken as a visual estimate of each plot covered by DALZ 0102 zoysiagrass and summer annual weeds.

Data Analysis

All data were subject to analysis of variance using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, NC). Tukey's Honestly Significant Difference (HSD) was used to detect treatment differences (α_{FER}=0.05) to protect from inflation of Type I error during pairwise comparisons.

Preliminary Results

Zoysiagrass Recovery

Turfgrass shoots began to emerge on June 10, two days after removing sod. Zoysiagrass in Princep-treated whole plots gradually recovered throughout the season and averaged greater than 50% cover by August 3. By September 28, zoysiagrass in Princep-treated plots averaged 92% cover. Untreated whole plots averaged 17% cover on July 8. Weed pressure was very high throughout the remainder of the growing season, and untreated whole plots became impossible to rate. Fertility treatments did not have an effect on zoysiagrass recovery.

Weed Cover

Summer annual weeds including smooth crabgrass (*Digitaria ischaemum*), goosegrass (*Eleusine indica*), and prostrate spurge (*Euphorbia supine*) began invading research plots on June 23. Whole plots receiving Princep application never averaged more than 4% weed cover in 2011 and had significantly less weed cover than untreated whole plots on 8 of 9 rating dates. Untreated whole plots averaged 98% weed cover by July 21 (Figure 1). Weeds in untreated whole plots remained for the duration of the growing season (Figures 2 and 3). Fertility treatments did not affect weed cover.

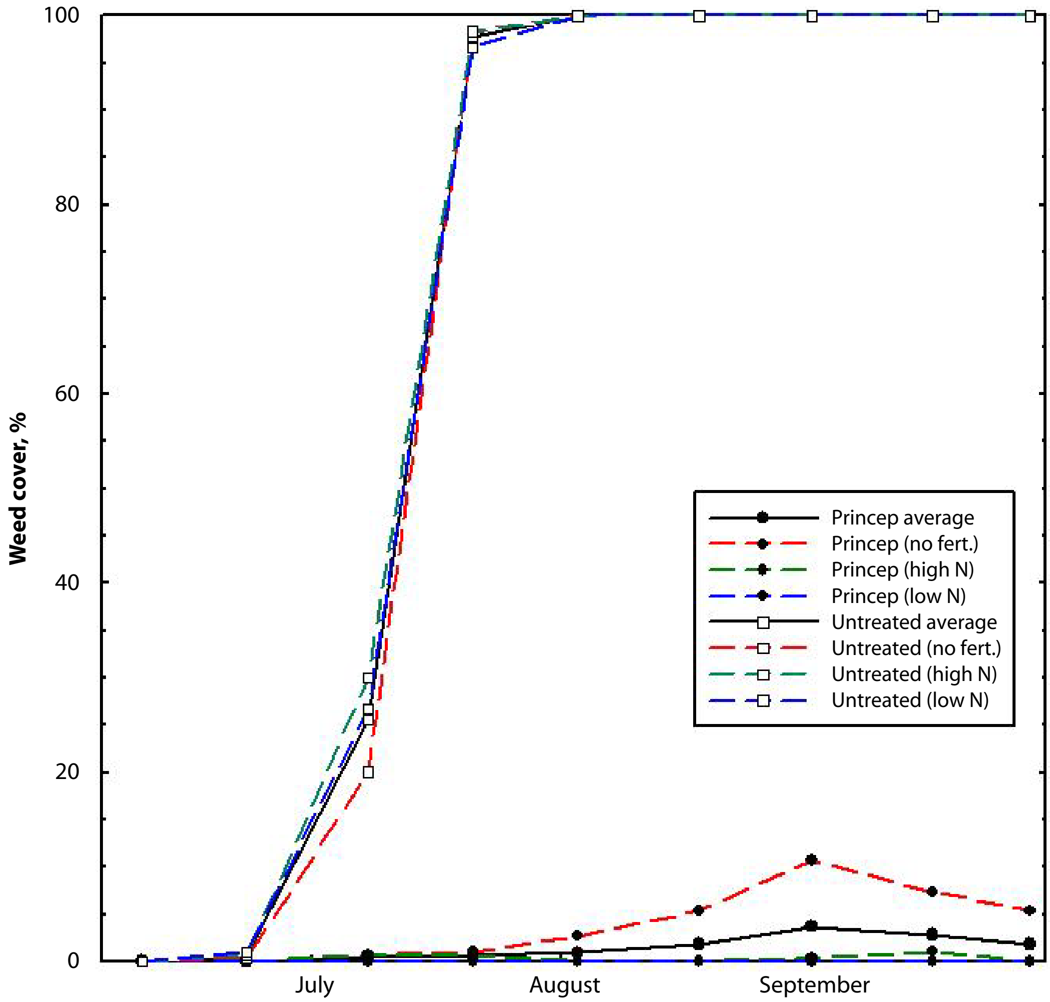

Figure 1. Effect of treatments on weed cover in 2011. Princep average and untreated average represent whole-plot treatment factors, and other lines represent split-plot treatment factors.

Figure 2. Research area on June 13, 2011, 5 days after harvesting sod.

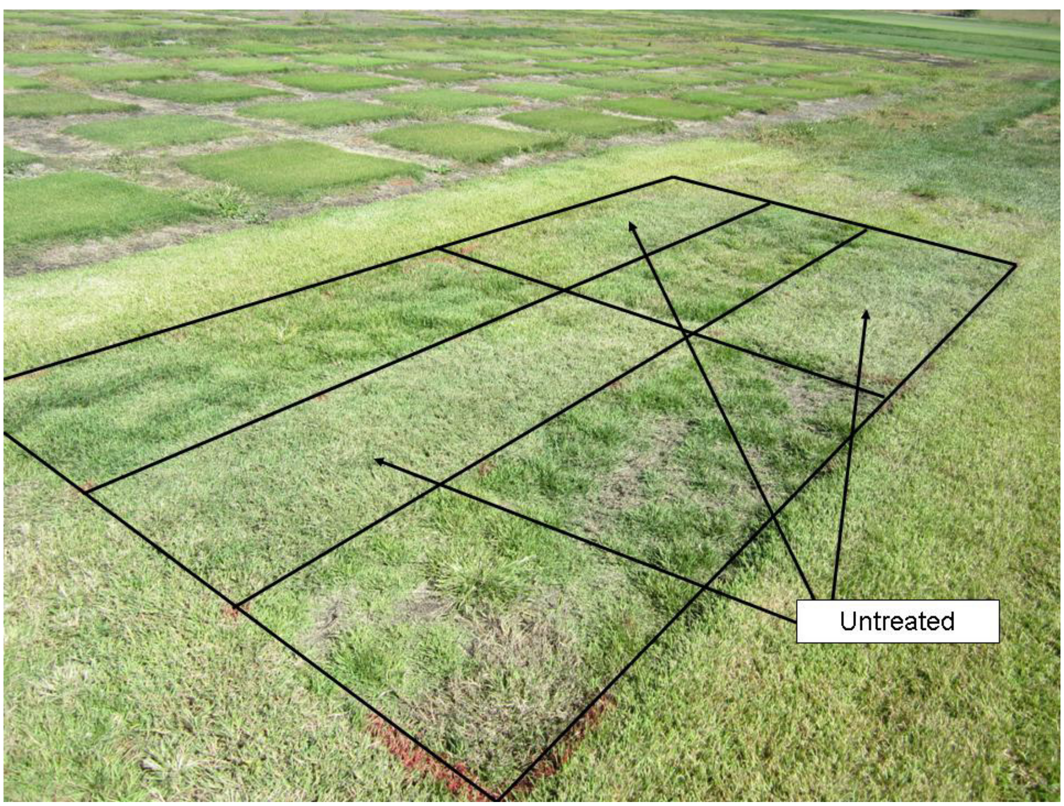

Figure 3. Zoysiagrass and weed cover on September 28, 2011. Note the complete cover of summer annual weeds in untreated plots compared with the noticeable lack of weeds in Princep-treated whole plots.

Establishment of Buffalograss from Vegetative Plugs After Short-Term Storage on Turf Reinforcement Mats

Objective: Evaluate the effect of storage time on vegetative buffalograss establishment from plugs on turf reinforcement mats.

Investigators: Tony Goldsby and Jack Fry

Sponsor: Kansas Turfgrass Foundation

Introduction

Buffalograss can be established in turf reinforcement mats (TRMs) prior to home installation. Turf reinforcement mats help prevent erosion from high-volume runoff events and encroachment of weeds. Several warm-season grass species have been successfully established using kenaf-based organic fiber mats as a growing medium, but information on establishment of buffalograss in TRMs is scarce. Additionally, little information is available regarding the impact that temporary storage of TRMs containing vegetative plugs may have on establishment.

Methods

This experiment was conducted using both the Rocky Ford Research Turfgrass Research Center in Manhattan, Kan., and the Olathe Horticultural Research Center, Olathe, Kan. 'Legacy' buffalograss plugs were evaluated for establishment from vegetative plugs on TRM after storage for: 1) 0 days, 2) 7 days, 3) 14 days, or 4) 21 days. Grasses were established as 2-in.-diameter vegetative plugs in TRMs in Manhattan on June 2, 2011. A slit was cut in the mat and the base of the plug was inserted into the slit. The mats were laid over a layer of black plastic in the field during a three-week establishment period. Irrigation was applied three times daily for 5 min to ensure mats remained wet and to prevent turfgrass stress. Each 1 m × 1 m mat contained nine evenly spaced plugs of 'Legacy' buffalograss.

After the three-week establishment period elapsed, the control treatment was planted into the study area in Olathe on June 24, 2011. Mats from other storage times were lifted from the full-sun plot in the field, rolled up, and placed under dense shade. Mats were unrolled every other day and moistened by hand-watering.

After the respective storage time for each treatment elapsed, the mats were transported to Olathe, unrolled, and planted in the study area. Planting dates for respective treatments were: July 1, 2011, for 7 days of storage; July 7, 2011, for 14 days of storage; and July 14, 2011, for 21 days of storage. Irrigation was applied as needed to prevent plug stress during establishment. Starter fertilizer (18-46-0 N-P-K) was used to apply 1 lb P per 1,000 ft^2 to all treatments at their respective time of planting. All plots received an additional 1 lb N/1,000 ft^2 from urea 46-0-0 in late August. Irrigation was applied as necessary to prevent water stress from occurring during the study, and buffalograss coverage was rated monthly on a 0 to 100% scale.

Treatments were arranged in a randomized complete block design with three replicates. Data were subjected to analysis of variance and means separated using Fisher's Protected LSD ($P < 0.05$).

Results

Buffalograss coverage was lower for 14- and 21-day storage treatments than the control or 7-day treatment (Figure 1). Buffalograss planted in the control treatment and 7-day treatment exhibited similar levels of coverage (approximately 75%) by the end of the growing season (Figures 2 and 3). Maximum coverage for buffalograss stored on TRMs for 14 days before planting was around 26% (Figure 4). For the 21-day storage treatment, only 1 replication exhibited any establishment (approximately 5%) by the end of the growing season (Figure 5). Overall, results suggest it may be possible to store buffalograss established in TRMs for up to seven days with little or no impact on establishment. Establishment beyond the seven-day storage time is possible but may result in little or no establishment of turfgrass plugs by the end of the first growing season. In addition, storage in an artificially cooled environment would also likely prolong potential storage time and should be investigated.

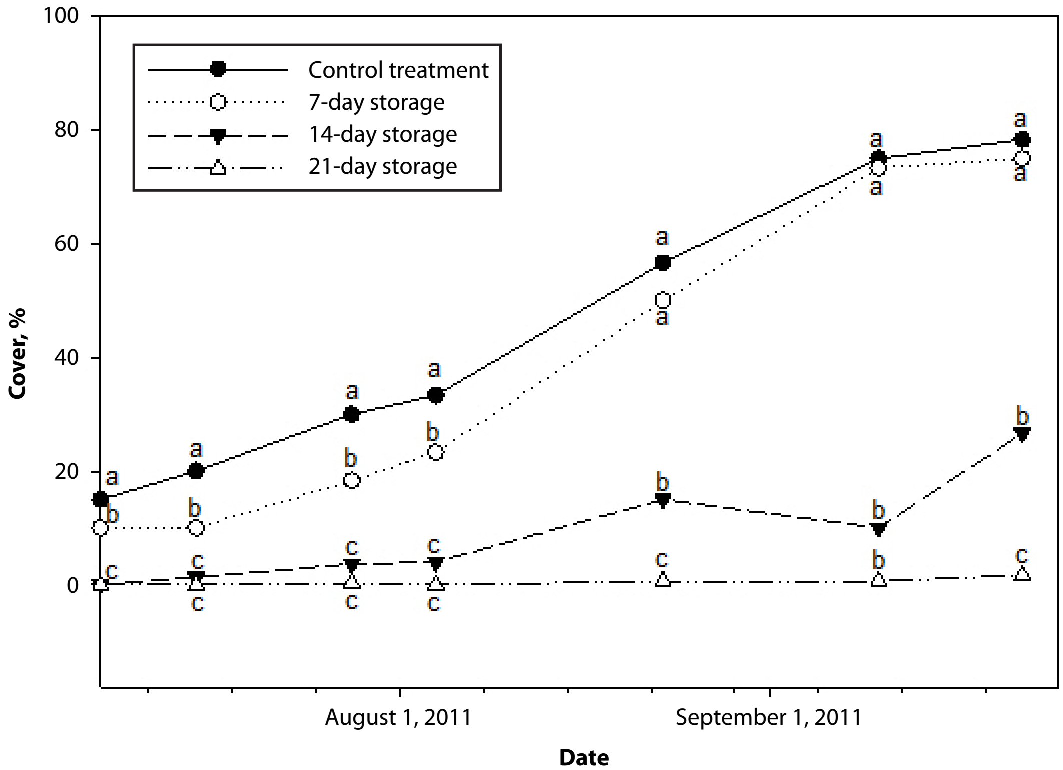

Figure 1. Coverage of buffalograss planted on TRMs, allowed to established in full sun for three weeks, and stored for 7, 14, or 21 days in dense shade before planting. Means (points) labeled with the same letter on a rating date are not significantly different ($P < 0.05$).

Figure 2. 'Legacy' Buffalograss treatment that received no storage prior to establishment. This photo was taken September 22, 2011, after planting on mat June 24, 2011.

Figure 3. 'Legacy' buffalograss stored for 7 days on TRM prior to establishment. This photo was taken September 22, 2011, after planting on mat July 1, 2011.

Figure 4. 'Legacy' buffalograss stored for 14 days on TRM prior to establishment. This photo was taken September 22, 2011, after planting on mat July 8, 2011.

Figure 5. 'Legacy' buffalograss stored for 21 days on TRM prior to establishment. This photo was taken September 22, 2011, after planting on mat July 15, 2011.

Evaluation of Turf Reinforcement Mats for Vegetative Establishment of Buffalograss and Zoysiagrass

Objective:	Evaluate growth of 'Legacy' buffalograss and DALZ 0102 zoysiagrass growth and weed incidence after planting plugs in turf reinforcement mats.
Investigators:	Tony Goldsby and Jack Fry
Sponsor:	Kansas Turfgrass Foundation

Introduction

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

Methods

This study was conducted at Rocky Ford Research Turfgrass Research Center in Manhattan, Kan. Two warm-season grasses, 'Legacy' buffalograss and DALZ 0102 zoysiagrass, were evaluated in separate studies for establishment from vegetative plugs with: 1) TRM, 2) an application of oxadiazon (Ronstar, Bayer Crop Science, Triangle Park, N.C.) just after planting, and 3) no treatment. Grasses were established as 2-in.-diameter vegetative plugs in TRMs in July 2010 and June 2011. A slit was cut in the mat and the base of the plug was inserted into the slit. The mats were laid over a layer of black plastic in the field during a three-week establishment period. Irrigation was applied three times daily for 5 min to ensure mats remained wet and to prevent plug stress. Each 5 ft × 5 ft mat contained 16 evenly spaced plugs of the respective turfgrass species.

Three weeks after planting plugs, mats were lifted from the plastic and laid in an adjacent study area. Ronstar and untreated treatments were subsequently planted in 5 ft × 5 ft plots containing 16 evenly spaced plugs. For these treatments, plugs were planted directly into the soil. Plots assigned to Ronstar treatments received a single application by shaker bottle at a rate of 4 lb ai/a. Plots were arranged in a randomized complete block design with three replicates. Irrigation was applied as needed to prevent stress during establishment. Starter fertilizer was applied to all treatments at the time of planting. Irrigation was applied as necessary to prevent stress.

Plots were arranged in a randomized complete block design with three replicates. Percentage coverage of desirable species and weeds were taken monthly in each study, and data were subjected to analysis of variance. Means were separated using Fisher's Protected LSD ($P < 0.05$).

Results

Zoysiagrass Establishment and Weed Control

Coverage ratings for zoysiagrass established on TRM were significantly lower compared with plots treated with Ronstar or with untreated plots in 2010 and 2011 (Figure 1). The use of TRM for establishment of DALZ 0102 zoysiagrass from plugs was not practical due to its growth habit. DALZ 0102 plugs produced stolons, but they grew below the TRM, did not receive photosynthetically active radiation, and appeared etiolated. This resulted in low coverage ratings, because these stolons were not visible on the surface. In 2010, weed coverage in untreated plots was significantly higher than in plots treated with Ronstar or the TRMs (Figure 2). In 2011, weed suppression provided by TRMs was superior to that provided by Ronstar, and both were superior to untreated plots. Prostrate spurge provided the greatest amount of pressure when comparing all recorded weed species (Figure 3). Both TRM and Ronstar suppressed weeds adequately; therefore, use of one or the other should be determined by cost and site specifications.

Buffalograss Establishment and Weed Control

Buffalograss coverage was similar among all treatments for eight weeks after planting (Figures 4 and 5). In 2010, plots treated with Ronstar or established on TRMs had significantly higher rates of coverage than untreated plots. Plots receiving Ronstar or TRMs averaged 93% plot coverage by the end of the 2010 growing season (Figure 4). This was significantly higher than the 78% plot coverage in untreated plots. In 2011, turfgrass coverage was similar among all treatments on all rating dates with the exception of July 13, 2011, when plots treated with Ronstar and untreated plots had greater coverage than the TRM. Plots receiving Ronstar or TRM averaged 65% plot coverage by the end of the 2011 growing season. Weed coverage in buffalograss TRM plots was superior to plots treated with Ronstar or untreated plots between July 17 and September 17, 2010. Likewise, the same differentiation in weed coverage occurred among all treatments between August 17 and September 30, 2011 (Figure 6). Lower coverage in untreated plots can be attributed to more competition for water and nutrients from presence of weeds. Total cost for 'Legacy' buffalograss plugs is approximately \$463/1,000 ft^2 if planted on 12-in. centers. Purchasing TRM to cover the same 1,000 ft^2 area would cost approximately \$220. In contrast, cost of Ronstar for weed control at the rate used herein would be approximately \$8.61/1,000 ft^2. High product costs may force turf managers to utilize TRMs only when pesticide use is not desired or the risk of erosion is high.

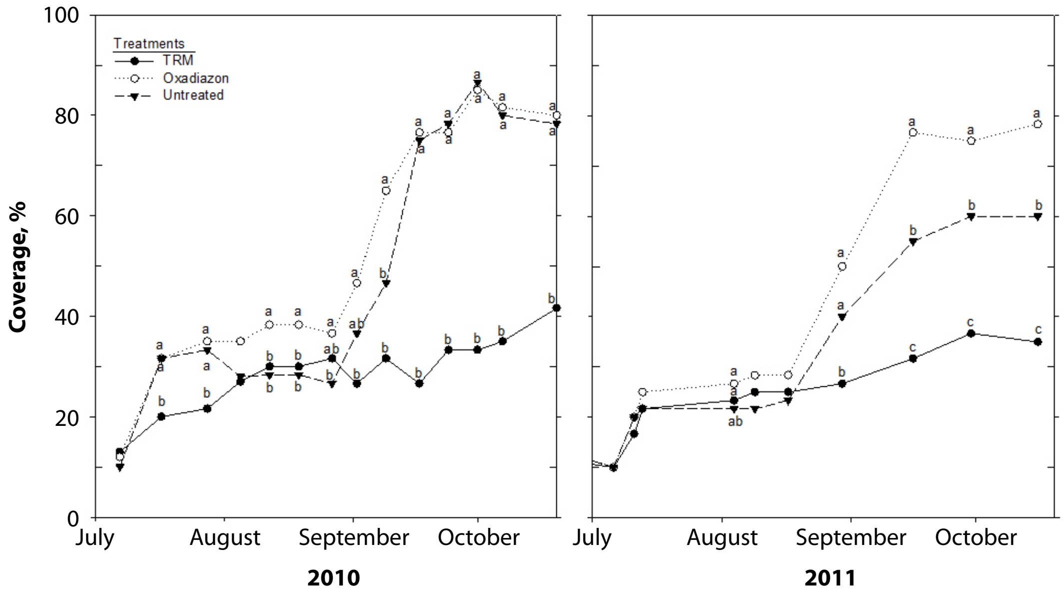

Figure 1. Weekly coverage of DALZ 0102 zoysiagrass at Manhattan, Kan., in 2010 and 2011. Means (points) labeled with the same letter on a rating date are not significantly different ($P < 0.05$).

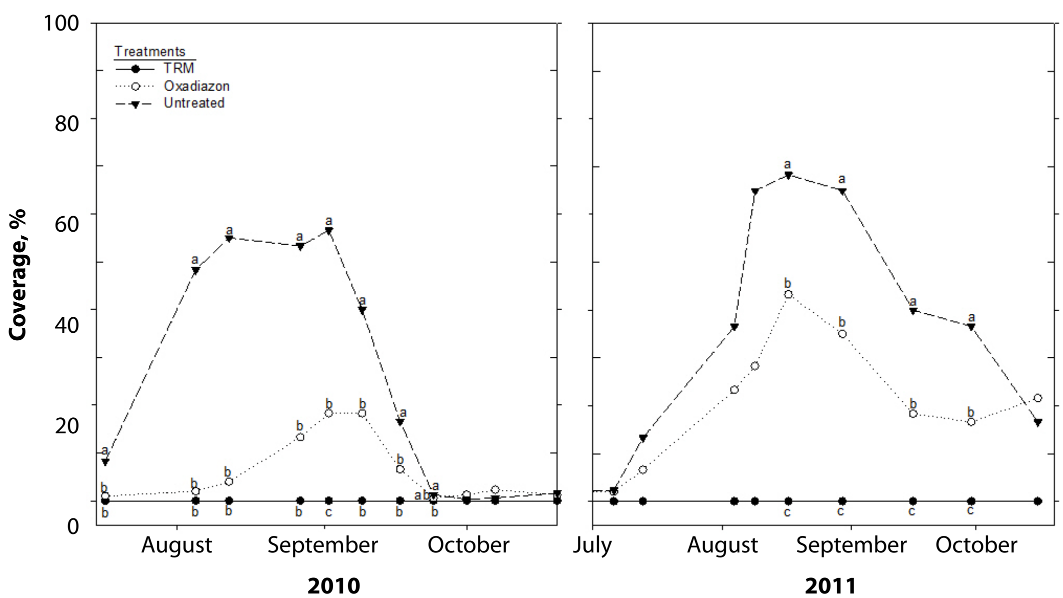

Figure 2. Weekly coverage of weeds in the zoysiagrass experiment at Manhattan, Kan., in 2010 and 2011. Means (points) labeled with the same letter on a rating date are not significantly different ($P < 0.05$).

Figure 3. Spotted Spurge (*Euphorbia maculate* L.) encroaching in an untreated DALZ 0102 zoysiagrass plot.

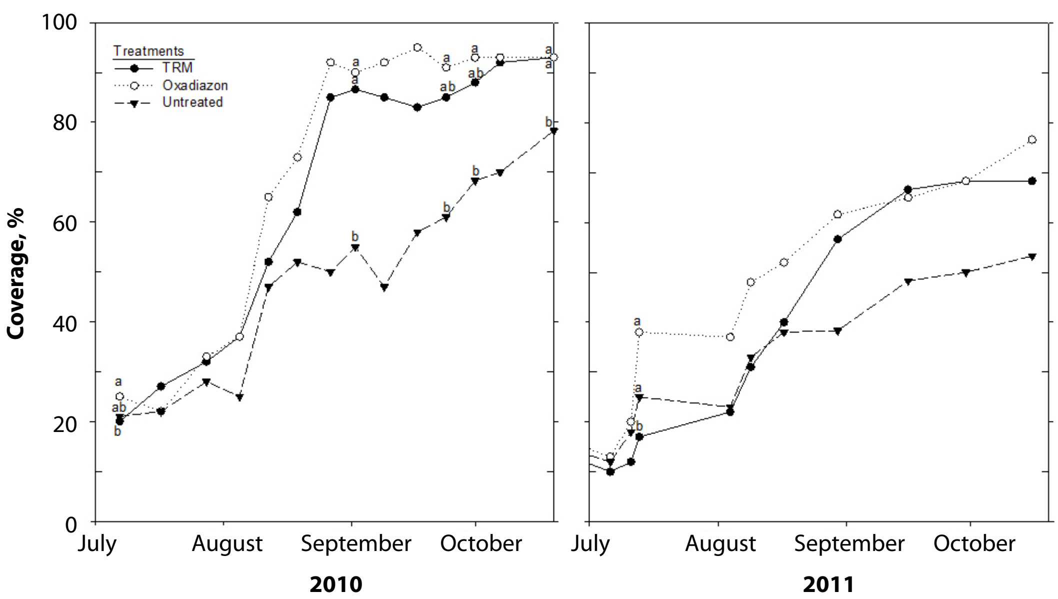

Figure 4. Weekly coverage of buffalograss at Manhattan, Kan., in 2010 and 2011. Means (points) labeled with the same letter on a rating date are not significantly different ($P < 0.05$).

Figure 5. 'Legacy' buffalograss successfully established on a turf reinforcement mat.

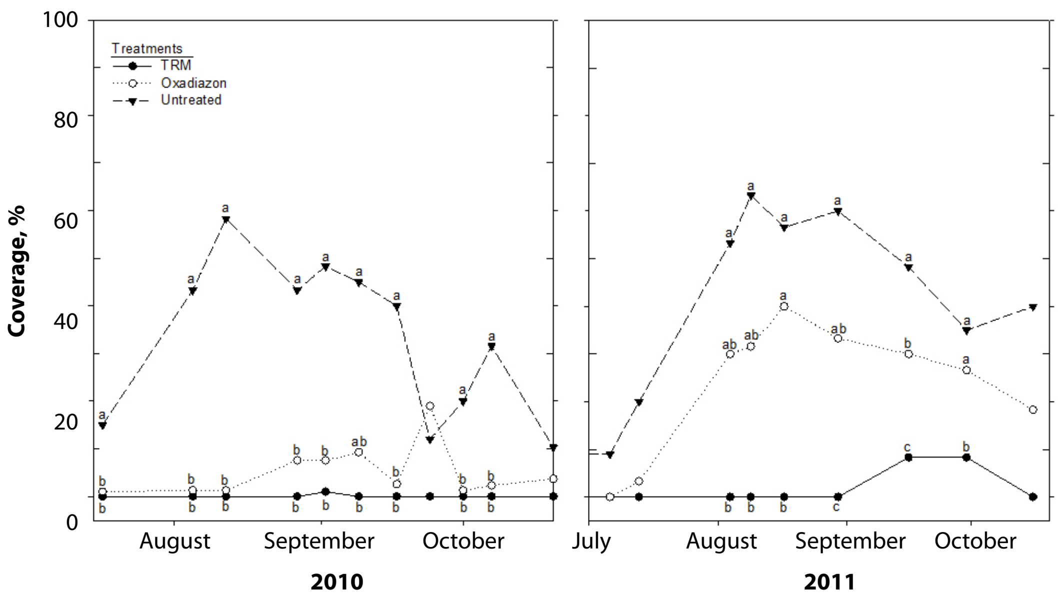

Figure 6. Weekly coverage of weeds in the buffalograss experiment at Manhattan, Kan., in 2010 and 2011. Means (points) labeled with the same letter on a rating date are not significantly different (*P* < 0.05).

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

Objective: Evaluate the potential for hyperspectral radiometry to accurately predict green leaf area index of Kentucky bluegrass

Investigators: Tony Goldsby and Dale Bremer

Introduction

Green leaf area index (LAI) provides an important measure of the photosynthetic capacity of a canopy. Green LAI can be determined through several methods in turfgrass, but typical sampling methods are destructive and time-consuming; for example, destructive sampling requires large research plots to allow for multiple sampling dates over a growing season. Using canopy spectral reflectance to predict green LAI in turfgrass has been suggested as an alternative to destructive sampling because research in agronomic crops has indicated that certain regions of the electromagnetic spectrum are good predictors of LAI.

Hyperspectral radiometry measures the spectral reflectance of plant canopies in approximately 2,000 narrow wavelength bands. These small bands result in a spectral signature with greater resolution than its predecessor, multispectral radiometry, which measures spectral reflectance in substantially wider bands than hyperspectral radiometry. Previous research indicated little success in estimating green LAI in turfgrass with multispectral radiometry (see "Evaluation of Turfgrass Quality and Green Leaf Area Index and Aboveground Biomass with Multispectral Radiometry," 2007 K-State Turfgrass Research, Report of Progress 981, p. 6); however, because of its greater resolution, hyperspectral radiometry may provide a means of discerning green LAI with spectral reflectance, and thus provide an alternate method to destructive sampling in turf.

A non-destructive, rapid estimation of LAI would be useful for both turfgrass researchers and breeders. The objective of our study was to evaluate whether hyperspectral radiometry can be utilized to accurately predict LAI of Kentucky bluegrass (*Poa Pratensis*).

Methods

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

Monthly hyperspectral measurements were acquired with a FieldSpec 3 Portable Spectoradiometer manufactured by ASD systems (Boulder, Colo.). Multiple radiometer scans were obtained from each plot, then averaged (Figure 2). Direct measurements of LAI were obtained immediately after radiometer measurements by destructively harvesting two random areas (7 $in.^2$ each using a 3-in.-diameter PVC ring) of the turfgrass canopy. The grass samples were then measured with an image analysis system (WinRHIZO, Regent Instruments, Quebec City, Canada) to calculate total leaf area. In total, data were collected on four dates in 2010 and seven dates in 2011. Data were analyzed using Partial Least Squares Regression (PLSR) in the GRAMS (Thermo Fisher Scientific) chemometrics software package. PLSR is a statistical technique particularly suited for use when predictor variables (e.g., 2,400 wavelengths) exceed response variables (nine treatments), as in this study. Standard regression methods will fail under these circumstances. PLSR models were created for each of the individual sampling dates for this study.

Preliminary Results

For the 2010 growing season, the PLSR method was able to create a viable model for only one sampling date, June 30, 2010 ($R^2 = 0.57$) (Figure 3); the R^2 value is a measure of how well one variable (spectra) predicts another variable (LAI). An $R^2 = 1$ would indicate that spectral data are highly accurate in prediction of the variable LAI. In 2010, no viable models resulted from data collected on the other three sampling dates, as denoted by the red arrows in Figure 3.

For 2011, viable PLSR models were developed for four of the seven sampling dates. The first was May 17, in which the model had $R^2 = 0.85$. This date yielded the strongest model of all sampling dates in the entire study (Figure 4). The other dates in 2011 that resulted in viable models included June 30 ($R^2 = 0.73$), July 17 ($R^2 = 0.52$), and August 24 ($R^2 = 0.79$).

Another piece of information provided by the PLSR method is the factor weights/loadings, which provides insight into the wavelengths that have the greatest influence on your prediction model. Factor weights for the models created in this study were consistently loading the highest, around 761 nm. Previous research has shown that chlorophyll pigments have a strong influence on the visible portions of the spectrum (400–700 nm). Additionally, the “red edge” (680–800 nm) has been reported to be highly correlated with chlorophyll concentrations in plants. Factor weights and loadings obtained from these models suggest the “red edge” is indeed highly related to LAI. The next step in analyzing these data will be an attempt to increase the fit of the models for the individual sampling dates. This procedure includes extracting regions (e.g., a 10–20 nm band surrounding 761 nm) with the highest factor weights and creating new PLSR models with these narrower spectral regions.

Results of this study suggest that spectral radiometry has the potential to accurately predict LAI, but accuracy varied over the course of the growing season, with some measurements on some dates yielding stronger models than others. Therefore, finding one model robust enough to accurately predict LAI from spectra at any point during the growing season may be unrealistic. Several models may be necessary to account for the change in canopy dynamics that occurs throughout a growing season.

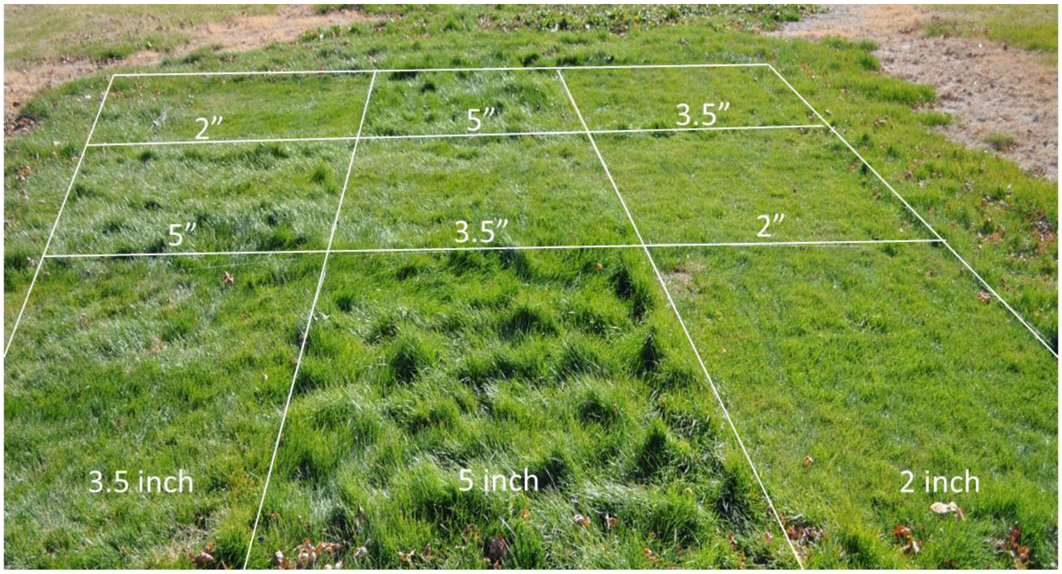

Figure 1. Treatments for the study included 2 in., 3.5 in., and 5 in.

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

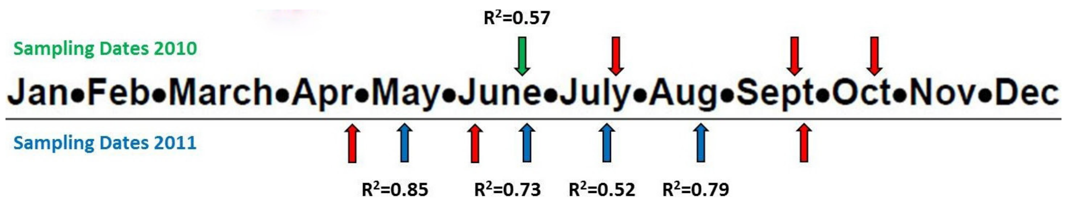

Figure 3. Partial Least Squares Regression models were created for each sampling period. Models for 2010 are indicated with a green arrow and respective R^2 value. Models for 2011 are indicated with a blue arrow and respective R^2 value. Months with a red arrow had very poor models.

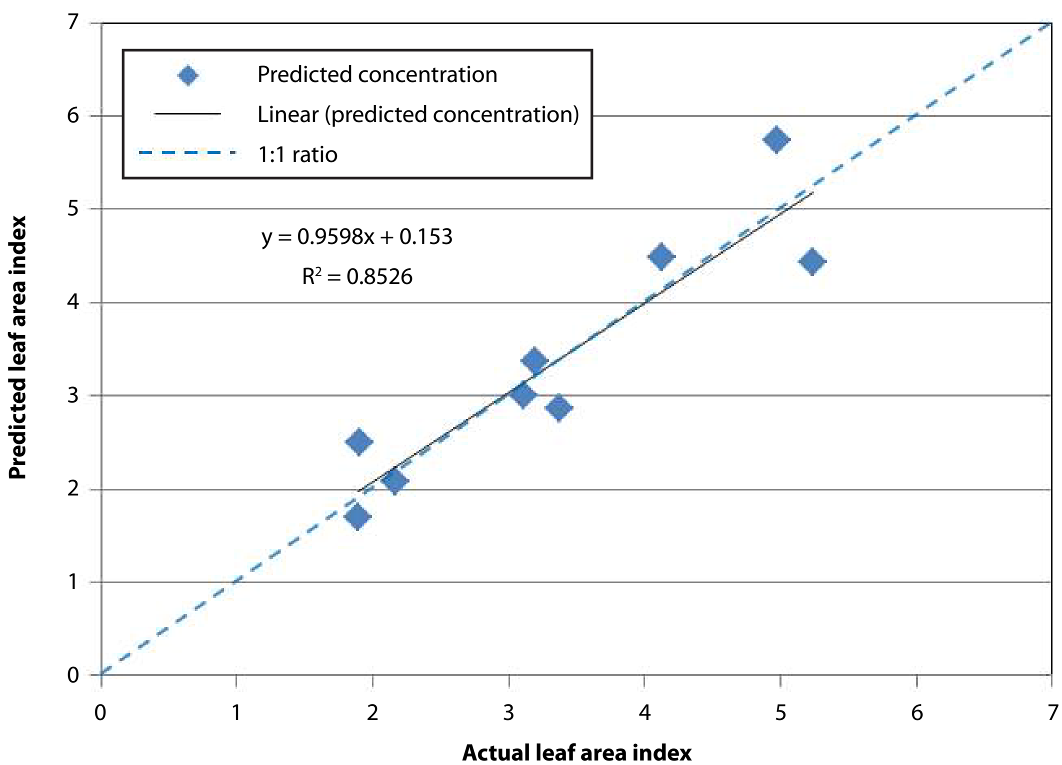

Figure 4. Partial Least Squares Regression model for May 17, 2011, sampling date.

Turf and Groundcover Evaluation

Objective: Evaluate turfgrasses and groundcovers for shady conditions under trees.

Investigators: Rodney St. John and Nadia DeMuro

Sponsor: Kansas Turfgrass Foundation

Introduction

Maintaining high-quality turfgrass under trees is difficult. Sometimes the shade and root competition for nutrients and water can be so severe that no turfgrass will grow under trees. The objectives of this study were to evaluate different shade-tolerant turfgrasses and different groundcovers that could replace turfgrass in shady-tree areas.

Methods

Twenty-seven different groundcovers and turfgrasses were planted in two locations, one full sun location and one full-shade location, at the Horticulture Research and Extension Center in Olathe, Kan. (Table 1). Five replicates of each were planted in each location. The groundcovers were established from seed and cuttings in the spring of 2011. All groundcovers were transferred to 3-in. pots and allowed to mature before transplanting them into the field July 20–25. The 'Bella' Kentucky bluegrass plugs were also transplanted into 3-in. pots in the spring of 2011 and transplanted into the field on July 21. Nine 3-in. pots were placed 12 in. apart into a 3 ft × 3 ft plot. The rest of the turfgrasses were seeded in place into 3 ft × 3 ft plots in the field on September 16.

The plots were irrigated frequently to promote establishment in the summer and fall of 2011 and are being irrigated to prevent dormancy during the 2012 season. Treflan preemergent herbicide and fertilizer was applied one week after planting and again on September 23, 2011, at a rate of 1 lb N/1,000 ft^2. Treflan preemergent was also applied on March 30, 2012. The plots will be evaluated for percentage cover and overall health and appearance once a month in the 2012 and following seasons.

Results

Table 2 lists the groundcovers and turfgrasses that survived the winter in each location. Many plants died in the sun trial due to sun exposure, drought, and deer grazing. Some plants died in the shade location due to drought and deer grazing. Some of the plants that were lost over the winter will be replanted in the spring of 2012. Figures 1 through 3 show two ground covers and one turfgrass from spring 2012.

Table 1. List of 27 different groundcovers and turfgrasses established in two locations at the Horticulture Research and Extension Center in Olathe, Kan.; five replications of each were planted in a full-sun location, and five replications were planted in a full-shade location

Botanical name	Common name
Ajuga reptans	Black Scallop
Ajuga reptans 'Valfredda'	Chocolate Chip Carpet Bugleweed
Alchemilla erythropoda 'Alma'	Lady's Mantle
Bergenia cordifolia	Red Beauty
Ceratostigma plumbaginoides	Dwarf plumbago, leadwort
Euonymus fortunei 'Coloratus'	Purple wintercreeper
Festuca glauca 'Festina'	Festina fescue
Hedera helix 'Gold Child'	English ivy
Hedera helix 'Thorndale'	English ivy
Lamiastrum galeobdolon	Herman's Pride Dead Nettle
Lamium maculatum	White Nancy Spotted Dead Nettle
Lysimachia nummularia 'Aurea'	Golden creeping Jenny, Moneywort
Nepeta nervosa 'Pink Cat'	Catmint
Sedum album	Coral Carpet
Sedum aureum	Golden Stonecrop
Sedum kamtschaticum	Russian Stonecrop
Sedum lydium	Stonecrop
Sedum pachyclados	Thick stem or white diamond stonecrop
Thymus	Red Creeping Thyme
Turf, *Poa pratensis* 'Bella'	Kentucky bluegrass
Turf, *Festuca arundinacea*	"No-Mow" Tall Fescue blend
Turf, *Festuca* rubra	Creeping Red Fescue
Turf, *Festuca arundinacea* and *Poa pratensis*	"Overtime" Plus tall fescue/Kentucky bluegrass mix
Turf, *Festuca arundinacea* and *Festuca* spp.	"Shade Mix" Tall and fine fescues
Turf, *Poa Pratensis* 'Yankee'	Kentucky bluegrass
Vinca minor 'Bowles'	Periwinkle

Table 2. Average number of groundcover plants per plot that survived the 2011–2012 winter and average percentage cover of turfgrasses after the winter as of April 15, 2012

Botanical name	Number of plants in shade location	Number of plants in sun location
Ajuga reptans	0.0	0.0
Ajuga reptans 'Valfredda'	0.0	0.0
Alchemilla erythropoda 'Alma'	7.4	7.4
Bergenia cordifolia	5.0	0.0
Ceratostigma plumbaginoides	7.0	0.0
Euonymus fortunei 'Coloratus'	8.8	7.8
Festuca glauca 'Festina'	8.8	7.4
Hedera helix 'Gold Child'	0.4	0.0
Hedera helix 'Thorndale'	6.0	1.0
Lamiastrum galeobdolon	8.4	6.2
Lamium maculatum	5.2	0.0
Lysimachia nummularia 'Aurea'	7.8	6.8
Nepeta nervosa 'Pink Cat'	0.0	0.0
Sedum album 'coral carpet'	8.6	1.8
Sedum aureum	8.6	3.4
Sedum kamtschaticum	9.0	9.0
Sedum lydium	3.25	1.6
Sedum pachyclados	0.2	0.0
Thymus	6.2	5.8
Turf, *Poa pratensis* 'Bella'	8.8	9.0
Turf, *Festuca arundinacea*	90%	30%
Turf, *Festuca* rubra	90%	60%
Turf, *Festuca arundinacea* and *Poa pratensis*	60%	70%
Turf, *Festuca arundinacea* and *Festuca* spp.	90%	50%
Turf, *Poa Pratensis* 'Yankee'	40%	30%
Vinca minor 'Bowles'	8.0	3.0

Figure 1. "No-Mow" fescue mix in the shade, spring 2012.

Figure 2. ***Sedum aureum*** **'Golden Stonecrop' in the shade, spring 2012.**

Figure 3. ***Sedum kamtschaticum*** **'Russian Stonecrop' in the shade, spring 2012.**

Evaluation of Zoysiagrasses in Southern Kansas

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

Investigators: Linda R. Parsons and Jack Fry

Sponsors: Kansas Turfgrass Foundation

Introduction

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

Methods

During the summer of 2009, we established 'Meyer' and eight experimental hybrids of zoysiagrass in 27 study plots, each measuring 5 ft × 5 ft, in a randomized complete block design at the John C. Pair Horticultural Center in Wichita, Kan. The experimental zoysiagrasses are progeny from crosses between *Zoysia matrella* cultivars ('Cavalier,' 'Zorro,' or the experimental type DALZ 8501) or between 'Emerald' (*Z. japonica* × *pacifica*) and *Z. japonica* (either 'Meyer' or Chinese Common). During the course of this study, we will collect information on establishment, spring greenup, quality, genetic color, leaf texture, fall color retention, percentage cover, and other measures when appropriate. We rate spring greenup, quality, genetic color, leaf texture, and fall color retention visually on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum). We rate percentage cover visually on a scale of 0% to 100%.

Results

We started the second full year of the study and the 2011 growing season by rating spring greenup. By April 28, 'Meyer,' KSUZ 0806, and KSUZ 0802 were the greenest (Table 1). When we rated percentage cover in October 2010, complete cover of the individual plots had not yet occurred; DALZ0102 and KSUZ 0802 exhibited the highest percentage cover and KSUZ 0805 and KSUZ 0806 exhibited the lowest. At the end of May 2011, cover throughout the trial had generally improved, but even though no winter injury had become apparent, 'Meyer' and KSUZ 0805 and KSUZ 0801 showed the poorest percentage cover. By the end of July 2011, all plots exhibited 90% or greater cover. We rated turf quality every month throughout the 2011 growing season. Ratings were influenced by degree of cover, weed infestation, and disease resistance as well as turf color, texture, and density. The overall best performers were KSUZ 0802, KSUZ 0807, and KSUZ 0803.

Table 1. Performance of zoysia cultivars in Wichita, 2011

Cultivar/ experimental number	Spring greenup[1]	% cover October 2010[2]	% cover March 2011	% cover July 2011	Quality May	Quality June	Quality July	Quality Aug.	Quality Sept.	Quality Average
KSUZ 0802	6.7	93.3	93.3	97.7	5.3	5.7	7.7	5.0	4.3	5.6
KSUZ 0807	4.7	83.3	93.3	98.0	4.7	6.3	7.0	5.0	4.7	5.5
KSUZ 0803	5.7	81.7	94.7	98.0	5.0	6.0	6.0	5.0	5.3	5.5
KSUZ 0805	6.3	80.0	85.0	96.0	5.0	5.0	6.7	5.0	5.3	5.4
KSUZ 0804	5.0	86.7	86.7	97.3	5.7	5.7	6.7	4.3	4.3	5.3
DALZ 0102	5.3	97.3	88.3	93.7	4.7	5.7	6.0	4.3	5.3	5.2
Meyer	7.3	86.7	83.3	96.0	4.7	5.0	6.3	5.0	5.0	5.2
KSUZ 0806	6.7	80.0	90.0	97.7	4.7	5.0	6.0	4.7	5.0	5.1
KSUZ 0801	5.7	82.7	85.0	97.3	4.7	4.7	5.7	4.3	4.7	4.8
LSD[3]	2.5	13.7	12.8	8.8	2.9	2.1	1.8	0.8	1.4	1.1

[1] Spring greenup and quality were rated visually on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum).
[2] Percentage cover was rated visually on a scale of 0% to 100%.
[3] 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.

2006 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. Tall fescue possesses a rather coarse leaf texture; it lacks stolons and has only very short rhizomes. Efforts to improve cultivar quality include selecting for finer leaf texture, a rich green color, and better sward density while maintaining good stress tolerance and disease resistance.

Methods

On September 8, 2006, we seeded 348 study plots, each measuring 5 ft × 5 ft, at the John C. Pair Horticultural Center in Wichita, Kan., with 116 tall fescue cultivars and experimental numbers in a randomized complete block design. We are maintaining fertility of the plots at 0.25 to 0.5 lb N/1,000 ft^2 per growing month. We mow plots weekly during the growing season at 2.5 in. and remove clippings. We control weeds, insects, and diseases only when they present a threat to the trial. From the time turf stands were established through May 2011, we irrigated as necessary to prevent stress.

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

Results

After the fescue stands were established in 2006, we irrigated the study through May 2011 as necessary to prevent stress. In compliance with our National Turfgrass Evaluation Program (NTEP) grant, we did not provide the test plots with supplemental water from the beginning of June 2011 through the end of August 2011; we began watering again in September 2011 to evaluate stand recovery. This report will summarize the results of our study from fall 2006 through May 2011, during which time we were providing the turf with enough supplemental water to prevent drought stress.

About six weeks after seeding the study plots in early September 2006, we rated the different fescue cultivars for establishment as measured by percentage ground cover. Our observations (Table 1) showed that by mid-October 2006, 'Plato,' 'Ky-31,' 'Braveheart' (DP 50-9407), and 'GO-1BFD' were the best established. We rated spring greenup when the overall study visually appeared to be about 50% green, which varied from year to year. We took spring greenup data on March 16, 2007; April 7, 2008; April 13, 2010; and March 31, 2011. The varieties that regularly greened up early were 'Braveheart' (DP 50-9407), 'LS 1200' (SC-1), 'Rhambler SRP' (Rhambler), and 'Shenandoah III' (SH 3).

Throughout the growing season, which usually ran from April into October, we rated the turf monthly for quality. Ratings were influenced by degree of cover, weed infestation, and disease resistance as well as turf color, texture, and density. 'Braveheart' (DP 50-9407), 'Talladega' (RP 3), 'Wolfpack II' (PST-5WMB), and 'Cochise IV' (RKCL) were the best overall performers throughout the course of the study. Over the years, we looked at turf color and texture and found that 'AST9002' (AST-2), 'Umbrella' (DP 50-9411), 'AST 7001,' 'AST9003' (AST-1), and 'Reunion' (LS-03) were the darkest green and that 'LS 1200' (SC-1), 'Cochise IV' (RKCL), 'Falcon V' (ATM), 'Firecracker LS' (MVS-MST), and 'Shenandoah III' (SH 3) had the finest texture.

We rated fall color retention in November for several years and found that 'LS 1200' (SC-1), 'MVS-1107,' 'PSG-TTRH,' 'Rhambler SRP' (Rhambler), and 'Wolfpack II' (PST-5WMB) all rated the same for best color retention. In 2007, the relatively cool, rainy days of early spring lasted well into summer and were abruptly followed by a period of hot, dry weather. As a result, some of the fescue plots began showing signs of brown patch. We rated the turf for resistance to the disease and found that 'Ky-31,' 'Braveheart' (DP 50-9407), 'Bullseye,' 'Finelawn Xpress' (RP 2), 'Firenza,' 'Talladega' (RP 3), 'Turbo RZ' (Burl-TF8), and 'Van Gogh' (LTP-RK2) fared the best.

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

Table 1. Performance of tall fescue cultivars in Wichita, 2006–2011[1]

Cultivar/ experimental number[2]	% estab.	Greenup	Genetic color	Leaf texture	Fall color retention	Brown patch	Quality								
							March	April	May	June	July	Aug.	Sept.	Oct.	Avg.
Braveheart (DP 50-9407)	81.7	5.3	7.3	5.8	5.3	8.3	6.0	5.3	5.6	5.8	6.1	6.3	5.9	5.3	5.6
Talladega (RP 3)*	48.3	4.9	6.0	5.8	4.8	8.3	4.0	5.3	5.8	5.9	5.8	6.0	5.8	5.6	5.6
Wolfpack II (PST-5WMB)*	56.7	5.2	5.9	6.2	5.5	7.7	4.7	5.5	5.7	5.7	5.8	5.6	5.9	4.9	5.6
Cochise IV (RKCL)	71.7	4.7	5.9	6.7	5.2	7.0	5.3	5.7	5.6	5.8	4.9	5.8	5.6	5.7	5.6
PSG-TTRH	68.3	4.9	6.0	5.3	5.5	6.0	5.0	5.3	5.9	5.8	5.5	5.6	5.6	4.9	5.5
LS 1200 (SC-1)	63.3	5.3	6.4	7.3	5.5	7.7	5.3	5.0	5.5	5.8	5.9	6.0	6.0	5.2	5.5
BAR Fa 6235	55.0	5.2	6.4	5.3	5.3	7.0	4.7	4.9	6.0	6.0	5.4	5.7	5.6	4.6	5.5
Rebel IV*	60.0	5.2	6.0	5.5	5.2	7.0	5.7	5.3	5.3	5.3	5.0	5.6	5.6	4.9	5.4
MVS-1107	56.7	4.8	6.2	5.7	5.5	7.3	5.7	5.2	5.3	5.6	5.3	5.9	5.9	5.0	5.4
Turbo*	53.3	4.8	6.0	5.8	5.2	8.0	5.0	5.5	5.5	5.3	5.3	5.8	5.8	4.9	5.4
SR 8650 (STR-8LMM)*	61.7	4.8	6.4	5.2	4.5	7.0	5.7	5.2	5.6	5.4	5.3	5.5	5.4	4.8	5.4
Shenandoah Elite (RK 6)*	61.7	5.2	6.3	6.2	5.0	7.3	5.3	5.3	5.5	5.2	5.3	5.8	5.6	5.0	5.3
Sunset Gold (KZ-2)*	56.7	4.5	7.3	5.5	4.5	6.0	5.0	5.2	5.7	5.6	4.9	5.3	5.2	5.0	5.3
Corona (Col-M)	46.7	5.0	7.0	5.5	5.0	7.3	4.0	5.3	5.4	5.6	5.4	5.6	5.2	4.7	5.3
Finelawn Xpress (RP 2)	51.7	5.0	6.1	6.0	5.2	8.3	4.0	4.8	5.3	5.4	5.4	6.1	5.8	5.0	5.3
J-140	65.0	5.2	6.0	5.8	4.8	8.0	5.0	5.2	5.4	4.8	5.1	5.6	6.0	4.7	5.3
Turbo RZ (Burl-TF8)*	71.7	4.7	6.1	5.5	4.5	8.3	5.0	4.8	5.3	5.3	5.6	5.6	5.4	5.2	5.3
Reunion (LS-03)*	48.3	4.6	7.4	5.8	4.8	6.7	4.3	5.3	5.8	5.9	5.3	4.7	4.8	4.8	5.3
AST 7001*	48.3	4.7	7.4	5.3	5.0	5.7	5.0	5.3	5.6	5.7	5.1	5.1	5.1	4.1	5.2
PSG-85QR	65.0	4.6	5.8	5.5	5.2	7.7	6.0	4.9	5.6	5.3	5.3	5.2	5.0	4.6	5.2
Hunter*	53.3	5.2	7.2	5.7	4.8	5.7	5.3	5.2	5.4	5.7	5.3	5.1	5.1	4.4	5.2
GWTF	60.0	4.8	6.9	5.7	4.8	8.0	4.7	5.0	5.7	5.3	5.3	5.2	5.3	4.4	5.2
STR-8GRQR	53.3	4.8	5.9	5.5	5.3	7.3	4.7	4.9	5.3	5.6	5.3	5.0	5.7	5.0	5.2
Catelyst (NA-BT-1)	70.0	4.8	5.4	6.2	5.0	7.3	5.3	5.3	5.1	5.0	5.3	5.8	5.6	4.8	5.2
Crossfire 3 (Col-J)	46.7	4.9	6.8	5.5	4.7	6.0	4.3	5.0	5.7	5.5	5.2	5.0	5.1	4.6	5.2
Rhambler SRP (Rhambler)*	70.0	5.3	5.7	5.8	5.5	7.3	5.7	4.8	5.3	5.3	5.3	5.7	5.7	4.8	5.2
Shenandoah III (SH 3)*	73.3	5.3	5.6	6.7	5.2	7.7	5.3	5.1	5.5	5.1	5.1	5.5	5.1	5.3	5.2
Firecracker LS (MVS-MST)*	51.7	4.9	5.7	6.7	5.3	7.0	5.0	4.8	5.7	5.3	5.4	5.4	5.3	4.8	5.2
Faith (K06-WA)*	75.0	4.7	6.2	6.2	5.2	7.0	5.0	5.1	5.3	5.5	5.6	5.3	5.2	5.3	5.2

continued

Table 1. Performance of tall fescue cultivars in Wichita, 2006–2011[1]

Cultivar/ experimental number[2]	% estab.	Greenup	Genetic color	Leaf texture	Fall color retention	Brown patch	Quality								
							March	April	May	June	July	Aug.	Sept.	Oct.	Avg.
Sidewinder (IS-TF-138)	50.0	4.8	6.7	6.5	4.7	8.0	4.3	5.0	5.7	5.8	5.3	5.4	5.0	4.2	5.2
JT-33	63.3	4.4	6.4	5.7	5.3	7.3	5.0	5.0	5.3	5.7	5.3	5.2	5.4	4.6	5.2
Speedway (STR-8BPDX)*	63.3	5.2	6.2	5.7	4.5	7.7	5.3	5.2	5.5	5.6	5.3	5.4	5.0	4.3	5.2
Tulsa Time (Tulsa III)*	61.7	4.8	6.3	6.0	4.8	7.7	5.0	5.1	5.0	5.1	5.2	5.5	5.9	4.7	5.2
Honky Tonk (RAD-TF17)*	56.7	5.1	6.2	5.3	5.0	7.3	5.3	5.1	5.5	5.4	5.6	5.3	4.9	4.6	5.2
Umbrella (DP 50-9411)	68.3	4.7	7.4	5.3	4.5	7.3	4.7	5.2	5.5	5.4	5.1	5.2	5.6	5.2	5.2
PSG-82BR	71.7	4.3	5.6	5.8	4.8	7.0	4.7	4.7	5.5	5.3	5.3	5.3	5.6	4.9	5.2
Bullseye*	53.3	4.5	6.0	6.0	4.2	8.3	4.7	5.1	5.5	4.8	5.5	5.3	5.3	5.2	5.2
3rd Millennium SRP*	75.0	4.1	6.0	5.5	4.8	7.7	5.3	4.9	5.5	5.2	5.0	5.3	5.4	4.8	5.2
JT-36	63.3	4.2	6.2	5.2	4.8	7.3	4.3	5.0	5.5	5.3	5.1	4.8	5.1	4.6	5.1
RK 5	75.0	4.7	6.0	6.5	5.0	7.7	5.7	5.1	5.3	5.3	5.2	5.4	5.3	4.9	5.1
Traverse SPR (RK-1)*	60.0	4.9	5.6	6.3	5.2	8.0	5.3	5.0	5.2	4.6	5.0	5.7	5.3	5.0	5.1
Raptor II (MVS-TF-158)*	41.7	4.5	6.7	5.7	4.7	7.0	4.0	4.8	5.5	5.9	5.4	5.3	5.0	4.3	5.1
Hudson (DKS)*	60.0	4.3	6.7	5.3	4.3	7.3	5.0	5.1	5.4	5.4	5.1	4.9	5.2	4.6	5.1
RK 4*	65.0	4.3	6.0	6.0	4.3	8.0	5.3	5.1	5.5	4.8	4.7	5.3	5.1	4.8	5.1
Gazelle II (PST-5HP)*	61.7	4.7	5.9	5.7	5.0	7.7	4.7	5.3	5.1	5.1	5.3	5.0	5.0	5.1	5.1
Falcon V (ATM)*	73.3	4.8	5.4	6.7	4.5	7.7	5.3	5.2	5.3	4.9	5.0	5.3	5.6	5.0	5.1
AST9001 (AST-3)*	58.3	4.4	7.2	5.3	4.5	7.3	5.0	4.9	5.5	5.3	5.3	5.3	5.0	4.7	5.1
Col-1	43.3	4.6	6.6	5.5	5.0	6.0	4.7	5.0	5.1	5.5	5.1	4.9	5.1	4.4	5.1
Firenza*	78.3	5.1	6.2	6.0	4.7	8.3	5.3	5.1	5.5	5.5	4.9	5.3	4.9	4.7	5.1
Renovate (LS-11)*	51.7	4.7	7.2	5.7	4.5	5.7	5.0	5.3	5.4	5.5	5.2	4.8	5.0	3.8	5.1
Greenbrooks (TG 50-9460)	73.3	4.5	6.2	5.7	4.5	7.7	5.0	4.9	5.3	5.8	5.5	5.2	4.9	4.3	5.1
Pedigree (ATF-1199)*	55.0	4.4	6.1	5.3	4.8	7.3	5.0	5.2	5.3	5.4	5.3	5.1	5.0	4.4	5.1
Skyline*	56.7	4.3	5.9	5.2	4.7	7.7	4.7	5.0	5.1	5.5	5.3	5.2	5.1	4.6	5.1
RNP*	63.3	4.2	7.3	5.2	4.5	7.0	5.0	5.3	5.6	5.3	4.9	5.0	4.9	4.6	5.1
Lindbergh*	78.3	4.8	5.7	5.2	4.8	6.7	5.3	4.9	5.0	5.1	5.1	5.3	4.9	4.6	5.0
Rembrandt*	58.3	4.8	5.2	4.8	5.2	6.0	5.7	5.0	5.2	5.0	4.9	5.2	4.9	4.9	5.0
Integrity (BGR-TF1)*	61.7	4.4	6.8	5.3	4.7	7.3	5.3	5.1	5.3	5.2	5.1	5.0	5.0	4.4	5.0
Trio (IS-TF-152)	51.7	3.8	6.8	5.5	5.0	7.7	4.0	5.0	5.1	5.3	5.3	5.3	5.2	4.4	5.0

continued

Table 1. Performance of tall fescue cultivars in Wichita, 2006–2011[1]

Cultivar/ experimental number[2]	% estab.	Greenup	Genetic color	Leaf texture	Fall color retention	Brown patch	Quality								
							March	April	May	June	July	Aug.	Sept.	Oct.	Avg.
AST9003 (AST-1)*	58.3	4.5	7.4	5.8	4.7	6.7	5.0	4.9	5.3	5.2	5.2	4.8	4.9	4.4	5.0
Biltmore*	70.0	4.8	6.4	4.7	4.8	7.0	5.3	4.8	5.4	5.3	4.8	4.8	5.1	4.4	5.0
STR-8BB5	53.3	4.6	5.7	5.8	4.8	7.3	5.0	5.1	5.5	5.1	4.9	5.2	5.4	4.6	5.0
Einstein*	75.0	4.8	5.8	5.3	4.8	7.3	5.3	4.8	5.0	5.4	5.2	5.3	5.2	4.3	5.0
JT-41	70.0	4.4	6.1	5.5	4.3	7.7	5.7	5.3	5.5	5.1	4.8	4.8	4.9	4.2	5.0
J-130	63.3	4.4	5.9	5.3	4.0	7.7	5.0	5.2	5.3	4.8	5.1	4.8	5.1	4.2	5.0
Rocket (IS-TF-147)	60.0	4.3	6.1	5.5	4.5	7.7	5.3	4.9	5.5	4.8	4.7	4.9	5.2	4.9	5.0
Terrier (IS-TF-135)	56.7	4.1	7.0	5.7	4.7	6.0	4.7	5.2	4.9	5.6	4.9	4.8	5.1	4.8	5.0
06-WALK	55.0	4.6	6.7	5.2	4.5	7.3	5.0	4.8	4.9	5.3	5.2	5.1	4.7	4.3	4.9
JT-42	76.7	3.9	6.2	5.2	4.3	7.0	5.0	4.7	5.4	4.9	4.8	4.8	5.1	4.6	4.9
JT-45	71.7	4.3	6.2	5.5	4.5	7.0	5.3	5.0	5.3	5.1	4.8	4.9	4.9	4.2	4.9
Escalade*	65.0	4.3	5.9	5.7	4.3	7.3	5.3	5.0	5.3	4.7	4.8	5.1	4.8	4.6	4.9
Spyder LS (Z-2000)*	61.7	4.3	6.2	5.7	4.3	7.3	4.7	4.8	4.8	5.5	5.6	5.2	5.3	4.4	4.9
Falcon IV*	71.7	4.6	5.8	4.8	4.7	7.7	5.7	4.8	5.1	4.8	4.9	5.0	5.1	4.7	4.9
Monet (LTP-610 CL)*	76.7	4.3	5.6	6.3	4.2	8.0	5.3	5.0	5.1	5.0	5.1	5.1	4.9	4.6	4.9
Mustang 4 (M4)*	76.7	4.4	6.2	6.3	4.7	8.0	5.0	4.9	5.3	4.8	4.9	5.0	5.3	4.2	4.9
Van Gogh (LTP-RK2)*	65.0	5.1	5.9	5.8	5.0	8.3	5.0	4.8	5.2	5.0	5.0	5.2	5.3	4.2	4.9
Falcon NG (CE 1)	70.0	5.1	5.6	5.8	4.5	7.7	5.7	4.8	5.2	5.0	4.8	5.4	5.1	4.2	4.9
Jamboree (IS-TF-128)	56.7	4.3	5.9	6.0	4.2	7.7	4.7	5.2	5.2	4.9	4.9	5.0	5.0	4.7	4.9
AST9002 (AST-2)*	46.7	4.8	7.6	5.8	5.0	6.7	4.7	5.1	5.1	5.0	4.7	5.0	4.7	4.4	4.9
Cannavaro (DP 50-9440)	65.0	4.2	6.0	6.5	4.2	7.7	4.7	5.2	5.3	5.2	4.9	4.9	4.4	4.0	4.9
PSG-TTST	66.7	4.8	5.3	5.3	4.5	7.0	5.3	5.1	4.8	4.6	4.9	4.8	4.8	4.6	4.9
Tahoe II*	60.0	4.6	6.1	4.8	5.0	6.3	4.3	5.0	5.3	4.9	4.5	4.4	4.6	4.3	4.9
MVS-341	55.0	4.6	6.2	5.2	4.7	6.7	4.3	5.0	5.3	5.2	4.9	4.3	4.7	4.2	4.9
Essential (IS-TF-154)*	65.0	4.9	5.9	5.8	4.7	7.7	4.0	4.8	5.3	5.0	4.8	5.3	4.6	4.7	4.8
LS 1010 (ATF 1328)	53.3	4.8	6.4	5.5	4.3	7.3	4.7	4.8	5.1	5.4	4.9	4.6	5.1	4.2	4.8
Hemi*	63.3	4.5	5.9	5.3	4.7	7.7	5.0	4.8	5.1	4.7	4.8	5.5	5.3	4.1	4.8
Aristotle*	75.0	4.8	6.2	4.7	4.7	6.7	5.7	4.8	4.9	5.2	4.8	4.7	4.4	4.7	4.8
Xtremegreen (BGR-TF2)*	60.0	4.7	6.9	5.5	4.2	7.3	5.0	4.8	5.4	5.1	4.8	4.4	4.7	4.2	4.8

continued

Table 1. Performance of tall fescue cultivars in Wichita, 2006–2011[1]

Cultivar/ experimental number[2]	% estab.	Greenup	Genetic color	Leaf texture	Fall color retention	Brown patch	Quality								
							March	April	May	June	July	Aug.	Sept.	Oct.	Avg.
AST 7003*	53.3	4.7	7.1	5.7	4.3	6.3	4.7	4.8	5.1	5.1	5.0	4.8	4.6	4.2	4.8
Titanium LS (MVS-BB-1)*	70.0	4.9	5.9	5.5	4.8	7.7	5.0	5.0	5.4	5.2	4.7	5.2	4.4	3.9	4.8
Compete (LS-06)*	56.7	4.7	7.0	5.3	4.3	7.0	5.3	4.8	5.3	4.9	4.7	4.6	4.4	4.0	4.8
Fat Cat (IS-TF-161)	61.7	4.3	6.6	5.5	4.5	7.3	4.3	4.8	5.1	5.0	4.8	4.8	4.8	4.9	4.8
Darlington (CS-TF1)*	65.0	4.4	7.3	5.3	4.8	6.3	5.0	5.3	5.3	4.9	4.4	4.7	4.3	3.9	4.8
Padre*	75.0	4.3	5.9	4.8	4.3	7.3	5.7	4.8	5.1	5.0	4.8	4.8	4.3	3.9	4.8
Tanzania (IS-TF-159)	55.0	4.4	6.4	6.0	4.0	7.0	3.7	4.9	5.3	4.8	4.8	4.8	4.7	4.3	4.8
Magellan*	78.3	4.4	5.9	4.8	4.3	7.7	6.0	4.9	5.0	4.4	4.4	4.7	5.0	4.1	4.8
Garrison (IS-TF-153)	61.7	4.3	6.3	5.5	4.5	8.0	5.0	4.8	5.0	5.1	4.4	5.0	5.1	4.3	4.8
06-DUST	68.3	5.1	6.1	5.7	4.3	7.0	5.0	4.8	5.0	4.8	4.9	4.6	5.0	4.0	4.7
Ninja 3 (ATF 1247)	58.3	4.3	6.3	5.0	4.5	5.3	4.7	4.6	5.1	4.7	4.5	4.8	4.9	4.3	4.7
PSG-RNDR	50.0	4.0	6.0	4.8	4.3	7.0	3.7	4.3	5.2	4.9	4.8	4.5	4.6	4.6	4.7
GE-1	61.7	4.4	6.0	5.2	4.5	8.0	5.3	4.8	5.1	5.3	4.7	4.7	4.6	3.9	4.7
Justice*	75.0	4.7	5.7	5.7	4.2	6.7	5.3	4.6	5.1	4.8	4.3	4.6	4.1	4.6	4.7
0312	61.7	4.8	6.2	5.7	4.2	6.3	5.0	4.7	5.1	4.8	4.1	4.4	4.4	4.4	4.6
Cezanne Rz (LTP-CRL)*	51.7	4.6	5.8	5.5	4.5	7.7	5.7	4.7	5.2	4.8	4.5	4.9	4.3	4.1	4.6
Plato*	86.7	4.6	5.4	5.7	4.5	6.7	5.7	4.5	5.2	4.4	4.5	4.5	4.3	3.9	4.6
AST1001 (AST-4)	60.0	4.7	7.2	5.5	3.8	6.7	5.0	4.6	5.2	4.6	4.7	4.3	4.1	4.0	4.6
Toccoa (IS-TF-151)*	63.3	4.2	6.7	6.0	4.2	7.0	4.0	4.4	5.0	4.8	4.8	4.9	4.4	4.0	4.6
Stetson II (NA-SS)	50.0	4.8	6.9	5.5	4.0	6.7	4.0	4.7	5.3	5.3	4.3	4.3	4.0	4.2	4.6
GO-1BFD	81.7	4.8	5.2	5.3	5.0	7.0	5.7	4.1	4.7	4.6	5.0	4.6	4.8	4.6	4.6
BAR Fa 6363	58.3	4.4	6.2	4.7	5.0	7.0	5.3	4.7	5.1	4.5	4.0	4.3	4.2	4.8	4.5
AST 7002*	55.0	4.3	6.4	5.2	4.2	6.7	4.3	4.5	4.9	4.5	4.4	4.3	4.3	4.1	4.5
Gold Medallion (KZ-1)*	58.3	4.3	6.7	4.8	4.3	6.7	4.7	4.9	4.9	4.5	4.3	4.2	4.2	4.0	4.5
Silverado*	75.0	4.3	4.1	4.0	3.8	7.3	5.7	4.1	4.3	3.7	3.8	3.8	3.9	3.4	4.0
Ky-31*	83.3	5.2	3.0	3.5	4.5	8.7	4.0	3.3	3.3	3.0	2.7	2.7	2.8	2.7	3.1
LSD[3]	18.0	0.9	0.6	0.7	3.7	2.1	2.5	0.7	0.7	1.4	1.4	1.1	1.6	1.4	0.8

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

[2] Cultivars marked with * were commercially available in 2011.

[3] 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.

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

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

Results

Wichita

We started the 2011 growing season by looking at spring greenup. By the end of April, vegetative types NE-BFG07-13 and NE-BFG07-10 and seeded types NE-BFG07-08 and NE-BFG07-03 were the greenest (Table 1). We rated turf quality every month throughout the growing season. Ratings were influenced by degree of cover, weed infestation, and disease resistance as well as turf color, texture, and density. The overall best performers were vegetative types NE-BFG07-10, NE-BFG07-11, NE-BFG07-12, and '609' and seeded types NE-BFG07-01, NE-BFG07-04, and NE-BFG07-02. We looked at spring and summer stand density. At the beginning of the growing season, vegetative types NE-BFG07-12, NE-BFG07-11, NE-BFG07-13, and 'Prestige' were the densest followed by seeded type NE-BFG07-03. At midsummer, vegetative types '609' and seeded types NE-BFG07-02 and NE-BFG07-03 had the densest stands. By September 20, after a hotter-than-average summer, we rated for dormancy rather than for fall density and found that vegetative types '609' and NE-BFG07-12 and seeded type 'Bison' were the greenest (Figure 1). By November 4, only vegetative type '609' retained much color (Figure 2).

Olathe

Summer was very long, hot, and dry. 'Prestige' and 'Legacy' continued to have the best color and texture compared with the other buffalograsses. '609' is usually slow to green up and sometimes has some winter damage, but the extra-long hot, dry summer allowed '609' to become a top performer in Olathe this year. Similar to Wichita results, '609' had the greatest amount of fall green color compared with the others on October 11 and October 26.

Table 1. Performance of buffalograss cultivars, Wichita, 2011[1]

Cultivar/ experimental number	Type	Spring greenup	Spring density	Summer density	Sept. fall color	Nov. fall color	Quality					
							May	June	July	Aug.	Sept.	Avg.
NE-BFG07-10	Vegetative	5.0	5.7	5.3	3.3	2.3	5.7	5.7	5.7	5.7	4.3	5.4
NE-BFG07-11	Vegetative	4.3	6.7	5.7	2.0	1.3	6.0	6.0	5.3	5.3	4.0	5.3
NE-BFG07-12	Vegetative	4.0	7.0	5.7	4.0	1.0	6.0	5.3	5.7	5.3	4.0	5.3
609	Vegetative	2.0	4.0	7.7	5.3	4.0	4.7	5.3	6.0	5.3	4.3	5.1
NE-BFG07-01	Seeded	4.0	5.0	6.0	3.0	1.0	5.3	5.3	5.3	5.7	4.0	5.1
NE-BFG07-04	Seeded	3.3	5.0	5.7	3.0	1.0	5.0	5.3	5.3	5.7	4.0	5.1
NE-BFG07-02	Seeded	3.7	5.0	6.3	2.7	1.0	5.0	5.3	5.0	5.7	4.0	5.0
Legacy	Vegetative	2.3	5.7	5.3	2.0	1.7	4.7	6.0	5.0	5.0	4.0	4.9
NE-BFG07-08	Seeded	5.0	5.0	6.0	2.7	1.0	5.0	5.0	5.0	5.7	4.0	4.9
Prestige	Vegetative	2.0	6.3	5.7	1.7	1.7	6.0	5.3	4.7	4.7	4.0	4.9
Cody	Seeded	3.7	4.7	5.0	2.7	1.0	4.7	5.3	5.0	5.7	4.0	4.9
NE-BFG07-09	Vegetative	3.3	5.3	5.0	3.7	2.7	5.3	4.7	5.0	5.3	4.3	4.9
Bowie	Seeded	3.7	5.0	5.0	2.7	1.0	5.0	5.7	5.0	4.7	4.0	4.9
NE-BFG07-03	Seeded	4.3	5.7	6.3	2.3	1.0	5.0	5.0	5.0	5.3	4.0	4.9
Bison	Seeded	3.0	4.0	5.3	4.0	1.3	4.3	4.3	5.0	5.3	4.0	4.6
Texoka	Seeded	3.3	4.3	6.0	3.7	1.3	4.0	4.7	5.3	5.0	4.0	4.6
NE-BFG07-13	Vegetative	6.0	6.3	5.0	1.0	1.0	4.7	4.7	4.7	4.3	4.0	4.5
LSD[2]		1.4	1.5	1.5	1.2	0.6	1.5	1.4	1.1	1.5	0.7	0.6

[1] Visual ratings based on a scale of 1 to 9 (1 = poorest, 6 = acceptable, and 9 = optimum).
[2] To determine statistical differences among entries, subtract one entry's mean from another's. If the result is larger than the corresponding least significant difference (LSD) value, the two are statistically different.

Table 1. Performance of buffalograss cultivars, Olathe, 2011[1]

Cultivar/ experimental number	Type	Spring greenup	Genetic color	Texture	Density	Fall color Oct. 11	Fall color Oct. 26	Quality June	Quality July	Quality Aug.	Quality Sept.	Quality Oct.	Quality Avg.
Prestige	Vegetative	5.7	5.0	9.0	9.0	5.7	2.3	8.0	6.7	8.0	8.0	8.3	7.8
609	Vegetative	4.7	5.3	7.7	8.3	8.0	6.0	7.7	6.7	7.7	7.7	7.3	7.4
NE-BFG07-09	Vegetative	5.3	5.7	8.0	7.7	5.0	2.7	7.3	7.0	7.7	7.0	7.7	7.3
Bowie	Seeded	3.7	5.0	8.0	6.3	2.7	2.3	6.7	7.0	6.7	7.0	8.0	7.1
NE-BFG07-04	Seeded	3.7	5.0	8.3	6.7	1.7	2.0	6.7	6.7	7.0	7.0	8.0	7.1
NE-BFG07-03	Seeded	3.7	5.0	8.3	6.7	2.7	2.3	6.7	7.3	6.7	6.7	7.7	7.0
NE-BFG07-08	Seeded	3.7	4.7	7.7	6.7	2.3	2.3	6.7	7.0	6.7	7.0	7.7	7.0
NE-BFG07-11	Vegetative	4.7	7.0	7.7	7.7	2.3	1.7	7.3	6.3	7.3	7.0	7.0	7.0
Cody	Seeded	3.0	5.0	7.7	6.3	2.7	2.0	6.7	6.7	7.0	7.0	7.3	6.9
Bison	Seeded	3.7	5.0	7.7	6.0	4.0	2.0	7.0	6.3	6.7	6.7	7.3	6.8
NE-BFG07-10	Vegetative	6.7	6.0	8.0	7.3	3.7	2.3	7.0	6.3	6.7	6.3	7.7	6.8
NE-BFG07-01	Seeded	3.7	5.0	8.0	6.0	1.3	2.0	6.3	7.3	6.7	5.7	7.7	6.7
Texoka	Seeded	3.3	5.0	8.0	6.3	4.0	2.0	6.3	6.7	7.0	7.0	6.7	6.7
NE-BFG07-02	Seeded	3.7	5.0	8.0	6.3	2.0	2.0	6.7	5.7	7.0	6.3	7.7	6.7
Legacy	Vegetative	5.0	6.0	8.3	8.3	4.0	3.0	6.0	6.7	5.7	7.3	7.7	6.7
NE-BFG07-12	Vegetative	5.3	6.7	7.0	7.0	2.0	1.3	6.3	6.3	6.3	7.0	7.3	6.7
NE-BFG07-13	Vegetative	6.0	4.3	7.7	6.0	1.7	1.0	6.0	6.3	5.7	4.0	4.3	5.3
LSD[2]		1.2	1.3	0.9	1.4	1.6	1.1	0.9	NS	0.7	1.1	1.3	0.57

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

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

Figure 1. Buffalograss fall color at Wichita on September 20, 2011, after an unusually hot summer.

Figure 2. Buffalograss fall color at Wichita on November 4, 2011, showing vegetative type '609' fall color retention (gold plot on right).

Influence of Spring and Fall Herbicide Application Timing on Dandelion Control in Turfgrass with Standard and New Herbicides

Objectives: Determine the effect of spring and fall application timing on dandelion control with seven herbicides in 2010 and nine herbicides in 2011.

Investigators: Zane Raudenbush and Steve Keeley

Introduction

Herbicidal control in fall is thought to be effective because perennial weeds are moving carbohydrate reserves to underground storage structures, which aids in the movement of herbicides to their site of action; however, turfgrass managers may need herbicidal options for spring weed control to meet the needs of their clients.

Most products used for broadleaf weed control in turfgrass are preformulated products that contain several active ingredients. Multiple active ingredients allow turf managers to control a wide array of broadleaf weeds. Because of the recent introduction of several new herbicides to the turfgrass market and the lack of research investigating the effect of application timing on their efficacy, the objectives of our study were to determine the effect of spring and fall application timing on dandelion control with seven herbicides in 2010 and nine herbicides in 2011.

Methods

Field studies were conducted in 2010 and 2011 on adjacent sites at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. The 4 ft × 6 ft plots were mown at 3 in. and irrigated as needed to prevent drought stress in 2010. In 2011, the site was irrigated as needed to prevent dormancy. The 2010 site contained turf-type tall fescue (*Festuca arundinacea* Schreb.) with an existing dandelion stand. The 2011 site was previously seeded to crested wheatgrass (*Agropyron cristatum* L.) and had an existing dandelion infestation; however, the crested wheatgrass density was poor and dandelions were much larger compared with the 2010 site.

All herbicides were applied at their lowest recommended label rate for dandelion control (Table 1). The seven herbicides in 2010 were Trimec Classic (PBI/Gordon Corporation, Kansas City, Mo.), Speedzone (PBI/Gordon Corporation, Kansas City, Mo.), Escalade II (Nufarm, Burr Ridge, Ill.), Surge (PBI/Gordon Corporation, Kansas City, Mo.), Confront (Dow AgroSciences, Indianapolis, Ind.), 4 Speed XT (Nufarm, Burr Ridge, Ill.), Cool-Power (PBI/Gordon Corporation, Kansas City, Mo.). In 2011, Imprelis SL and Imprelis G (DuPont, Wilmington, Del.) were added for a total of nine herbicides. The spring application timings coincided with dandelion prebloom, peak bloom, and postbloom. In 2010, treatments were applied on April 4 (prebloom), April 20 (peak bloom), May 27 (postbloom), September 11, and October 6. The sixth herbicide timing consisted of a split application, the first on April 4 and second on October 6. In 2011, the treatments were applied on April 8 (prebloom), April 18 (peak bloom), May 31 (postbloom), September 14, and October 11. The sixth treatment was a split application on April 8 and October 11. Herbicides were applied with a two-nozzle (TeeJet XR8002VS, Spray Systems Co., Wheaton, Ill.), CO_2-pressurized backpack sprayer operating at 30 psi to deliver a spray volume of 36.6 gal/a.

In 2010, percentage control data were determined at 30 days after treatment (DAT), end of season (November 10, 2010), and the following spring (April 27, 2011). In 2011, percentage control data were determined at 30 DAT, 60 DAT, and end of season (November 12, 2011).

Results

Percentage dandelion control was evaluated in the spring of 2011 (April 8) for all herbicides applied at the six application timings in 2010 (Table 2). All herbicides provided ≥95.2% at the spring prebloom timing when rated the following spring. When applied at spring peak bloom, dandelion control ranged from 79.8 to 100.0%, but we observed no differences. All herbicides applied at the spring postbloom timing in 2010 provided ≥95.1% dandelion control at the spring rating date in 2011. We observed no differences among herbicides at the late-summer application timing, in which dandelion control ranged from 81.3 to 98.0%. 4 Speed XT gave 99.1% dandelion control at the early fall timing, but was not different from Confront, Trimec Classic, Escalade 2, and Cool Power. All herbicides provided ≥99.5% dandelion control when applied spring prebloom + early fall.

For the 2011 study, at 60 DAT, Imprelis SL at the spring prebloom timing gave 99.4% dandelion control, which was greater than all herbicides except 4 Speed XT (Table 3). The remaining herbicides provided ≥88.5% control, except Cool Power and Confront, which gave 54.8 and 48.7% control, respectively. At spring peak bloom, Imprelis SL gave 99.3% dandelion control 60 DAT, which was greater than all herbicides except Speedzone or Imprelis G. In contrast, Trimec Classic, Surge, Cool Power, and Confront all provided ≤66.1% dandelion control. When applied spring postbloom, Imprelis SL gave 99.5% control 60 DAT, which was greater than all herbicides except 4 Speed XT, Trimec Classic, and Speedzone. All other herbicides gave ≤73.7% control, with Imprelis G and Confront giving ≤48.8%. We recorded no significant differences at 60 DAT among herbicides when applied in late summer.

Table 1. Herbicide active ingredients and lowest recommended label rates for common dandelion control for herbicides used in application timing studies in 2010 and 2011

Herbicide	Active ingredients	Product/a
Trimec Classic	2,4-D, dimethylamine salt	52.2 oz
	MCPP, dimethylamine salt	
	Dicamba, dimethylamine salt	
Speedzone	Carfentrazone-ethyl	47.9 oz
	2,4-D, 2-ethylhexyl ester	
	MCPP acid	
	Dicamba acid	
Escalade 2	2,4-D, dimethylamine salt	32.6 oz
	Fluroxypr,1-methylheptyl ester	
	Dicamba acid	
Surge	Sulfentrazone	52.2 oz
	2,4-D, dimethylamine salt	
	MCPP, dimethylamine salt	
	Dicamba, dimethylamine salt	
Confront	Triclopyr, triethylamine salt	16.1 oz
	Clopyralid, triethylamine salt	
4 Speed XT	2,4-D, isooctyl ester	49.7 oz
	Triclopyr, butoxyethyl ester	
	Dicamba acid	
	Pyraflufen ethyl	
Cool Power	MCPA, isooctyl ester	39.6 oz
	Triclopyr, butoxyethyl ester	
	Dicamba acid	
Imprelis SL	Aminocyclopyrachlor, potassium salt	4.5 oz
Imprelis 0.05G	Aminocyclopyrachlor, potassium salt	200 lb

Table 2. Percentage dandelion control in spring 2011 from herbicides applied at various timings[1] in 2010

	% dandelion control					
Herbicide[2]	Spring prebloom	Spring peak bloom[3]	Spring postbloom[3]	Late summer[3]	Early fall[4]	Spring prebloom + early fall[3]
4 Speed XT	99.0	100.0	96.7	97.1	99.1 a	100.0
Surge	99.5	98.7	95.4	94.0	81.6 bc	99.5
Speedzone	95.2	93.7	95.1	81.3	83.8 c	100.0
Confront	100.0	93.0	98.1	94.7	89.8 abc	100.0
Escalade 2	99.0	89.8	97.0	98.0	96.8 ab	100.0
Cool Power	97.6	84.6	95.5	92.6	97.6 ab	100.0
Trimec Classic	98.6	79.8	98.0	97.5	90.8 ab	100.0

[1] Spring prebloom, April 7; spring peak bloom, April 20; spring postbloom, May 27; late summer, September 11; early fall, October 6.
[2] Herbicides are ranked over spring peak bloom timing.
[3] No significant differences among treatments.
[4] Means followed by the same letter in a column are not statistically different ($P \leq 0.05$) by Fisher's least significant difference test.

Table 3. Percentage dandelion control 60 days after treatment (DAT) in 2011 when broadleaf herbicides were applied at different application timings[1]

	% dandelion control[2]			
Herbicide[3]	Spring prebloom	Spring peak bloom	Spring postbloom	Late summer[4]
Imprelis SL	99.4 a	99.3 a	99.5 a	81.9
4 Speed XT	97.3 ab	86.0 bc	96.9 a	89.5
Trimec Classic	92.2 bc	61.2 de	96.4 a	98.4
Speedzone	88.5 c	93.8 ab	88.9 ab	91.6
Surge	89.8 c	66.1 de	73.7 bc	94.6
Escalade 2	90.7 c	77.7 cd	72.2 dc	96.8
Cool Power	54.8 d	52.5 e	67.7 bcd	84.7
Imprelis G	93.2 bc	92.5 ab	48.8 cd	90.5
Confront	48.7 d	61.4 de	35.2 d	98.2

[1] Spring prebloom, April 8; spring peak bloom, April 18; spring postbloom: May 31; late summer: September 19.
[2] Means followed by the same letter in a column are not statistically different ($P \leq 0.05$) by Fisher's least significant difference test.
[3] Herbicides are ranked over spring peak bloom timing.
[4] No significant differences among treatments.

A Comparison of Organic and Conventional Tactics for Dandelion Control in Turfgrass

Objectives: 1) Determine if organic weed control options including corn gluten meal (CGM), hand-weeding, and horticultural vinegar could provide acceptable control of established dandelions in a stand of tall fescue, compared with a conventional herbicide; 2) determine the effect of the nitrogen component of CGM on its control of dandelions; and 3) evaluate the practical implementation of organic weed control tactics by conducting a cost analysis.

Investigators: Zane Raudenbush and Steve Keeley

Introduction

Weed control is one of the biggest hurdles when adopting organic production. Turf managers need organic weed control options to meet the needs of their clients, especially where governments have banned the use of synthetic pesticides. Many researchers have determined the importance of sound cultural practices such as proper irrigation, fertilization, and mowing for effective long-term weed control; however, the success of organic weed control may be more reliant on those practices than conventional methods.

Although several options are available for organic weed control in turfgrass, their efficacy in removing established perennial weeds from an existing turfgrass stand has not been well established. The objectives of this study were: 1) to determine if organic weed control options including corn gluten meal (CGM), hand-weeding, and horticultural vinegar could provide acceptable control of established dandelions in a stand of tall fescue compared with a conventional herbicide; 2) to determine the effect of the nitrogen component of CGM on its control of dandelions; and 3) to evaluate the practical implementation of organic weed control tactics by conducting a cost analysis.

Methods

A two-year field study was conducted at Rocky Ford Turfgrass Research Center in Manhattan, Kan., from May 2010 through November 2011. The site contained turf-type tall fescue with an existing dandelion infestation. The 4 ft × 6 ft plots were mown twice weekly at 3.25 in. and irrigated as needed to prevent drought stress.

Ten treatments included four different organic weed control tactics: CGM, hand-weeding, horticultural vinegar, and organic fertilizer only, and one conventionally managed treatment; each received a total of 2 or 4 lb N/1,000 ft^2 annually. Trimec Classic was included as the conventional herbicide. Sustane (8-2-4 N-P-K) was the N-source for all organic control tactics, excluding CGM. A polymer-coated urea (PCU; 41-0-0 N-P-K) was the N source for the conventional herbicide treatment. All N was applied in split applications, with half applied in spring (May 4, 2010, and April 12, 2011) and the other half in fall (September 21, 2010, and September 16, 2011). All fertilizer applications were made on the same day for all treatments.

Dandelions were hand-weeded once yearly in the spring using a hand-weeding tool (Figure 1). A stopwatch was used to record the time needed to hand-weed each plot.

Horticultural vinegar was spring-applied to dandelions using a two-nozzle CO_2 backpack sprayer at a rate of 36.6 gal/a. The product was applied undiluted. Although this product is intended for spot treatment of weeds, the dandelions were so prevalent in the plots that spot treatment was not practical, so the entire plot was treated.

Trimec Classic (PBI/Gordon Corporation, Kansas City, Mo.) was included as the conventional control tactic. Trimec Classic was applied at a rate of 1.2 fl. oz /1,000 ft^2 in the spring of 2010. Trimec Classic was not applied in 2011. Two fertilization-only treatments were included as checks. For these treatments, Sustane (8-2-4 N-P-K) was applied at the 2 and 4 lb N/1,000 ft^2 rates and split between spring and fall as previously described.

Percentage dandelion control was determined using a 4 ft × 6 ft rating grid. Percentage control was calculated by comparing the counts in treated plots with untreated plots in the same block. Percentage control for each plot was recorded in the spring and fall. Plots were rated for visual quality and color every two weeks from April through November. A 1 to 9 scale was used for both parameters; for visual quality, 1 = brown, dead turf, 6 = minimum acceptable turf quality, and 9 = optimum turf quality; for color, 1 = completely brown, 6 = minimum acceptable turf color, and 9 = optimal turf color.

Results

The single application of Trimec Classic in spring 2010 provided the highest dandelion control at all rating dates in both years, followed by hand-weeding (Table 1). No differences in control were recorded among CGM, horticultural vinegar, and fertilizer-only treatments at any rating date. The initial spring rating in 2010 was the only occasion when Trimec Classic (81.6%) did not provide better control than hand-weeding (71.9%). By fall 2010, control improved to 99.3% with Trimec Classic, whereas hand-weeding remained steady at 70.4%. In 2011, hand-weeding dropped to around 60%, and Trimec Classic continued to give >96% control.

Hand-weeding was generally more effective than the other organic control tactics but not as effective as Trimec Classic. The fall 2010 rating was the only instance when hand-weeding (70.4%) and horticultural vinegar (23.7%) were not different in dandelion control (Table 1). Similarly, spring 2011 was the only rating date when hand-weeding (61.4%) was not greater than CGM (24.4%). Hand-weeding provided greater dandelion control than the fertilizer-only treatments at all rating dates.

Trimec Classic generally gave the highest turfgrass visual quality throughout the study (Figure 2); however, June 2 was the only rating date in 2010 when Trimec Classic (7.1) had significantly higher quality compared with hand-weeding (6.8). We recorded no significant differences in turf quality among all five treatments from July 1 through

September 9, 2010 (Figure 1). Trimec Classic had significantly higher quality on September 22 and October 6 compared with CGM, horticultural vinegar, and fertilizer-only treatments.

In 2011, Trimec Classic provided the greatest overall quality and was greater compared with hand-weeding treatments on four of the 10 rating dates (Figure 1). Hand-weeding had greater overall quality than the other organic control tactics and higher quality compared with CGM on three rating dates and greater quality compared with fertilizer on five rating dates. Horticultural vinegar had the lowest quality at all ratings dates in 2011, and was less than all other organic treatments on 3 of 10 rating dates.

Hand-weeding was the only organic tactic that provided a significant level of dandelion control; unfortunately, the cost of control is about nine times higher than conventional methods because of labor inputs (Table 2). Also, removing the entire taproot is difficult, thus reducing its overall effectiveness. Hand-weeding may be a practical option when dandelion densities are low and the area to be treated is small. Horticultural vinegar is non-selective and resulted in severe necrosis to the desired turf (Figure 3). Horticultural vinegar is applied undiluted, making it an expensive option; furthermore, multiple applications would likely be needed for successful long-term control, as many dandelions in our study reemerged within 21 DAT (Figure 4). Turfgrass managers will have difficulty removing established dandelions from lawns if CGM is their only tactic. Based on this two-year study, CGM did not show an herbicidal effect on dandelions. The minimal control achieved with CGM was probably due to its N content. Fertilizer-only treatments with organic fertilizer Sustane were three times more expensive than the synthetic slow-release N-source (Polyon) and were not effective in reducing high dandelion densities over the course of this research.

A conventional herbicide applied one time, prior to using organic tactics, could provide the initial long-term broadleaf weed control that is needed to establish a competitive turfgrass stand. The stand could then be managed organically from that point forward. Although this approach would not qualify as organic, it presently appears to be the only practical option for large turf areas with moderate to high perennial weed populations.

Table 1. Dandelion (*Taraxacum officinale* Weber) control in field-grown turf-type tall fescue in 2010 and 2011 when using organic and conventional weed control tactics

	% dandelion control[1]			
	2010		2011	
Treatment[2]	Spring[3]	Fall	Spring	Fall
Trimec Classic	81.6 a	99.3 a	99.3 a	96.6 a
Hand-weeding	71.9 a	70.4 b	61.4 b	58.5 b
Corn gluten meal	15.2 b	17.1 c	24.4 bc	14.6 c
Horticultural vinegar	19.2 b	23.7 bc	18.2 c	11.1 c
Fertilizer only	10.5 b	12.7 c	13.8 c	10.9 c

[1] Means followed by the same letter in a column are not statistically different ($P \leq 0.05$) by Fisher's least significant difference test.
[2] Treatments were ranked over 2011.
[3] Spring rating in 2010 was recorded 22 days after treatment.

Table 2. Cost analysis of organic and conventional weed control tactics

Treatment	Price,[1] $	Rate	Price, $/1,000 ft^2
Trimec Classic	50.00/gal	1.2 fl. oz/1,000 ft^2	0.46
Hand-weeding	8.25/hr	128 ft^2/hr	64.47
Corn gluten meal 9-0-0	0.75/lb	2 lb N/ 1,000 ft^2	33.79
Purcell Polyon 41-0-0	1.01/lb	2 lb N/ 1,000 ft^2	9.95
Sustane 8-2-4	0.60/lb	2 lb N/ 1,000 ft^2	30.00

Treatment	Total cost, $/1,000 ft^2	% dandelion control, fall 2011[2]
Trimec Classic + Purcell Polyon 41-0-0	10.41	96.6 a
Hand-weeding + Sustane 8-2-4	94.47	58.5 b
Corn gluten meal 9-0-0	33.79	14.6 c

[1] Prices are estimates based on quotes obtained on February 20, 2012, from several retailers.
[2] Means followed by the same letter in a column are not statistically different ($P \leq 0.05$) by Fisher's least significant difference test.

Figure 1. Hand-weeding tool used in studies.

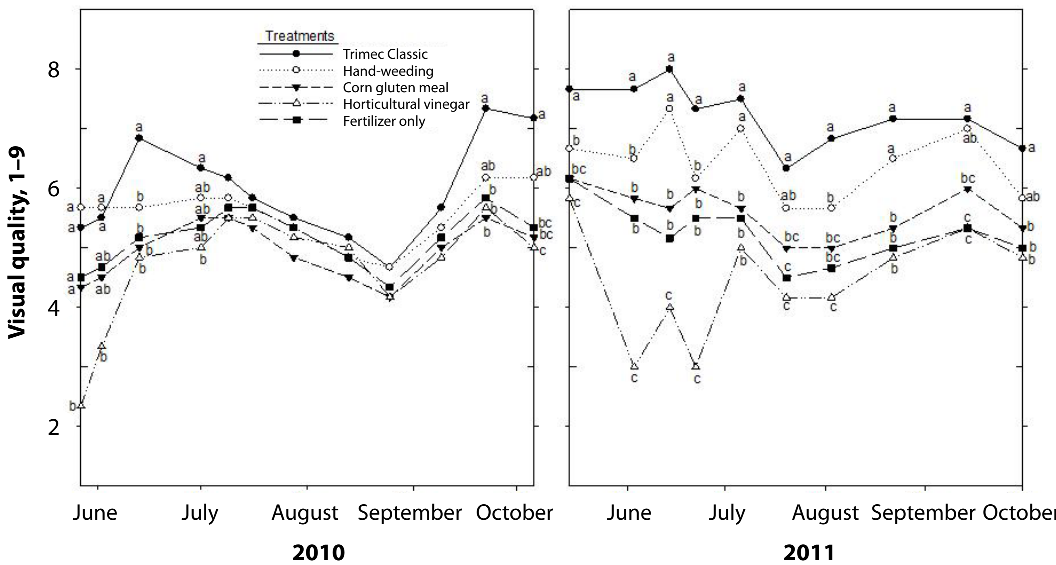

Figure 2. Turfgrass visual quality (1 to 9 scale, where 1 = brown, dead turf, 6 = minimum acceptable turf quality, and 9 = optimum turf quality) **throughout the 2010 and 2011 growing seasons when organic and conventional weed control strategies were implemented. Means followed by the same letter on a date are not significantly different according to Fisher's protected least significant difference test (*P* ≤ 0.05).**

Figure 3. Phytotoxicity of horticultural vinegar on tall fescue 5 days after treatment.

Figure 4. Dandelion regrowth 21 days after treatment with horticultural vinegar. The horticultural vinegar was applied in late May of 2010 and 2011.

Volatility of Broadleaf Weed Herbicides Applied to Turfgrass

Objectives: Evaluate the volatility of eight commonly used turfgrass broadleaf herbicides when applied to tall fescue (*Festuca arundinacea* Schreb.), a common cool-season turfgrass.

Investigators: Zane Raudenbush and Steve Keeley

Introduction

Volatilization occurs when pesticides applied to plant and/or soil surfaces evaporate and form an invisible gas. Volatility is a concern because herbicides are highly selective and may cause severe injury when they come into contact with non-target plants. The invisibility of the gas makes it difficult for field managers to determine the source of plant damage, and they may attribute the injury to other factors such as drift. Volatilization may account for up to 90% of pesticide loss and decrease pesticide efficacy.

Environmental factors such as temperature, humidity, and wind speed play a crucial role in volatilization. All of these factors must be considered when making herbicide applications; however, the most important factor influencing herbicide volatility may be the formulation of the active ingredient.

New ester formulations of 2,4-D and other phenoxy herbicides that may have a lower potential to volatilize have been released for use on turfgrass. The objective of our research was to evaluate the volatility of eight commonly used turfgrass broadleaf herbicides when applied to tall fescue. To our knowledge, this study was the first to evaluate several newer herbicides containing "low-volatile" esters in combination with other active ingredients. This research should provide turfgrass managers with the information needed to select an herbicide when volatility is a concern.

Methods

Greenhouse Studies

Eight herbicides plus 2,4-D butyl ester (highly volatile standard) and a water control were applied to tall fescue turf in two separate greenhouse studies (Study 1 and Study 2). Using a spray chamber, all herbicides were applied at the high label rate for dandelion control. Tomatoes (*Lycopersicon lycopersicum*) were used as indicator plants to detect volatility. Two tomato plants were placed on the herbicide-treated tall fescue and enclosed in translucent plastic containers in the laboratory at 72°F for 24 hours (Figures 1 and 2). The tomatoes were removed from the containers and grown in the greenhouse for 18 days while data was collected. Visual ratings of tomato quality, epinasty, and callus formation were recorded daily, and dry weights were recorded at the end of the 18-day period. Only quality data are presented here.

Field Studies

Two herbicides plus 2,4-D butyl ester (highly volatile standard) and a water control were applied to 12 ft × 12 ft tall fescue plots. Treatments were applied using a CO_2-powered backpack sprayer operating at 30 psi, using XR8002VS nozzles to deliver a spray volume of 36.6 gal/a. Tomatoes were placed at 1, 2, and 4 meters on the north, south, east, and west sides of the treated area. The tomatoes were removed from the field after 12 hours and placed in the greenhouse for an 18-day observation period. Visual ratings of tomato quality, epinasty, and callus formation were recorded daily, and dry weights were recorded at the end of the 18-day period. Only quality data are presented here.

Results

Greenhouse Studies

Tomato quality after exposure to turf treated with Confront (Dow AgroSciences, Indianapolis, Ind.), Surge (PBI/Gordon Corporation, Kansas City, Mo.), and Escalade II (Nufarm, Burr Ridge, Ill.) was not different from the water control; all had tomato quality ratings ≥7.6 at all rating dates (Table 1). Additionally, tomatoes exposed to Trimec Classic (PBI/Gordon Corporation) were not different from the water control until 16 days after treatment (DAT). Conversely, tomato plants exposed to turf treated with Speedzone (PBI/Gordon Corporation), 4 Speed XT (Nufarm, Burr Ridge, Ill.), and Cool Power (PBI/Gordon Corporation) had lower quality (≤5.1) at all rating dates when compared with the water control. Tomatoes exposed to 2,4-D butyl ester had the lowest visual quality (≤ 2.8) at all rating dates and was lower than all other treatments at 1, 10, and 16 DAT.

In Study 2, Trimec Classic, Imprelis SL (DuPont, Wilmington, Del.), and Surge did not reduce tomato quality compared with the water control; all had tomato quality ratings ≥7.7 for each rating date (Table 2). Conversely, tomatoes exposed to Speedzone and 2,4-D butyl ester had lower quality ratings (≤6.0) than the water control at all rating dates. Although Speedzone reduced quality compared with the water control, quality was still higher than that caused by 2,4-D butyl ester at all rating dates except for 1 DAT. Tomatoes did not receive a quality rating ≥4.0 after exposure to 2,4-D butyl ester at any rating date.

Field Studies

Tomato quality after exposure to turf treated with Imprelis SL was not different from the untreated control at any rating date: all these treatments had quality ratings ≥7.6 (Table 3). Conversely, tomato plants exposed to Speedzone had lower quality ratings at all rating dates compared with the water control. Tomatoes exposed to 2,4-D butyl ester had the lowest visual quality (≤5.3) at all rating dates.

Table 1. Effect of herbicide volatility on tomato plant visual quality after potted tomato plants were enclosed in a chamber with herbicide-treated tall fescue for 24 hours in Study 1

	Quality[1,2]			
Treatment[3]	1 DAT[4]	3 DAT	10 DAT	16 DAT
Water control	8.6 a	8.5 a	8.5 a	8.6 a
Confront	8.6 a	8.5 a	8.1 a	8.5 ab
Surge	8.3 a	8.3 a	8.5 a	8.6 a
Trimec Classic	8.5 a	8.3 a	8.5 a	7.8 b
Escalade II	8.0 a	7.6 a	8.0 a	8.0 ab
Speedzone	3.0 b	3.3 b	5.1 b	4.6 c
4 Speed XT	2.6 b	3.1 b	4.6 bc	4.6 c
Cool Power	2.5 b	2.8 b	4.1 c	4.3 c
2,4-D butyl ester	1.6 c	2.8 b	2.5 d	1.5 d

[1] Tomatoes were rated on a 1 to 9 scale (1 = dead; 9 = green, healthy, turgid plants).
[2] Means followed by the same letter in a column are not statistically different ($P \leq 0.05$) by Fisher's least significant difference test.
[3] Treatments were ranked over 3 days after treatment (DAT).
[4] Days after treatment.

Table 2. Effect of herbicide volatility on tomato plant visual quality after potted tomato plants were enclosed in a chamber with herbicide-treated tall fescue for 24 hours in Study 2

	Quality[1,2]			
Treatment[3]	1 DAT[4]	3 DAT	10 DAT	16 DAT
Trimec Classic	8.8 a	8.5 a	8.4 a	8.3 a
Water control	8.7 a	8.5 a	8.3 a	8.2 a
Imprelis SL	8.5 a	8.6 a	8.1 a	8.4 a
Surge	8.5 a	8.6 a	8.2 a	7.7 a
Speedzone	3.8 b	6.0 b	5.8 b	4.9 b
2,4-D butyl ester	3.5 b	4.0 c	3.3 c	1.9 c

[1] Tomatoes were rated on a 1 to 9 scale (1 = dead; 9 = green, healthy, turgid plants).
[2] Means followed by the same letter in a column are not statistically different ($P \leq 0.05$) by Fisher's least significant difference test.
[3] Treatments were ranked over 1 day after treatment (DAT).
[4] Days after treatment.

Table 3. Effect of herbicide volatility on tomato plant visual quality after potted tomato plants were exposed to herbicide-treated tall fescue in the field for 12 hours in 2011

	Quality[1,2]			
Treatment[3]	2 DAT[4]	7 DAT	10 DAT	16 DAT
Imprelis SL	7.7 a	7.7 a	7.7 a	7.8 a
Water control	7.7 a	7.7 a	7.6 a	7.6 a
Speedzone	6.4 b	6.0 b	6.2 b	6.4 b
2,4-D butyl ester	5.3 c	5.3 c	5.1 c	5.0 c

[1] Tomatoes were rated on a 1 to 9 scale (1 = dead; 9 = green, healthy, turgid plants).
[2] Means followed by the same letter in a column are not statistically different ($P \leq 0.05$) by Fisher's least significant difference test.
[3] Treatments were ranked over 10 days after treatment (DAT).
[4] Days after treatment.

Figure 1. Spray chamber and turf placement.

Figure 2. Tomato placement on treated turf in translucent plastic containers.

Figure 3. Effects of water control and 2,4-D butyl ester on tomatoes 16 days after treatment.

Figure 4. Effects of water control and Speedzone on tomatoes 16 days after treatment.

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

Effect of Glyphosate Application Timing on Rough Bluegrass Control

Objective: Determine the most appropriate time of year to apply glyphosate for optimum rough bluegrass control.

Investigators: Cole Thompson, Jack Fry, and Megan Kennelly

Introduction

Roughstalk bluegrass (*Poa trivialis* L.) is a problematic weed in tall fescue (*Festuca arundinacea* Schreb.) and Kentucky bluegrass (*Poa pratensis* L.) lawns and roughs, as well as creeping bentgrass (*Agrostis stolonifera* L.) fairways and tees. Chemical control of rough bluegrass can prove challenging because herbicides labeled for the selective removal of the species are limited. Nonselective herbicides can control rough bluegrass, and properly timed applications may offer better control. Applying a nonselective herbicide in late summer, as is often done prior to overseeding, may not effectively control rough bluegrass.

Methods

'Laser' rough bluegrass was seeded at 1.25 lb/1,000 ft^2 on September 7, 2009, within a 30 ft × 80 ft area. Research plots were set up in a randomized complete block design with four replications. Individual plots are 3 ft × 3 ft. Glyphosate (Glyphomate 41) treatments consisted of 3 application dates: May 21, July 26, and August 25, 2011, at 6.4 pints/a. Herbicide was applied in 0.8 gal water/1,000 ft^2.

Data Collection

Percentage cover and turfgrass quality were monitored weekly from May 26 through November 11, 2011. Rough bluegrass cover was again rated on April 23, 2012. Percentage cover data was taken as a visual estimate of each plot covered by rough bluegrass. Turfgrass quality was determined by considering color, density, and uniformity on a 1 to 9 scale (1 = completely brown; 6 = minimum acceptable quality; 9 = optimum color, density, and uniformity).

Data Analysis

Turfgrass quality data were normally distributed in 2011. Percentage cover data were not normally distributed, and data were subjected to a $\log_{10}(y+1)$ transformation to normalize. All data were subject to analysis of variance using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, N.C.). We used Tukey's Honestly Significant Difference (HSD) to detect treatment differences ($\alpha_{FER} = 0.05$) and to protect from inflation of Type I error during pairwise comparisons,

Preliminary Results

Turfgrass Quality

Turfgrass quality decreased through the summer in 2011, and even untreated plots averaged unacceptable quality by July 20. Rough bluegrass in untreated plots began to recover from summer stress around September 28, but plots were not considered acceptable by the end of the growing season. In 2011, we observed no recovery in plots treated with glyphosate regardless of timing.

Rough Bluegrass Coverage

As with quality, rough bluegrass coverage decreased with increasing summer temperatures. Untreated plots averaged less than 30% coverage by August 3, and were the lowest in cover on September 16 (1.3%). Rough bluegrass in untreated plots then began to recover, but averaged only 15% cover on the final rating date of the season (November 11). Rough bluegrass coverage reached 0% in all glyphosate-treated plots regardless of timing. Rough bluegrass shoots began to emerge in plots treated with glyphosate late in the fall, and mid-May, midsummer, and fall timings averaged 0.3, 1.5, and 0.5% cover, respectively, on November 11, 2011. On April 23, 2012, untreated plots averaged nearly 81% cover. Treatment with glyphosate in mid-May allowed significantly less recovery (1.3%) than the midsummer timing (7.8%) (Figures 1 and 2). Fall-applied glyphosate was not different from the other two timings.

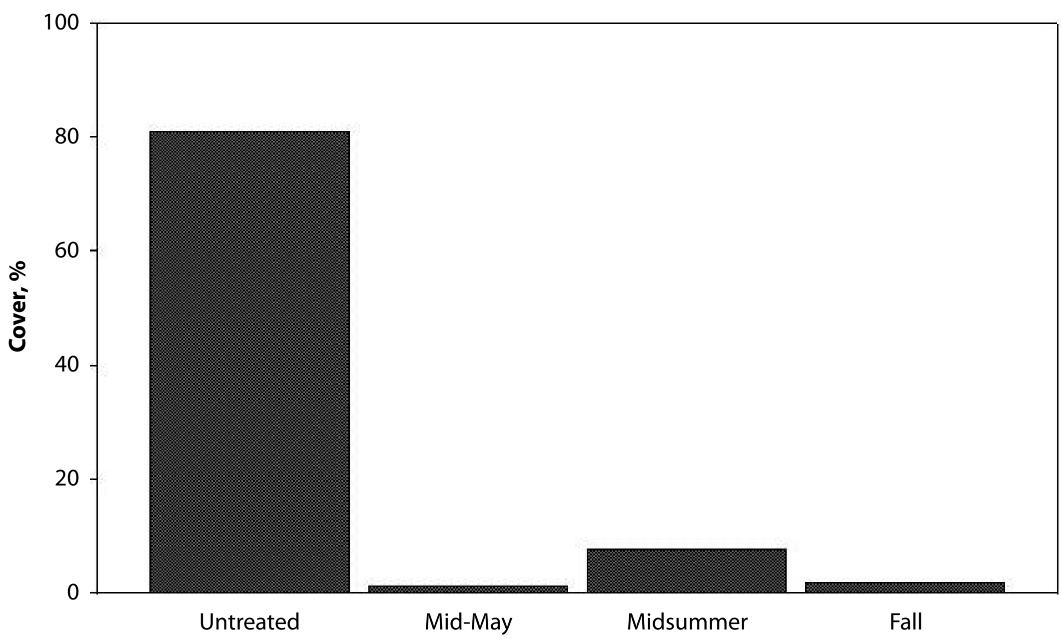

Figure 1. Rough bluegrass recovery as of April 23, 2012, after glyphosate applications in 2011. The mid-May application yielded significantly less recovery than midsummer treatment.

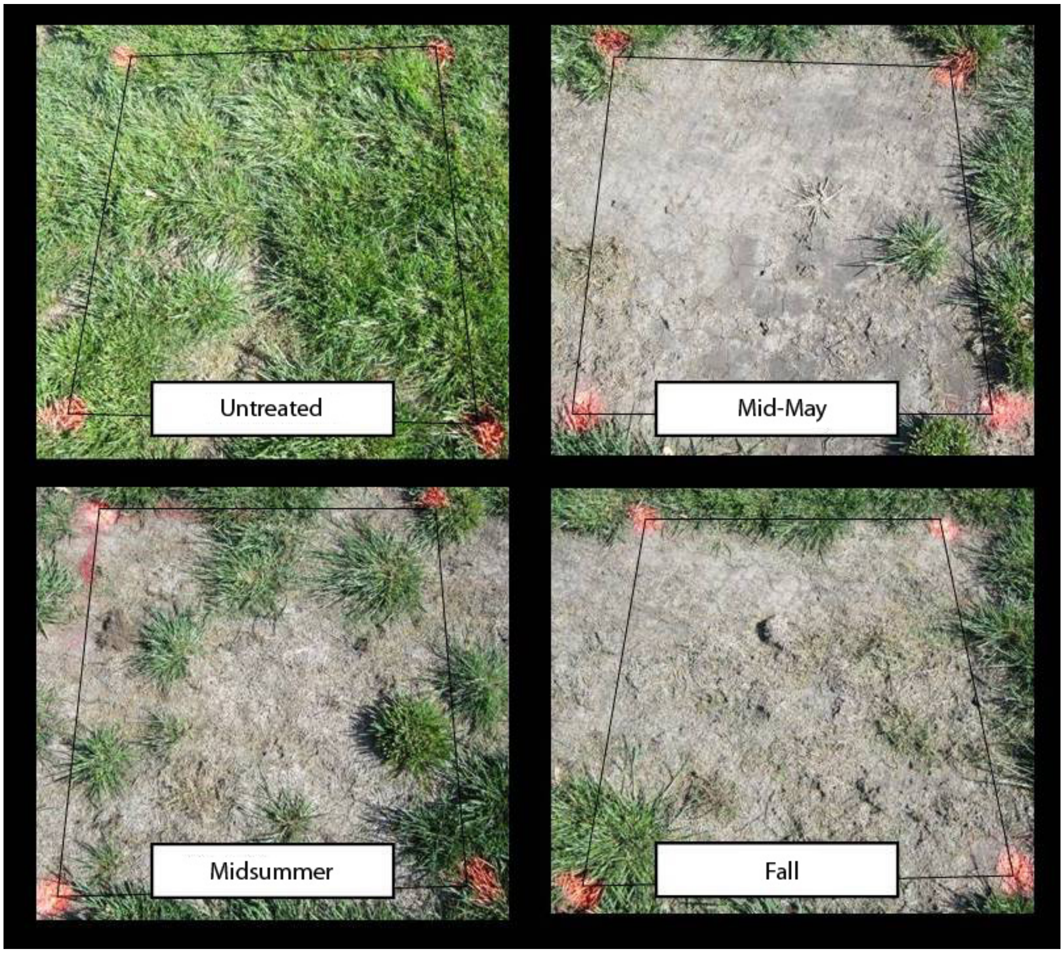

Figure 2. Rough bluegrass recovery as of April 23, 2012, after glyphosate applications in 2011. The mid-May application yielded significantly less recovery than midsummer treatment.

Evaluation of Headway G for Control of Brown Patch in Lawn-Height Tall Fescue

Objective: Evaluate a new granular fungicide for brown patch control.

Investigators: Cole Thompson and Megan Kennelly

Sponsors: Kansas Turfgrass Foundation, Syngenta

Introduction

Brown patch, caused by *Rhizoctonia solani*, is the most common disease problem on tall fescue lawns in Kansas. Identifying effective granular fungicides is a plus for lawn and landscape companies that are not equipped to apply liquids.

Methods

Headway G (Syngenta, Greensboro, N.C.) was evaluated on an established stand of tall fescue on Chase silt loam at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. The area was mown weekly at 3 in. and irrigated for 10 min. each night. Turf was fertilized with urea (46-0-0 N-P-K) to provide 1 lb N/1,000 ft^2 on June 22 and July 21 to promote brown patch development. Headway G was applied preventatively at approximately a 28-day interval at two rates on June 8, July 6, and August 3; fungicide was applied in at least two directions over plots using a shaker jar. Plots were 6 ft × 6 ft and arranged in a randomized complete block design with four replications. Disease severity and turfgrass quality were assessed weekly. Brown patch severity was determined by visually estimating the percentage of each plot affected by blight symptoms. Turfgrass quality ratings followed a 1 to 9 scale (1 = completely brown, 6 = minimum acceptable quality, and 9 = optimum green color/no disease symptoms).

Results

See Table 1 for disease assessment data. Disease pressure was very low until August and was highest on August 9, when untreated plots averaged approximately 14% blight from brown batch symptoms. Both rates of Headway G suppressed brown patch development compared with no treatment. Untreated plots averaged significantly lower turfgrass quality than plots treated with Headway G on August 9. Headway G was not phytotoxic to turf.

Table 1. Effect of Headway G on brown patch severity

Treatment[2] and rate/1,000 ft^2	Brown patch severity[1]					
	Aug. 9	Aug. 18	Aug. 28	Sept. 1	Sept. 9	Sept. 16
Untreated	13.8 a	6.3 a	11.3 a	3.8 a	5.0 a	0.0 a
3 lb Headway G	1.8 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 a
4 lb Headway G	1.5 b	0.0 b	0.5 b	0.0 b	0.0 b	0.0 a

[1] Data were collected on 15 dates from June 6 through September 16, 2011. The first nine dates have been omitted because disease pressure was very low. Values represent the average percentage of plot area blighted by brown patch symptoms. Means within columns followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference test ($\alpha = 0.05$). Values were arcsine(y) transformed for analysis and back-transformed for presentation.

[2] Treatments were applied at approximately a 28-day interval on June 8, July 6, and August 3.

Evaluation of Velista and Four Fungicide Programs for Control of Dollar Spot and Brown Patch on Creeping Bentgrass in Kansas

Objective: Evaluate fungicides and fungicide rotational programs for disease control

Investigators: Ken Obasa and Megan Kennelly

Sponsors: Kansas Turfgrass Foundation, DuPont, BASF

Introduction

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

Methods

Four fungicide programs and Velista (Dupont, Wilmington, DE) were evaluated on an established stand of a blend of 'Crenshaw' and 'Cato' creeping bentgrass on a sand-based putting green at the Rocky Ford Turf Research Center in Manhattan, Kan. The turf was mowed to a height of 0.156 in. and irrigated daily for 15 min. The area was fertilized biweekly with 0.25 lb N/1,000 ft^2 using urea (46-0-0 N-P-K) in March through June and 0.33 lb N/1,000 ft^2 in July through November. Beginning on May 19, Velista was applied at two application rates, and four fungicide programs with eight individual fungicide applications were made at 14-day intervals. Fungicides were applied with a CO_2-powered boom sprayer equipped with two XR Tee Jet 8002VS nozzles (Tee Jet, Wheaton, Ill.) at 30 psi in water equivalent to 2.2 gal/1,000 ft^2. Plots were 6 ft × 4 ft and arranged in a randomized complete block design with three replications. Plots were rated periodically by visually estimating the percentage of each plot affected by dollar spot and brown patch, as well as assessing turf quality using a 1 to 9 quality rating scale (1 = dead turf; 6= acceptable quality; 9 = optimum quality). Disease and quality data were subjected to analysis of variance and treatment means were compared using Fisher's individual error rate at a $P = 0.05$.

Results

Dollar spot and brown patch activity were not visible until the first week in August (Table 1). At this time, disease symptoms were visible in the untreated plots. Trace (<2%) levels of disease were evident in programs 1, 2, and 4, but they were not significantly ($P = 0.05$) different from the other treated plots, which had no disease symptoms throughout the study period. The four fungicide programs and the applications of Velista successfully controlled dollar spot and brown patch symptoms throughout the study period. Turfgrass quality was significantly higher in the treated plots compared with the untreated plots. We found no significant differences in turfgrass quality among the fungicide treatments and observed no phytotoxicity or growth regulator effects.

Table 1. Effect of Velista and four fungicide programs on dollar spot, brown patch, and quality

	Spray interval	Dollar spot severity[1]					Brown patch severity[2]				Mean[3] turf
Treatment[4]	(days)	Aug. 11	Aug. 18	Aug. 25	Sept. 1	Sept. 12	Sept. 22	Aug. 11	Aug. 18	Aug. 25	quality
Untreated control	-	1.3 a	4.3 a	3.8 a	20.8 a	26.7 a	17.7 a	38.7 a	5.7 a	0.0 b	7.1 b
Program 1	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	2.0 a	8.1 a
Program 2	14	0.0 b	0.7 b	0.3 b	0.3 b	0.0 b	0.3 b	0.0 b	0.0 b	0.0 b	8.3 a
Program 3	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	8.1 a
Program 4	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.3 b	0.0 b	0.0 b	0.0 b	8.4 a
Velista 50 WDG (0.3 oz)	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	8.0 a
Velista 50 WDG (0.5 oz)	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	8.1 a

[1] Values represent the average percentage of plot area with dollar spot symptoms. Means within columns followed by the same letter are not significantly different according to Fisher's pairwise comparisons (family error rate $P = 0.05$).

[2] Values represent the average percentage of plot area with brown patch symptoms. Means within columns followed by the same letter are not significantly different according to Fisher's pairwise comparisons (family error rate $P = 0.05$).

[3] Means within columns followed by the same letter are not significantly different according to Fisher's pairwise comparisons (individual error rate $P = 0.05$).

[4] 14-day interval application calendar dates were May 19, June 2, June 17, June 30, July 14, July 28, August 11, and August 25. A final application of Velista was made on September 8. Programs and their respective order of applied fungicides and rates/1,000 ft^2 includes:

Program 1: Honor 50WG (1.1 oz), Insignia SC (0.7 fl oz), Spectro 90 WDG (5.75 oz), Signature 80WG + Daconil Ultrex 82.5WDG (4 oz + 3.2 oz), Insignia SC (0.7 fl oz), Signature 80WG + Daconil Ultrex 82.5WDG (4 oz + 3.2 oz), Chipco 26GT 2SC (4 fl oz), Honor 50WG (1.1 oz); **Program 2**: Headway 1.39ME (3 fl oz), Heritage TL 0.8ME (2 fl oz), Spectro 90 WDG (5.75 oz), Signature 80WG + Daconil Ultrex 82.5WDG (4 oz + 3.2 oz), Heritage TL 0.8ME (2 fl oz), Signature 80WG + Daconil Ultrex 85.5WDG (4 oz + 3.2 oz), Chipco 26GT 2SC (4 fl oz), Headway 1.39ME (3 fl oz); **Program 3**: Disarm M 15SC (1 fl oz), Disarm 480SC (0.36 fl oz), Spectro 90 WDG (5.75 oz), Signature 80WG + Daconil Ultrex 82.5WDG (4 oz + 3.2 oz), Disarm 480SC (0.36 fl oz), Signature 80WG + Daconil Ultrex 82.5WDG (4 oz + 3.2 oz), Chipco 26GT 2SC (4 fl oz), Disarm M 15SC (1 fl oz); and **Program 4**: Tartan 2.4SC (2 fl oz), Compass 50WG (0.25 oz), Spectro 90 WDG (5.75 oz), Signature 80WG + Daconil Ultrex 82.5WDG (4 oz + 3.2 oz), Chipco 26GT 2SC (4 fl oz), Tartan 2.4SC (2 fl oz).

Evaluation of Cold-Hardy Zoysiagrass Breeding Lines for Susceptibility to Large Patch

Objective: Evaluate 14 new freeze-tolerant zoysiagrass progeny.

Investigators: Ken Obasa, Jack Fry, and Megan Kennelly

Sponsors: Kansas Turfgrass Foundation, U.S. Golf Association, Heart of America Golf Course Superintendents' Association, Kansas Golf Course Superintendents' Association

Introduction

Since 2004, turfgrass researchers at Kansas State University have evaluated over 600 new zoysiagrass progeny for winter survival and quality. These progeny were the result of crosses made at Texas A&M-Dallas, most of which involved one parent from *Z. japonica* and one from a *Z. matrella* cultivar or 'Emerald' (*Z. japonica* × *Z. pacifica*). The crosses were made in an effort to develop one or more cultivars with freezing tolerance as good as or better than 'Meyer,' as well as good density, finer leaf texture, and quality. In a recent study, K-State Ph.D. student David Okeyo found that zoysiagrass progeny associated with reciprocal crosses of *Z. matrella* (L.) Merr. × *Z. japonica* or 'Emerald' × Meyer, 'Cavalier' (*Z. matrella*), and DALZ 0102 (*Z. japonica*) showed freezing tolerance comparable with 'Meyer.' The goal of this study was to evaluate the susceptibility to large patch of 14 new freeze-tolerant zoysiagrass progeny and 'Meyer' under growth chamber and field conditions. The 14 progeny are a subset of selections made from evaluations of the original 600 zoysiagrass progeny for cold tolerance and the other traits. The breeding lines evaluated are listed in Tables 1 and 2.

Methods

Laboratory Growth Chamber Studies

Stolons of the 14 new lines and Meyer were propagated in the greenhouse. Each type was inoculated with oats infested with the large patch pathogen. After five days, and at 5-day intervals thereafter for 25 days, three pots of each line were randomly selected and removed from the growth chamber for destructive sampling. They were rated for disease incidence by determining the percentage of individual shoots in each pot with distinct, water-soaked brown lesions on the leaf sheath. After 25 days, the three uninoculated pots of each zoysia line were also removed from the growth chamber and similarly rated for disease incidence as controls. This study was conducted in 2009 and repeated in 2010.

Field Studies

The study was conducted at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. Plots of the new zoysiagrass progeny and Meyer measuring 5 ft × 5 ft were used for the study. The plots were arranged in a randomized complete block design with three replicates per line. All the plots were inoculated with large patch in September of 2008.

In the spring of 2009, patch diameters in progeny field plots were measured weekly. Additionally, analysis of digital images of plots was carried out in 2010 to determine the percentage of non-green (blighted) turf per plot.

Results

Growth Chamber

Based on overall disease development over the 25 days of the study, none of the progeny had disease levels significantly different from 'Meyer' (data not shown).

Field

In 2009, patch diameters in the new lines were not significantly different from those of 'Meyer' on June 12 and 19 (Table 1). We found no differences in percentage of diseased turf based on three weeks of digital image analysis in 2009 (data not shown). In 2010, the area under the disease progress curve (AUDPC) of 'Meyer,' a cumulative measure of disease development based on digital image analysis from May 1 through June 24, was significantly lower compared with eight (5313-71, 5313-46, 5327-67, 5325-11, 5324-32, DALZ 0102, 5324-26, and 5321-9) of the new lines (Table 2). The remaining six of the 13 new lines (5313-23, 5313-34, 5321-18, 5334-59, 5312-55, and 5311-16) had AUDPC values that were not statistically different from Meyer.

Correlation Analysis

We compared the results for the performance of the progeny based on their average AUDPC values for 2009 and 2010 under growth chamber and field conditions, respectively, and found no significant correlation. Additionally, we found no significant correlation between the performance of the progenies under growth chamber conditions in 2009 and 2010 and no significant correlation between the 2009 and 2010 field studies. The lack of correlation among the different tests indicates high inherent variability in this study system, which means that growth chamber assays are unlikely to be able to serve as shortcuts/replacements for field studies. In the future, screenings for large patch should occur at several locations in large replicated plots unless a modified greenhouse or lab test is developed that can reliably predict field performance.

Table 1. Large patch diameter and percentage of new zoysiagrass lines and 'Meyer' under field conditions at Manhattan, Kan., in 2009

	Avg. patch diameter (cm)[1]	
Parent/progeny[2]	June 12	June 19
Cavalier × Chinese Common		
5311-16	109.0	114.0
5312-55	116.5	116.0
Zorro × Meyer		
5313-23	128.5	121.5
5313-34	105.8	111.8
5313-71	118.3	120.3
5313-46	99.5	115.5
Emerald × Meyer		
5321-9	103.8	115.8
5321-18	119.3	119.5
Meyer × 8501		
5324-26	109.5	116.0
5324-32	91.0	118.5
Meyer × 8508		
5325-11	104.0	120.2
Meyer × Diamond		
5327-67	128.8	127.8
Emerald × Zenith		
5334-59	131.3	113.3
DALZ 0102	113.5	96.8
Meyer	127.5	117.8

[1] Plots were inoculated in fall 2008.
[2] Meyer, DALZ 0102, and Anderson (Chinese common) = *Z. japonica*. Zorro, 8501, 8508, and Diamond = *Z. matrella*.

Table 2. Percentage of large patch (caused by *R. solani* AG 2-2 LP) diseased turf of new zoysiagrass lines and 'Meyer' under field conditions at Manhattan, Kan., 2010

	Percentage of diseased turf[1, 2]				
Parent/progeny	May 1	May 7	May 28	June 24	AUDPC[3]
Cavalier × Chinese Common					
5311-16	28.6ef	27.2de	36.6de	17.1bc	86.7ef
5312-55	38.0cdef	39.9cde	47.0bcde	9.5c	110.6def
Zorro × Meyer					
5313-23	61.3abcd	46.1cde	45.3bcde	8.6c	126.4cdef
5313-34	48.4bcdef	43.8cde	48.4bcde	11.6bc	122.2def
5313-71	79.9a	80.2a	77.9a	39.7a	217.9a
5313-46	77.2a	72.2ab	76.8a	12.3bc	193.9ab
Emerald × Meyer					
5321-9	58.1abcd	50.8bcd	43.9cde	15.3bc	131.4cde
5321-18	27.8ef	35.2cde	54.9bcd	18.4bc	113.2def
Meyer × 8501					
5324-26	52.8abcde	45.6cde	53.7bcd	14.3bc	132.8cde
5324-32	61.7abcd	47.8bcde	65.9ab	11.1bc	150.1bcd
Meyer × 8508					
5325-11	64.6abc	58.7abc	60.4abc	18.0bc	160.4bcd
Meyer × Diamond					
5327-67	70.1ab	72.3ab	66.0ab	14.1bc	180.4abc
Emerald × Zenith					
5334-59	35.2def	29.8de	49.4bcde	27.2ab	110.4def
DALZ 0102	53.4abcde	57.3abc	52.1bcde	13.2bc	142.7bcd
Meyer	20.14f	23.5e	31.0e	19.8bc	74.5f

[1] For digital image analysis, values show percentage of pixels representing large patch symptom from digital images taken of plots of each zoysiagrass line and averaged across three replicated plots per line.

[2] Within a column, values followed by a letter in common are not statistically different (error level 5%).

[3] Area under disease progress curve (AUDPC) is a cumulative measure of disease development summed over time.

Evaluation of Spring and Fall Fungicide Applications for Large Patch Management in Zoysiagrass

Objective: Evaluate fungicide timing for large patch control.

Investigators: Ken Obasa, Jack Fry, Megan Kennelly

Sponsors: U.S. Golf Association, Heart of America Golf Course Superintendents' Association, Kansas Golf Course Superintendents' Association, Kansas Turf Foundation

Introduction

Preventative fungicide applications made before the development of large patch symptoms have been demonstrated to provide better disease control than applications made after the onset of disease symptoms. Preventative applications made in the fall not only inhibit fall symptoms, but also suppress or delay disease development during the following spring; however, the timing and number of applications need further optimization. The goal of this study was to evaluate different fungicides and fungicide timings for large patch control.

Methods

The study was conducted on two stands of the cultivar 'Meyer' at the Rocky Ford Turfgrass Research Center in Manhattan, Kan. Plots used for the fall application study were inoculated on September 26, 2007. Plots used in the spring studies were inoculated on September 25, 2008. The dates of the fungicide applications are shown in Figures 1–5. Thatch temperatures were measured using soil-encapsulated thermocouples. The average thatch temperature for the seven days prior to each application is provided in Figures 1–5.

Flutolanil was applied as ProStar 70WP (Bayer Crop Science, Research Triangle Park, N.C.) at a product rate of 2.2 oz/1,000 ft^2. Azoxystrobin was applied as Heritage 50WDG (Syngenta, Greensboro, N.C.) at a product rate of 0.2 oz/1,000 ft^2. Triticonazole was applied as Trinity 1.69SC (BASF) at a product rate of 1.5 oz/1,000 ft^2. All fungicide applications were made with a CO_2-powered boom sprayer with XR Tee Jet 8003VS nozzles (Tee Jet, Wheaton, Ill.) at 30PSI in water equivalent to 2 gal/1,000 ft^2. Disease was assessed by measuring patch size diameters and/or digital image analysis (estimated percentage of non-green turf per plot). Area under the disease progress curve (AUDPC) is a measure of season-long disease activity that sums disease over time. We calculated AUDPC for some seasons.

Results

Effect of Fall 2008 Applications of Flutolanil on Disease in Spring 2009

After inoculations in fall 2008, patch sizes in the untreated plots on May 15, 2009, were 70.5 cm (Figure 1). All applications except the September 9 application of flutolanil reduced patch size significantly compared with the untreated plot, and we found no significant differences among those treatments. In general, two applications did not perform better than one; for example, using two applications on September 16 and 30 did not perform better than either date alone. Two applications on September 23 and October 7 did not perform better than September 23 alone. Although the September 9 and 23 double application performed better than September 9, it did not perform better than September 23 alone.

Effect of Fall 2009 Applications of Flutolanil, Azoxystrobin, and Triticonazole on Large Patch in Spring 2010

The patches had outgrown the plots by spring 2010, so we used digital image analysis to determine the percentage blighting in the plots. In the untreated plots, blighting was about 40% (Figure 2). The September 3 application of flutolanil did not reduce disease compared with the control. All other treatments reduced disease compared with the control. The September 24 application of triticonazole did not perform as well as some of the other treatments.

Effect of Spring 2009 Applications on Disease in Spring 2009

Based on AUDPC values calculated from weekly patch size measurements, all the application regimes, with the exception of azoxystrobin applied on May 8, resulted in significantly reduced disease compared with the untreated control (Figure 3). In general, double fungicide applications did not reduce AUDPC compared with single fungicide applications.

For the single applications made on May 1, triticonazole had a significantly lower disease than flutolanil but not azoxystrobin. The single application of azoxystrobin made on May 1 had lower disease than its single application made on May 8 and double azoxystrobin applications on May 8 and 22. The disease levels of treatments receiving sequential applications of azoxystrobin or flutolanil on May 1 and 15 were not significantly different from the corresponding single application on May 1; furthermore, disease in plots receiving sequential applications of either fungicide on May 8 and 22 was not significantly different from that in plots receiving the single application on May 8.

On June 26, when patch margins were indistinct and digital analysis was used, plots that received a single azoxystrobin, triticonazole, or flutolanil application on May 1, or a double application for which the first treatment occurred May 1, had significantly lower percentages of diseased turf than the untreated control (Figure 4). The sequential applications of flutolanil and azoxystrobin on May 8 and 22 also reduced disease compared with the untreated control. Disease in turf receiving sequential applications was not significantly different from that in turf receiving one fungicide application.

Effect of Spring 2010 Applications on Disease in Spring 2010

The AUDPC values for large patch, calculated from digital image analysis over several weeks, of single applications of flutolanil, azoxystrobin, and triticonazole on April 16 and 23 indicated lower percentages of diseased turf compared with the untreated control (Figure 5). For applications made on April 30 and May 7, only azoxystrobin consistently resulted in significantly lower overall (AUDPC) percentages of diseased turf compared with the untreated control.

Discussion

The timing of fungicide applications for turfgrasses can be scheduled based on calendar dates, weather, scouting, or combinations of those factors. Environmental conditions and soil microclimate, which may influence the efficacy of applied fungicides, vary from year to year; for instance, thatch temperatures were slightly higher in the fall of 2009 compared with similar periods in 2008 during the fall fungicide application-timing studies. Temperatures also fluctuated in some seasons.

The single applications of flutolanil on September 9, 2008, and September 3, 2009, when the thatch temperature averaged 69 and 71°F, respectively, failed to achieve a significant reduction in patch sizes compared with the untreated controls. In contrast, single applications of azoxystrobin and triticonazole made on September 3, 2009, resulted in significantly reduced patch sizes compared with the untreated control. Aside from the failure of the first fall flutolanil applications to manage large patch, fall application timings at thatch temperatures from 61 to 74°F across the two years of the study reduced disease compared with the untreated control.

Because the fungicides are locally systemic, the first spring applications were made after the turf had broken dormancy and plots were mostly green to allow for the uptake of the fungicides by the growing plants. The results of the 2009 and 2010 spring application studies showed that the earlier fungicide applications provided better control of large patch symptoms.

This study did not use predetermined specific thatch temperatures as triggers for application timing. Additional studies should be done using more targeted thatch temperatures and other environmental factors as a guide for fungicide deployment in the management of large patch to further determine suitability and applicability of the different classes of fungicides used in the management of the disease. The mode of action of each fungicide, the fungicide rate, the ability of the plant to take up the fungicides at different temperatures, and/or environmental factors not considered in this study may play a role.

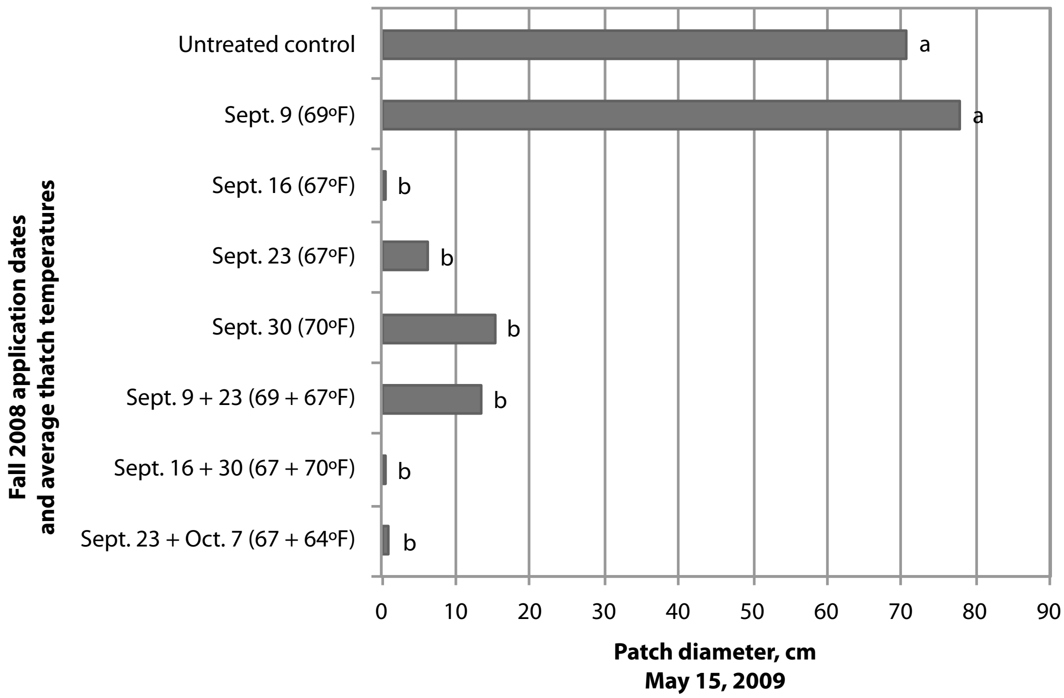

Figure 1. Effect of fall 2008 applications of flutolanil on disease in spring 2009. Treatments (bars) followed by the same letter are not statistically different (*P* < 0.05).

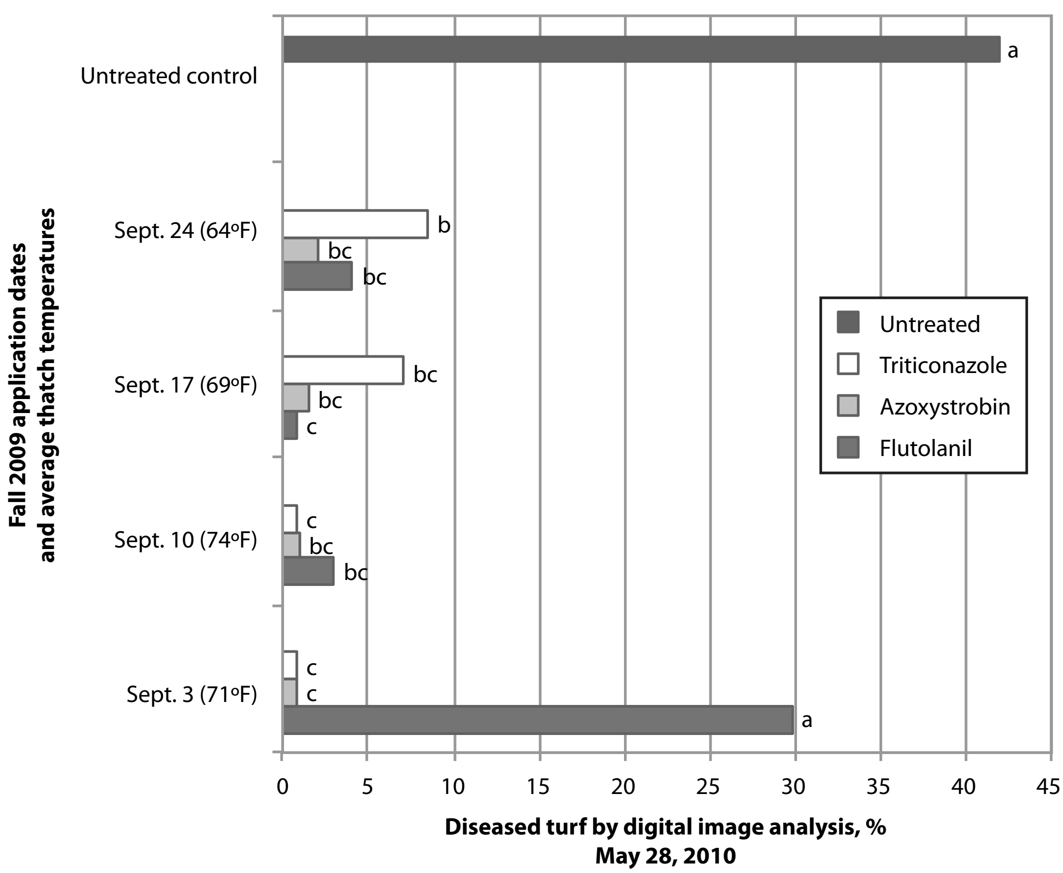

Figure 2. Effect of fall 2009 applications of fungicides on disease in spring 2010. Treatments (bars) followed by the same letter are not statistically different (*P* < 0.05).

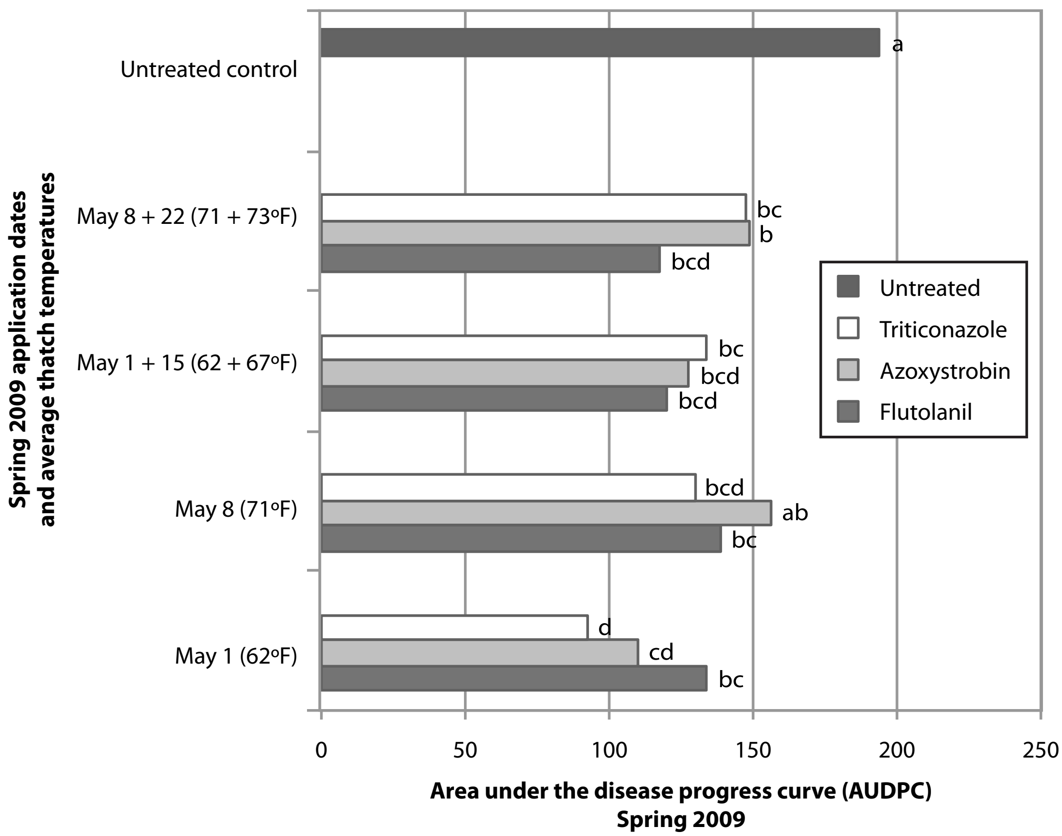

Figure 3. Effect of spring 2009 applications of fungicides on disease in spring 2009, based on patch size. Treatments (bars) followed by the same letter are not statistically different ($P < 0.05$).

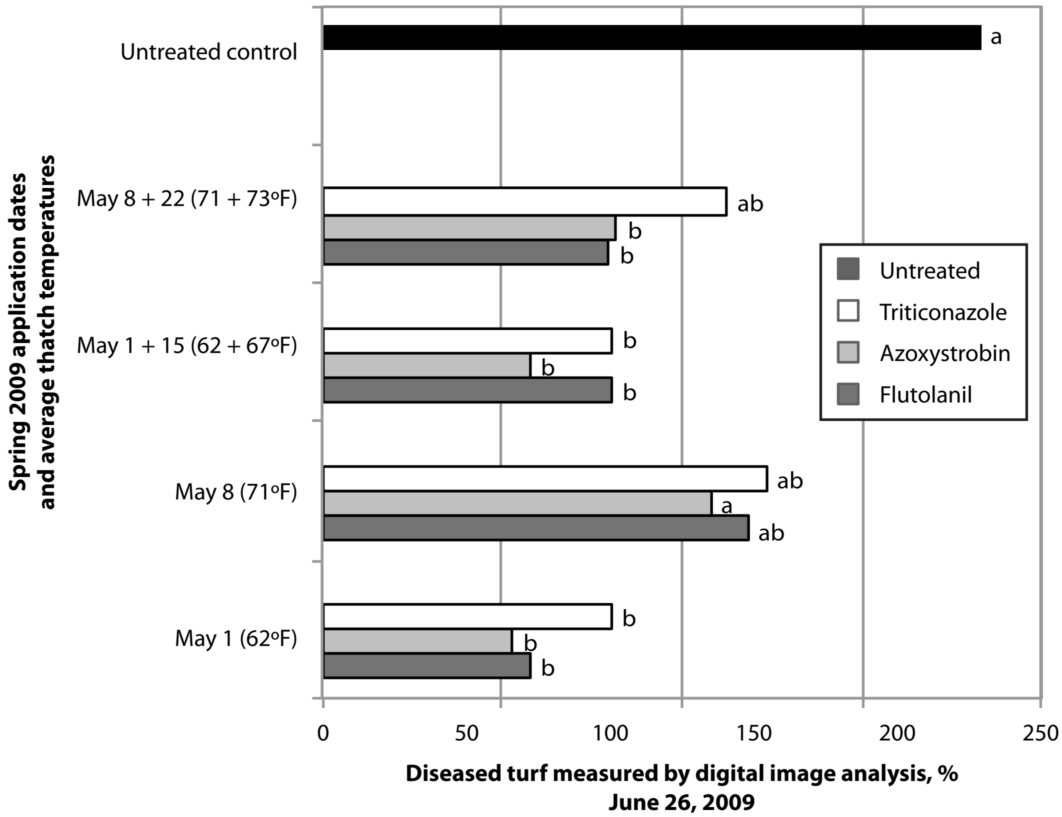

Figure 4. Effect of spring 2009 applications of flutolanil on disease in spring 2009, based on digital image analysis. Treatments (bars) followed by the same letter are not statistically different ($P < 0.05$).

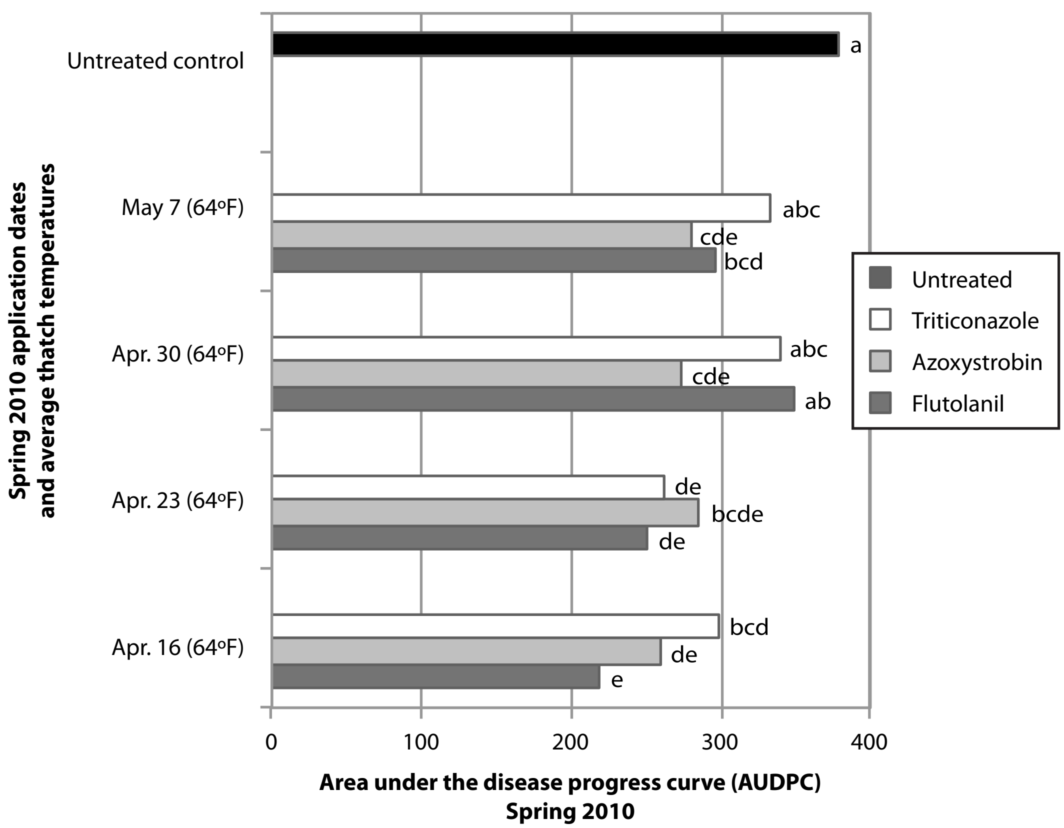

Figure 5. Effect of spring 2010 applications of fungicide on disease in spring 2010. Treatments (bars) followed by the same letter are not statistically different ($P < 0.05$).

Physiological and Pathological Contributors to Rough Bluegrass Decline

Objectives: 1) Observe seasonal physiological changes of rough bluegrass, 2) evaluate fungicides as a summer decline mitigation strategy for rough bluegrass, and 3) determine if a pathogen is contributing to the seasonal decline of rough bluegrass.

Investigators: Cole Thompson, Jack Fry, and Megan Kennelly

Introduction

Roughstalk bluegrass (*Poa trivialis* L.) is a fine-textured, cool-season, perennial turfgrass species that spreads via seed and stolons. The species is used in wet, shady areas in northern climates and cool-humid regions and is also commonly used in warmer climates to overseed dormant bermudagrass (*Cynodon* spp.) during winter months. Rough bluegrass has excellent cold tolerance but poor drought and heat tolerance, making it a problematic weed in tall fescue (*Festuca arundinacea* Schreb.) and Kentucky bluegrass (*Poa pratensis* L.) lawns and roughs as well as creeping bentgrass (*Agrostis stolonifera* L.) fairways and tees. Rough bluegrass will encroach on desired turf species with favorable growing conditions, but will enter a stress-induced dormancy with undesirable heat or drought stress, leaving behind brown patches of dormant turf that can be easily mistaken for disease. Because it can be a contaminant included under the "other crop" category on seed labels, the species is often unknowingly planted along with desirable turfgrass species.

Methods

'Laser' rough bluegrass was seeded at 1.25 lb/1,000 ft^2 on September 7, 2009, within a 30 ft × 80 ft area. Research plots were established in a randomized complete block design with four replications. Individual plots were 3 ft × 3 ft. Treatments consisted of 4 fungicides: azoxystrobin (Heritage, Syngenta, Greensboro, N.C.) at 0.4 oz/1,000 ft^2, azoxystrobin (Heritage TL) at 2 fl oz/1,000 ft^2, pyraclostrobin (Insignia) at 0.9 oz/1,000 ft^2, and pyraclostrobin (Insignia SC, BASF, Research Triangle Park, N.C.) at 0.7 fl oz/1,000 ft^2. Treatments were applied at two-week intervals from May 21 through August 23, 2011.

Data Collection

Percentage cover, turfgrass quality, photosynthetic rate, and electrolyte leakage were monitored weekly. Percentage cover data was taken as a visual estimate of each plot covered by rough bluegrass. Turfgrass quality included color, density, and uniformity on a 1 to 9 scale (1=completely brown; 6=minimum acceptable quality; 9=optimum color, density, and uniformity). Photosynthetic rate was estimated by monitoring carbon dioxide concentrations using a non-steady state chamber that was developed at Kansas State University and configured with a closed path infrared gas analyzer (LI-840, Li-Cor Industries, Lincoln, Neb.).

Electrolyte leakage is a measure of cell membrane thermostability. Leaf samples were collected weekly from field plots. For each plot, samples were collected from the healthiest areas in the plot. For each sample, three 1-in. segments were then collected from fully expanded leaves and placed in a test tube containing 25 mL of distilled water. Samples were then agitated for 24 hours to remove electrolytes adhering to and released from cutting plant tissue. After shaking for 24 hours, the electrical conductivity of the solution in each test tube was measured, and test tubes were placed in a 90°C (194°F) water bath for 1 hour. After agitating samples for an additional 24 hours, final electrical conductivity measurements were taken. Resulting electrolyte leakage (%) is the ratio of initial and final electrical conductivity measurements.

Plots were sampled for the presence of pathogens on May 24 and July 11, 2011. On May 24, two 1-in.-diameter × 6-in.-deep plugs were removed from each plot and incubated in a sealed, clear bag with a moist paper towel. Foliage was analyzed for lesions the following day, and roots were soaked in water overnight to loosen field soil. Soil was removed from roots the following day, and roots were analyzed for the presence of pathogens/overall health. On July 11, one 4-in.-diameter × 6-in.-deep plug was removed from each plot. Plugs were incubated overnight, and foliage was examined the following day. Five pieces of leaf tissue (approximately 5mm in length) that exhibited both healthy and necrotic tissue were plated on one-quarter strength potato dextrose agar (¼ PDA ++). Tissue was surface-sterilized in 10% bleach, rinsed in sterile water, and blotted dry before plating. Cultures were examined after three days. For root analysis, approximately 1 in. of the margin of each plug was removed, soaked, and cleaned. On both sampling dates, roots were examined under a compound microscope in at least 10 fields of view. Roots were rated on a 1 to 5 scale (1 = mushy/rotten; 2 = mostly dark roots; 3 = some tan roots; some dark, some tissue sloughing, small amount of dark fungal runner hyphae; 4 = a few tan/dark roots; and 5 = healthy, no oospores, good root hairs).

Data Analysis

Turfgrass quality and grid-based data were normally distributed in 2011. Percentage cover and electrolyte leakage data were not normally distributed, and data were subjected to a $\log_{10}(y+1)$ transformation to normalize. All data were subject to analysis of variance using the GLIMMIX procedure of SAS (SAS Institute Inc., Cary, N.C.). Tukey's Honestly Significant Difference (HSD) was used to detect treatment differences (α_{FER} = 0.05) to protect from inflation of Type I error during pairwise comparisons.

Preliminary Results

Gross Photosynthesis

Photosynthetic rates of rough bluegrass declined during the summer of 2011; furthermore, fungicide applications did not help rough bluegrass maintain maximum rates of photosynthesis during periods of heat stress. Compared with untreated plots, however, plots treated with Heritage TL averaged significantly greater gross photosynthesis on June 15 and August 16, and plots treated with Insignia SC averaged significantly greater gross photosynthesis than untreated plots on June 15 and June 28, 2011 (Figure 1).

Turfgrass Quality

No treatment resulted in acceptable rough bluegrass quality throughout the summer in 2011. All treatments averaged unacceptable quality by July 27 and failed to return to an acceptable level before the end of the 2011 growing season (Figure 2). Compared with untreated plots, plots treated with Heritage TL averaged higher quality on 11 dates, plots treated with Heritage averaged higher quality on four dates, and plots treated with Insignia WG averaged higher quality on two dates. Treatment with Insignia SC never resulted in higher quality than untreated in 2011.

Rough Bluegrass Coverage

No treatment maintained rough bluegrass cover through the summer in 2011. All treatments averaged 50% (or less) by August 3 and did not average more than 25% cover by the end of the growing season (Figure 3). Compared with untreated, plots treated with Heritage TL averaged greater rough bluegrass coverage on 12 dates (Figure 4), plots treated with Heritage averaged greater cover on seven dates, plots treated with Insignia WG averaged greater cover on two dates, and plots treated with Insignia SC averaged greater coverage on one date in 2011.

Electrolyte Leakage and Disease Sampling

Electrolyte leakage was never greater than 30% for any treatment. Untreated plots averaged greater electrolyte leakage than all fungicide treatments on one date (August 23). No foliar or root pathogens were consistently detected on either disease sampling date in 2011.

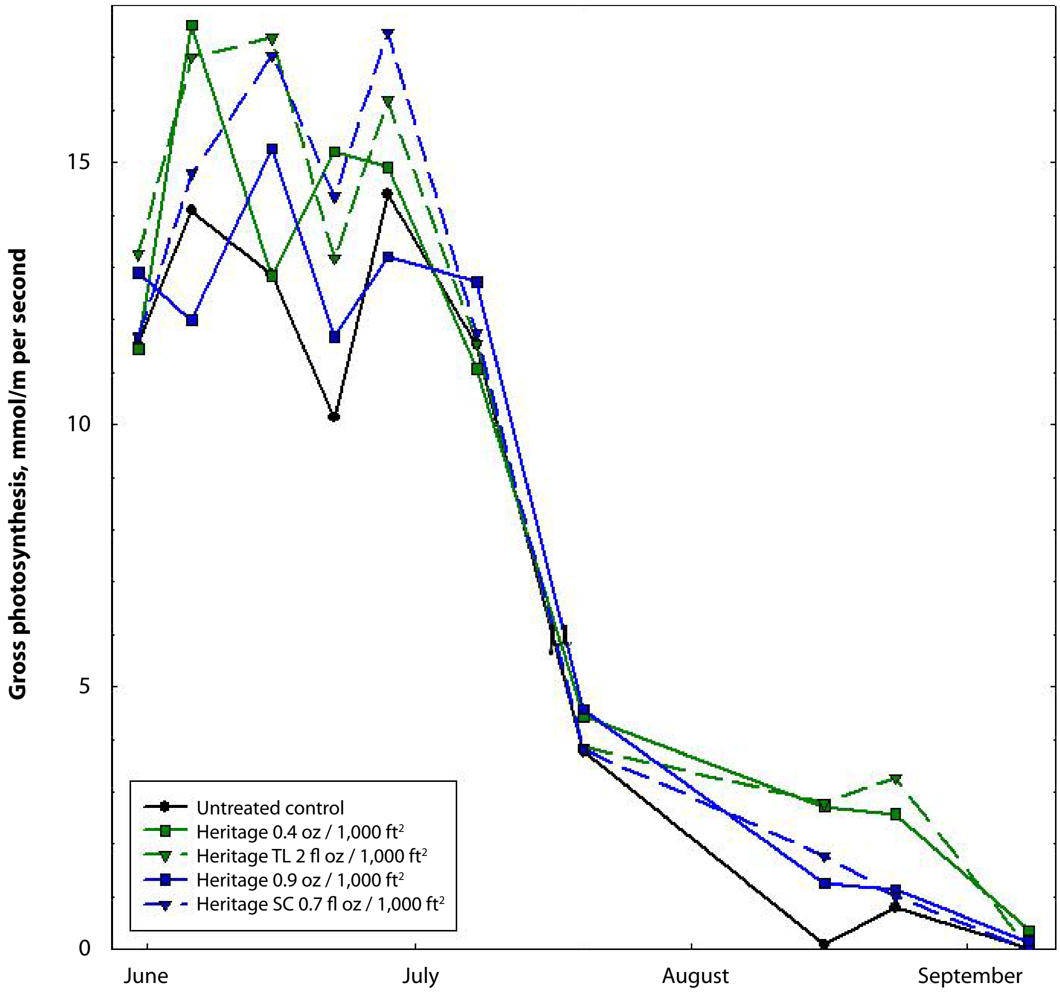

Figure 1. Effects of fungicide treatments on gross photosynthesis in 2011.

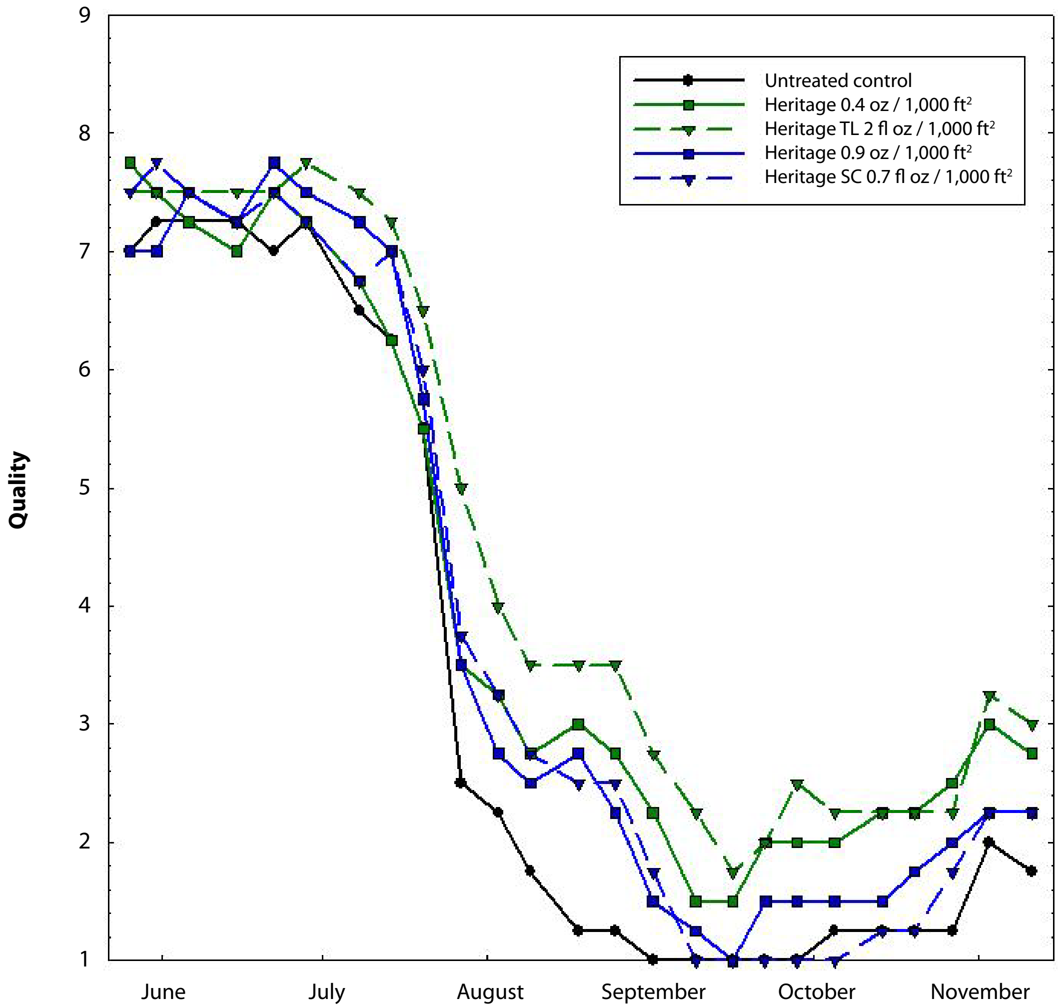

Figure 2. Effect of fungicide treatments on rough bluegrass quality in 2011.

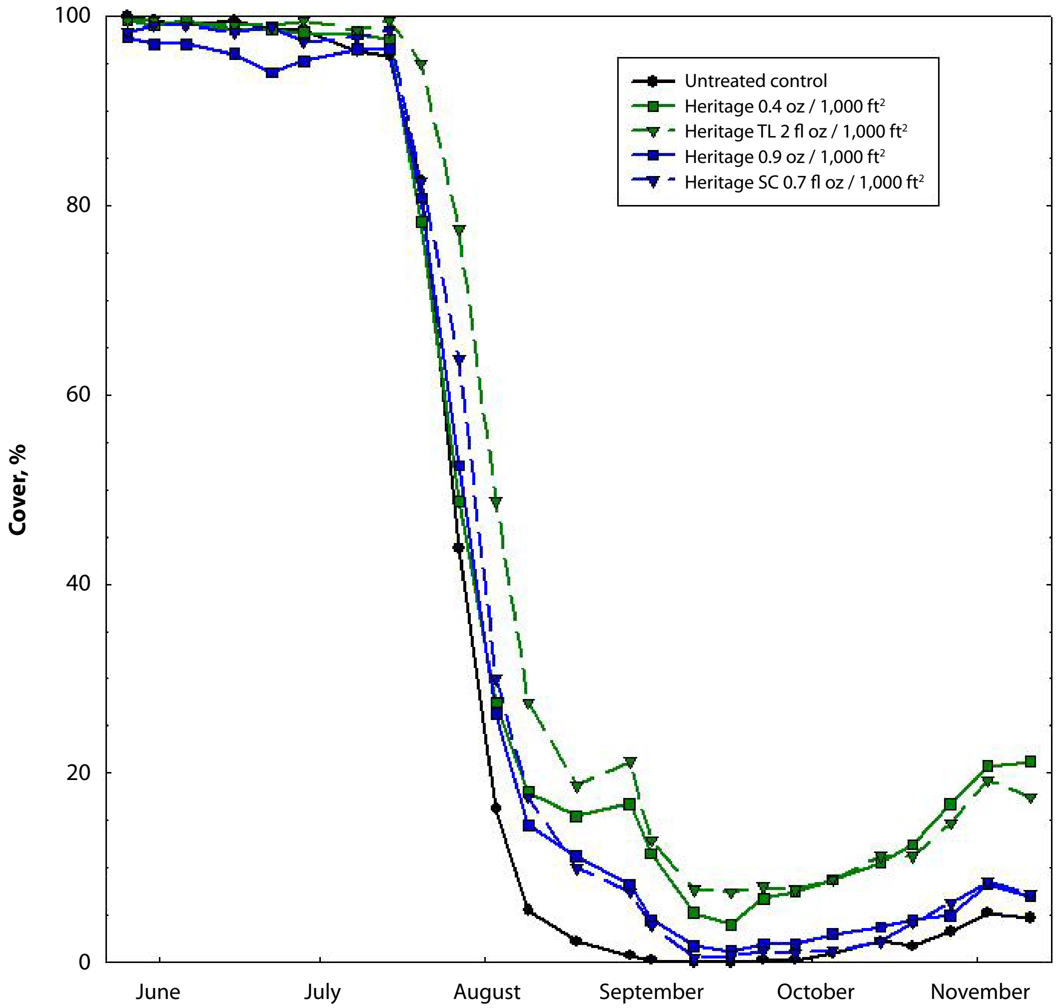

Figure 3. Effect of fungicide treatments on rough bluegrass cover in 2011.

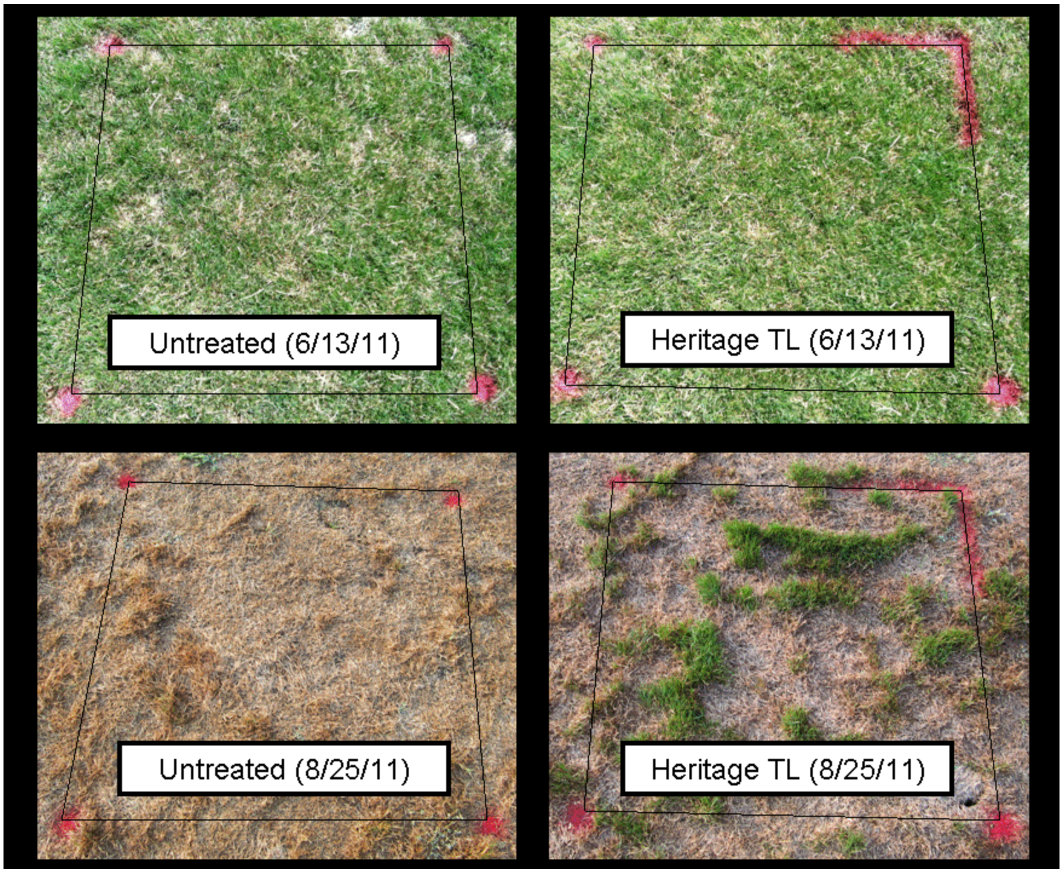

Figure 4. Rough bluegrass cover of representative untreated and Heritage TL plots when rough bluegrass was unstressed on June 6, 2011, and when untreated plots had entered dormancy on August 25, 2011.

Evaluation of Atmometers for Measurement of Evapotranspiration in Different Microclimates

Objective: Compare estimates of evapotranspiration (ET) from atmometers to FAO56 Penman-Monteith and Priestley-Taylor empirical ET models calculated from weather data.

Investigators: Kenton Peterson, Dale Bremer, and Jack Fry

Sponsor: United States Department of Agriculture National Integrated Water Quality Program

Introduction

Golf courses and home lawns typically contain a number of microclimates, each of which may cover large areas. Estimating evapotranspiration (ET) within these microclimates is difficult without directly measuring ET within the microclimate. Often, golf course superintendents and homeowners who base their irrigation on evapotranspiration will obtain their ET data from a nearby weather station. These weather stations are usually placed in open areas, and reference ET is calculated using empirical models. Estimating ET from data obtained from an open area will likely generate ET values that are different from those within various microclimates, which could result in the over- or under-application of water to the site. One way to evaluate this issue is to compare measurements of ET obtained within a given microclimate to concurrent measurements of ET obtained from an open area.

Evapotranspiration measurement within a microclimate may be conducted using a weather station or atmometer. Weather stations (Figure 1) can be cumbersome and expensive to set up and maintain, which makes them impractical for most applications. An atmometer (Figure 1) is an inexpensive ET measurement device that is relatively easy to set up and maintain. Previous research has demonstrated that atmometers can provide more precise estimates of ET in turfgrass than the Penman-Monteith model; however, the performance of atmometers within different microclimates is not well documented.

Methods

This investigation was initiated in June 2010 in Manhattan and Wichita, Kan. In 2010, ET was measured in six urban lawns in Manhattan, and in 2011 ET was measured in one and four lawns in Manhattan and Wichita, respectively. Within each lawn, a weather station and atmometer (Figure 1) were placed in two contrasting microclimates (e.g., shaded and sunlit areas) for a defined period. A weather station and atmometer were concurrently placed in an open sward of turfgrass near each city to provide a reference ET. Atmometers (ETgage Model E, ETgage Company, Loveland, CO) using #54 canvas cover to represent reference ET from grass were placed near the portable weather stations at each location. Temperature, net radiation, relative humidity, and wind speed were measured at 1 Hz, and ET was calculated for 24-h periods. The FAO56 Penman-Monteith and Priestley-Taylor empirical models were utilized to calculate ET.

Results

The FAO56 Penman-Monteith and Priestley-Taylor models exhibited significant correlations ($P < 0.001$) with the atmometers, with r = 0.83 and r = 0.75 (Figure 2), respectively, for all ET data from the microclimates and open sward; however, the atmometer mean ET was 4.3 mm/day, which was 54 and 34% greater than the FAO56 Penman-Monteith (2.8 mm/day) and Priestley-Taylor (3.2 mm/day) models, respectively. The maximum ET from the atmometer for a single day was 11.7 mm, whereas maximum FAO56 Penman-Monteith and Priestley-Taylor ET were 5.9 and 6.9 mm, respectively.

At the open sward, ET measured with the atmometer averaged 33 and 10% greater than FAO56 Penman-Monteith and Priestley-Taylor ET, respectively. Thus, disparity was greater in ET estimates between the atmometers and empirical models within the urban lawn microclimates than in the open area.

Interestingly, estimates of daily ET between the atmometer and empirical models were more similar when the average daily air temperature was below 25°C (77°F) than above 25°C (Figure 3). Among all ET data from the microclimates and open sward, atmometer ET was 30 and 15% greater than FAO56 Penman-Monteith and Priestley-Taylor ET, respectively, at mean daily air temperatures below 25°C (Figure 3). Observing ET data from the open sward weather station revealed that the atmometer ET was only 5% greater than the FAO56 Penman-Monteith ET and 9% less than the Priestley-Taylor ET at mean daily air temperatures below 25°C. At temperatures above 25°C, however, the differences in ET estimates between the atmometers and empirical models increased substantially with temperature. Saturation vapor pressure, which increases exponentially with air temperature, could be a major factor affecting ET as estimated with these methods (Figure 3). Increasing the air temperature results in a greater quantity of water that can be stored in the atmosphere; therefore, as the air in the atmosphere warms, it has much greater drying power than at cooler temperatures. This can increase water loss from plants through transpiration and may be driving water loss from the atmometer. The empirical models utilize vapor pressure deficit in their ET calculations, but the atmometer may be more sensitive to high vapor pressure deficits.

Based on these findings, greater differences between the empirical models and the atmometer may be expected in urban lawn microclimates than in open areas of turfgrass, as well as when average daily temperatures are above 25°C (77°F). More research is needed to understand to accuracy of these ET measurement techniques within microclimates.

Figure 1. Closeup of an atmometer (A) and a weather station with atmometer (B) collecting data in an urban microclimate.

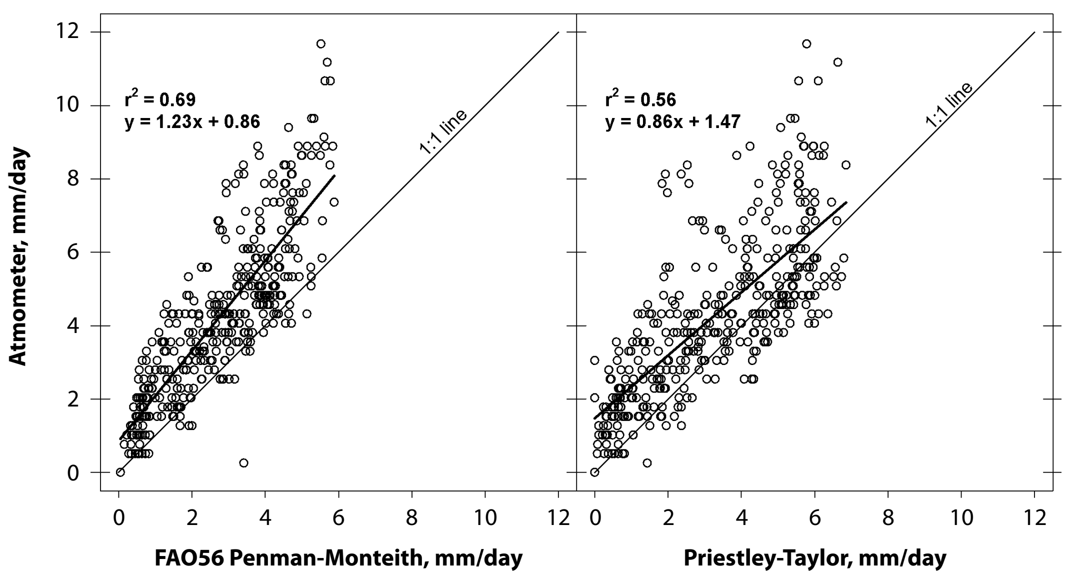

Figure 2. Comparison of evapotranspiration from the atmometer to the empirical models, FAO56 Penman-Monteith and Priestley-Taylor. All evapotranspiration data were pooled from the microclimates and open sward.

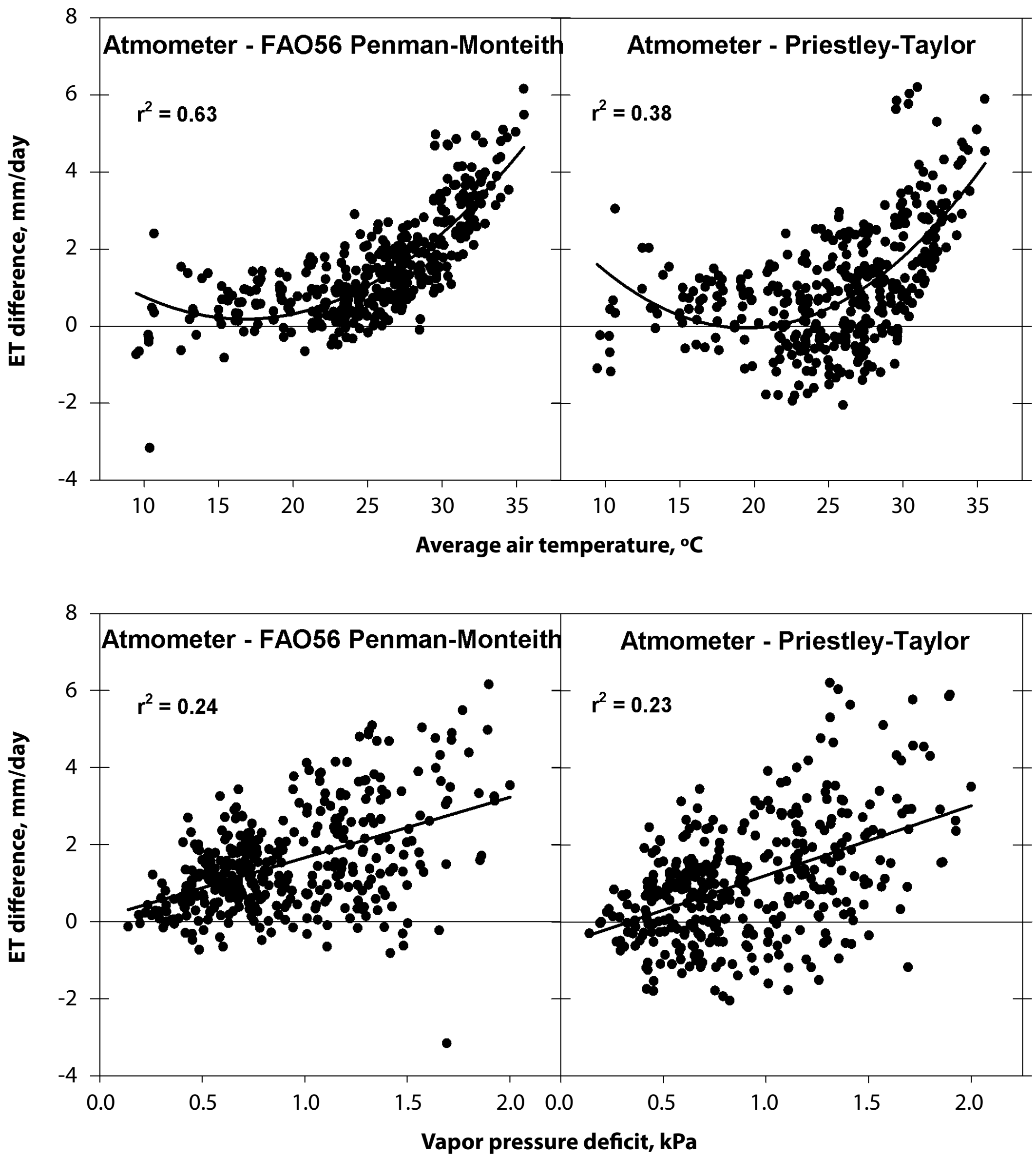

Figure 3. Relationship of differences in daily evapotranspiration (ET) (atmometer ET – empirical model ET) to average air temperature and vapor pressure deficit. All ET data are pooled from the microclimates and open sward.

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

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

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

Introduction

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

Kentucky Bluegrass (KBG) (*Poa pratensis)* is the most widely used cool-season turfgrass in the United States. It can be found on lawns, golf courses, cemeteries, parks, school grounds, athletic fields, and other areas where a dense grass cover is desired. Because of differences in water use rates and substantial morphological and physiological diversity among cultivars of KBG, some cultivars may be better able to withstand long periods of drought and recover faster than others.

A fully automated rainout shelter (Figure 1) located in the transition zone at Rocky Ford Turfgrass Research Center in Manhattan, Kan., offers the ability to compare multiple KBG cultivars while restricting water. Kentucky bluegrass cultivars that have greater drought resistance and recovery ability may be useful in areas where water restrictions are expected. The objective of this study was to evaluate the response of seven cultivars of KBG to prolonged drought exposure and their recovery thereafter.

Methods

The seven cultivars of KBG evaluated in this study were a subset of a larger group of KBG plots established for a previous study (see "Irrigation Requirements of 28 Kentucky Bluegrass Cultivars and Two Texas Bluegrass Hybrids in the Transition Zone," K-State Turfgrass Research 2010, Report of Progress 1035, p. 74). These seven cultivars were selected based on results from that study, which ranked cultivars by the amount of water applied over two years. We selected cultivars that had a broad range of water requirements to better understand the physiological mechanisms behind their drought resistance or lack thereof. These cultivars included 'Abbey,' 'Apollo,' 'Bedazzled,' 'Blue Velvet,' 'Cabernet,' 'Moonlight,' and 'Wellington.' Individual plots (3.7 ft × 4.0 ft each) were arranged in a randomized complete block design, and cultivars were replicated three times each. Plots were mown at approximately 3 in. as needed.

This study was conducted from July 4 through September 4, 2010, and June 1 through August 1, 2011. The plots were well watered until July 4, 2010, and June 1, 2011. Thereafter, plots were allowed to dry down for 60 days with no irrigation. Percentage green turfgrass cover was estimated from digital images, which were acquired weekly. Additional physiological measurements included leaf water potential (measured bi-weekly), electrolyte leakage (EL; measured weekly), and gross photosynthesis (measured weekly) (EL and photo data not included). Volumetric soil water content was monitored daily at 5 and 20 cm using the dual probe heat pulse technique. In addition, volumetric soil water content from 0–50 cm was measured weekly in the seven cultivars with time domain reflectometry.

Results

Water potential and green cover among all cultivars declined during the 60-day drydown in both years (Figures 2 and 3). Extreme heat conditions were experienced during the drydown in both years. Air temperature exceeded 85°F on 52 of the 60 days in 2010 and 51 of the 60 days in 2011. Additionally, air temperature exceeded 100°F on 8 of 60 days in 2010 and 16 of 60 days in 2011. In 2010, nearly all plots were completely brown (~0% green cover) by the end of the drydown (Figure 1). In 2011, plots were less brown (~15–30% green cover) by the end of the 60-day period (Figure 4), probably because a malfunction in the rainout shelter resulted in all plots receiving water during at least one rainfall.

All cultivars of KBG recovered well after the drydown in both years, but were slower in 2010 (Figures 2 and 3). Even after a slower recovery after the first year's dry down, plots had fully recovered by the following spring before the study began in 2011 (Figure 5). During the drydown and recovery, variability was high within plots of each cultivar. This generally minimized statistical differences among cultivars during those periods. Results indicated few differences in physiological mechanisms as they related to drought tolerance among the seven cultivars compared in this study.

Previous research has indicated that common-type KBG cultivars are ideal for low-maintenance areas. Given that all cultivars recovered after the 60-day drydown, any of the seven cultivars in this experiment would likely be suitable for use in areas that may experience extended periods of drought; however, if turf quality is a concern, selection should focus on cultivars that have shown higher quality than common types, such as 'Apollo' and 'Bedazzled.'

Figure 1. Plots on September 4, 2010, after receiving no irrigation for 60 days.

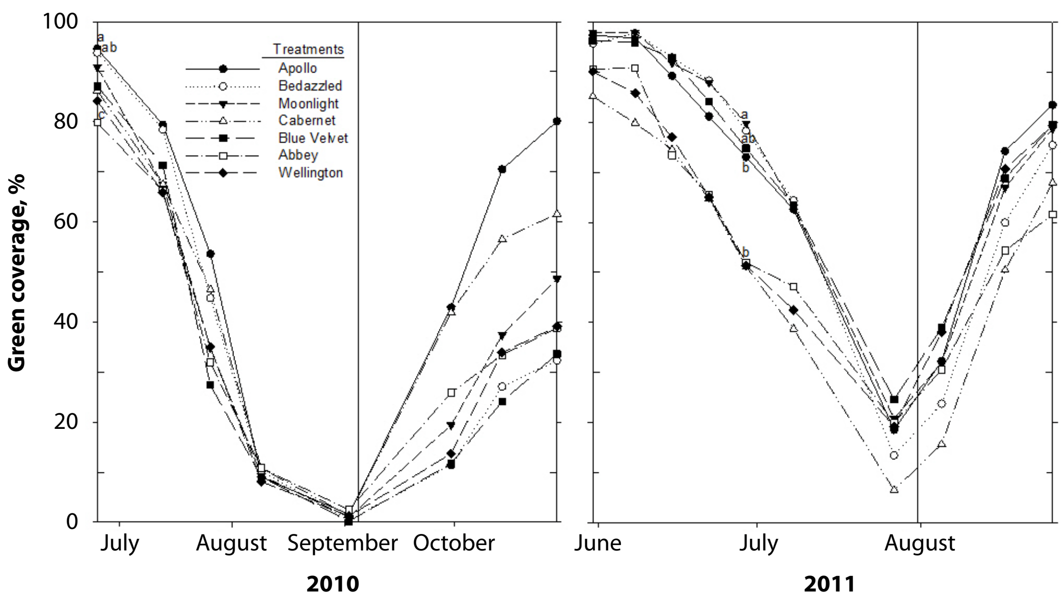

Figure 2. Percentage green cover of seven cultivars of Kentucky bluegrass during a 60-day drydown in 2010 and 2011. Treatments included 'Apollo,' 'Bedazzled,' 'Moonlight,' 'Cabernet,' 'Blue Velvet,' 'Abbey,' and 'Wellington.' Means followed with the same letter on a given day are not significantly different (*P* = 0.05). Vertical line represents the end of the 60-day drydown.

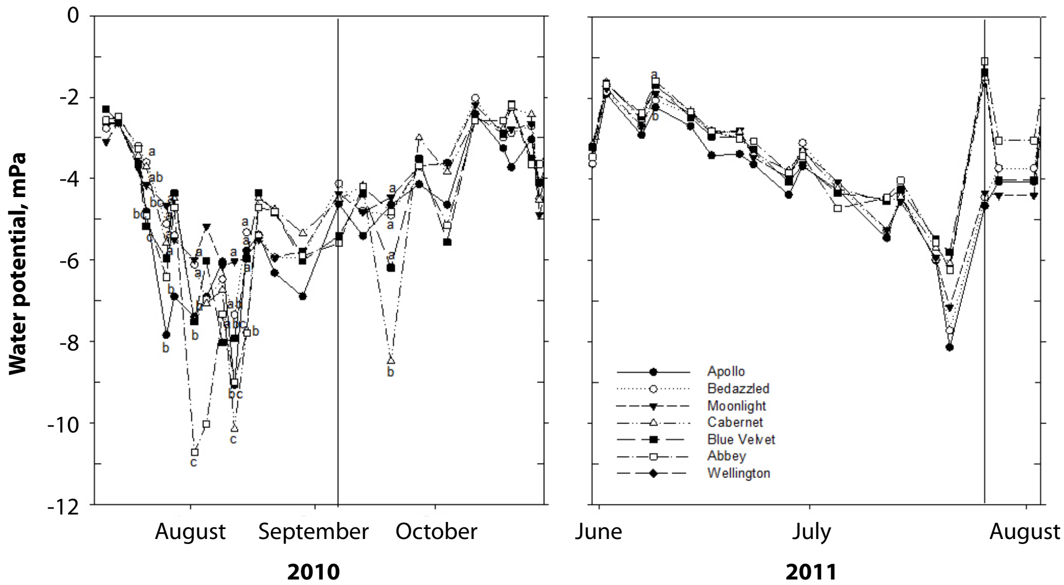

Figure 3. Leaf water potential of seven cultivars of KBG during a 60-day drydown in 2010 and 2011. Treatments included 'Apollo,' 'Bedazzled,' 'Moonlight,' 'Cabernet,' 'Blue Velvet,' 'Abbey,' and 'Wellington.' Coverage was calculated by analyzing images in Sigmascan Pro. Vertical line represents the end of the 60-day drydown.

Figure 4. Plots on August 1, 2011, after receiving no irrigation for 60 days.

Figure 5. After the severe drydown of 2010 and a slow recovery during the fall, plots had fully recovered by the beginning of the drydown in 2011.

Residential Homeowners with In-Ground Irrigation Systems Water Their Lawns Differently Than Those without In-Ground Systems

Objective: Survey residential homeowners who do and don't have in-ground irrigation sprinkler systems about how they irrigate their lawns.

Investigators: Dale Bremer, Steve Keeley, Abigail Jager, and Jack Fry

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

Introduction

Urbanization is increasing the land area covered with turfgrasses, which may have implications for water quantity and quality. The largest sector of turfgrass is residential lawns. Homeowners' use of automatic irrigation systems, which are typically installed during construction of new single-family homes in urbanizing watersheds, may be both problematic and advantageous to water conservation efforts. In-ground irrigation systems may use twice the amount of water as manual irrigation if the systems are improperly adjusted, but these systems also may present opportunities for more accurate irrigation (e.g., match the minimal or actual water needs of the turfgrass) if residents are given proper education.

Our objectives were to understand the perceptions and behaviors of residential homeowners about the irrigation of their lawns during summer months. In this study, we surveyed residential homeowners in Wichita, Olathe, and Salina, Kan., each of which has distinct combinations of climate, demographics, and water issues. Survey responses were compared between those with and without in-ground irrigation sprinkler systems in each city.

Methods

Surveys were mailed to homeowners in Wichita, Olathe, and Salina. The total population of residential homeowners was 98,708 in Wichita, 26,333 in Olathe, and 14,971 in Salina. To ensure that sampling was uniform geographically across each city, a stratified design was employed. This involved dividing each city arbitrarily into sections. Addresses were then selected randomly from within each section based on its population proportionate to the total population of the city. Accordingly, Wichita was divided by ZIP codes into 23 sections, Olathe was divided into 13 sections, and Salina was divided into 54 sections based on route numbers assigned by the municipality.

Each address selected received a one-page, tri-fold survey mailer. Homeowners were asked to complete the survey and return it postage paid. The total number of surveys mailed to residential homeowners included 4,992 in Salina on April 28, 9,992 in Olathe on May 27, and 15,534 in Wichita on July 2, 2009. The total number of surveys returned by residents included 1,772 from Wichita, 1,110 from Olathe, and 652 from Salina. Thus, the total return rate was 11.4% for Wichita, 13.1% for Olathe, and 11.1% for Salina, or an overall return rate of 11.6%.

Results

Responses to the question “How often do you water your lawn during dry periods of the summer?” indicated that homeowners who had in-ground sprinkler systems (IGS) watered much more frequently than those who did not have in-ground sprinkler systems (NIGS) (Figure 1). In Wichita and Olathe, a total of 89.5% of homeowners with IGS watered two to three times per week or more, whereas only 30% of NIGS homeowners watered that frequently. Increased watering frequency by IGS homeowners is likely due to both convenience and a desire for a higher-quality lawn, which is implied by their investment in an IGS. In Salina, although more IGS homeowners watered frequently (67% watering two to three times per week or more) than NIGS homeowners (19%), we noted that 32% of Salina IGS homeowners still watered once per week or less compared with only 10 to 11% of IGS homeowners in that category in Olathe and Wichita. We also found that many more IGS homeowners in Wichita watered very frequently, with 21% watering five to seven times per week or more, compared with only 1 and 8% of IGS homeowners in Salina and Olathe, respectively.

In response to the question, “How do you decide when it is time to water your lawn?” IGS homeowners were much more likely to water on a routine schedule (Figure 2). By city, the percentage of IGS compared with NIGS homeowners watering on a routine schedule was 60:12 in Wichita, 56:5 in Olathe, and 45:15 in Salina. This discrepancy was likely due to the convenience afforded by the automatic timer, which may have led to a “set it and forget it” mentality in IGS homeowners. In contrast, NIGS homeowners were much more likely to water when the lawn looked dry; the percentage of NIGS compared with IGS homeowners using this strategy was 56:19 in Wichita, 60:24 in Olathe, and 52:26 in Salina.

In response to the question “How do you decide how much to water your lawn?” IGS homeowners were much more likely than NIGS homeowners to apply the same amount at each irrigation (Figure 3). IGS homeowners applying the same amount every time ranged from 56 to 59% across cities, whereas NIGS homeowners in this category ranged from 34 to 38%. The “set it and forget it” mentality is probably at least partially responsible for this discrepancy; however, although fewer NIGS than IGS homeowners applied the same amount each time, in Wichita and Olathe NIGS homeowners were still just as likely to apply the same amount every time versus adjusting irrigation amounts based on the lawn’s appearance (i.e., “I apply more if the lawn looks dry”), and in Salina they were more likely to do so. Nevertheless, NIGS homeowners in each city were much more likely than IGS homeowners to adjust irrigation amounts based on the lawn’s appearance. The ratio of NIGS homeowners to IGS homeowners using this strategy was 33:16 in Wichita, 36:22 in Olathe, and 26:17 in Salina.

IGS homeowners were much more likely than NIGS homeowners to consider a green lawn important or very important (i.e., a rating of 4 or 5) (Figure 4), with ratios of IGS to NIGS homeowners in this category at 78:44 in Wichita, 79:45 in Olathe, and 60:42 in Salina. In contrast, NIGS homeowners were much more likely than IGS homeowners to say a green lawn was of little to no importance (i.e., a rating of 1 or 2), with ratios of NIGS to IGS homeowners in this category at 23:5 in Wichita, 21:3 in Olathe, and 24:11 in Salina. This result is not surprising, because IGS homeowners apparently consider a green lawn important enough to make the substantial investment required to install an automatic system.

Wichita had the highest percentage of IGS homeowners, with a ratio of IGS to NIGS homeowners of 46:54, whereas Olathe had 28:72 and Salina had 24:75. Wichita residents are probably more likely than Olathe residents to invest in an IGS because of the higher evaporative demand in Wichita, which would lead to higher irrigation requirements. Conversely, the lower percentage of IGS homeowners in Salina despite evaporative demand similar to Wichita may be a result of Salina residents' heightened concern about potential water shortages (their main water source, the Smoky Hill River, nearly ran dry in 2006 despite near-normal precipitation in that year) and the higher water costs in Salina; these factors may have reduced their interest in investing in an IGS. In all cities, most IGS homeowners adjusted their sprinkler timer seasonally (39–51%) (Figure 5), whereas 32 to 40% adjusted more actively (i.e., daily, weekly, biweekly, monthly, or when the lawn looks dry), and 16 to 24% said they never or rarely adjusted their timer. Clearly, the latter group is under- or over-irrigating most of the time, and gains in irrigation efficiency and perhaps water conservation would be possible if "smart controllers" that schedule irrigation based on soil-moisture sensors or evaporative demand were used.

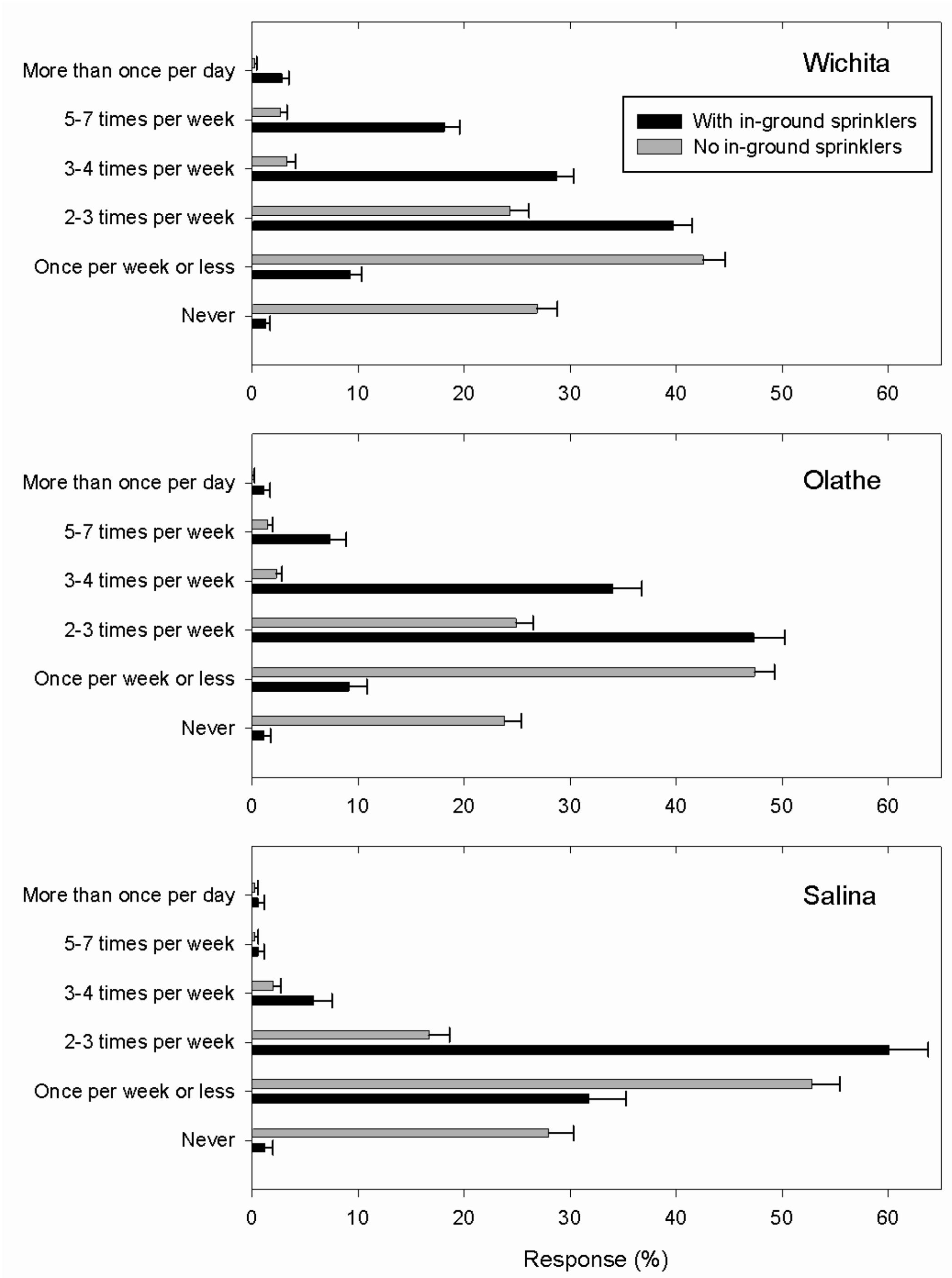

Figure 1. Responses of residential homeowners with and without in-ground irrigation systems in three urban areas in Kansas to the survey question, "How often do you water your lawn during dry periods of the summer?" Error bars denote the standard error.

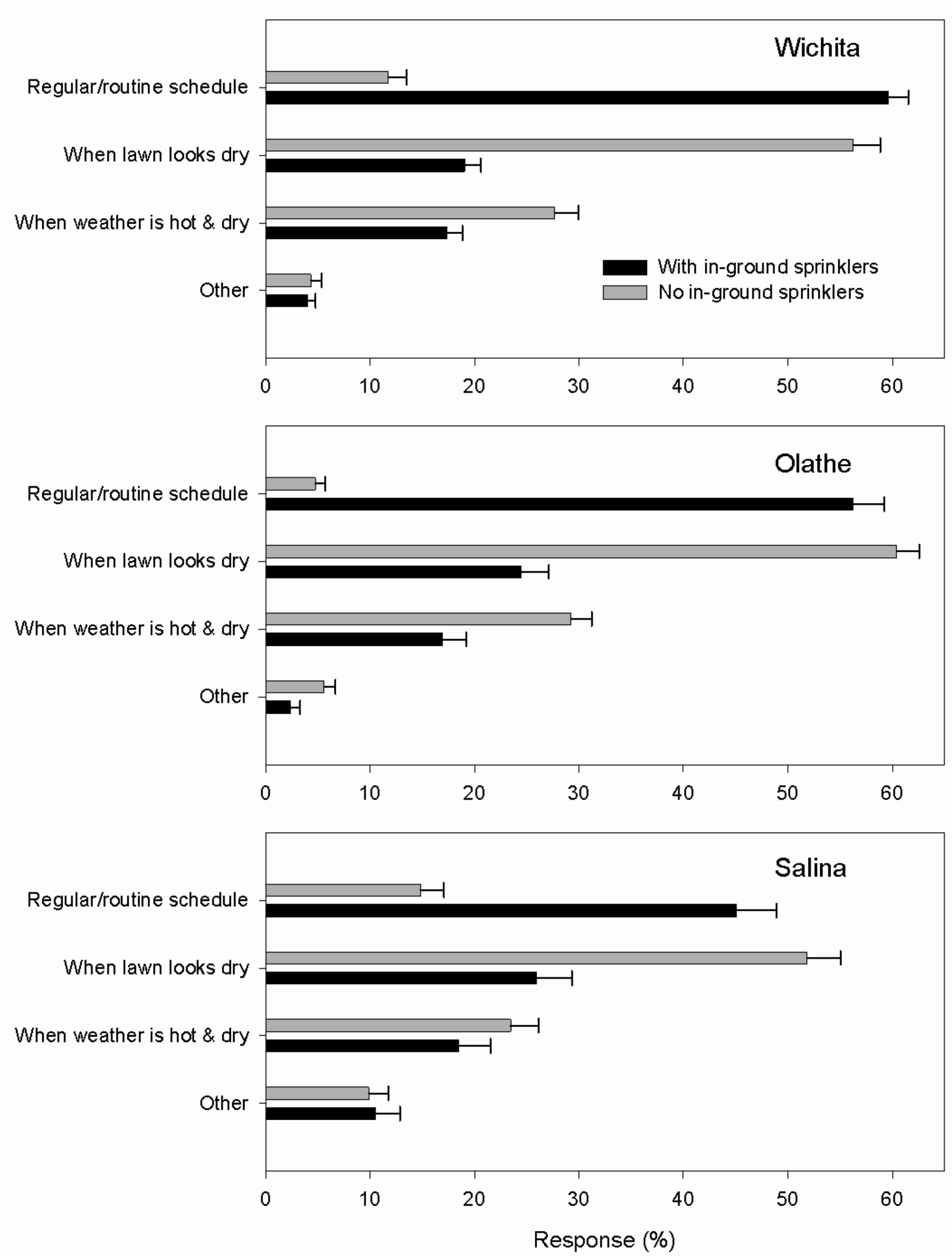

Figure 2. Responses of residential homeowners with and without in-ground irrigation systems in three urban areas in Kansas to the survey question, "How do you decide when it is time to water your lawn?" Error bars denote the standard error.

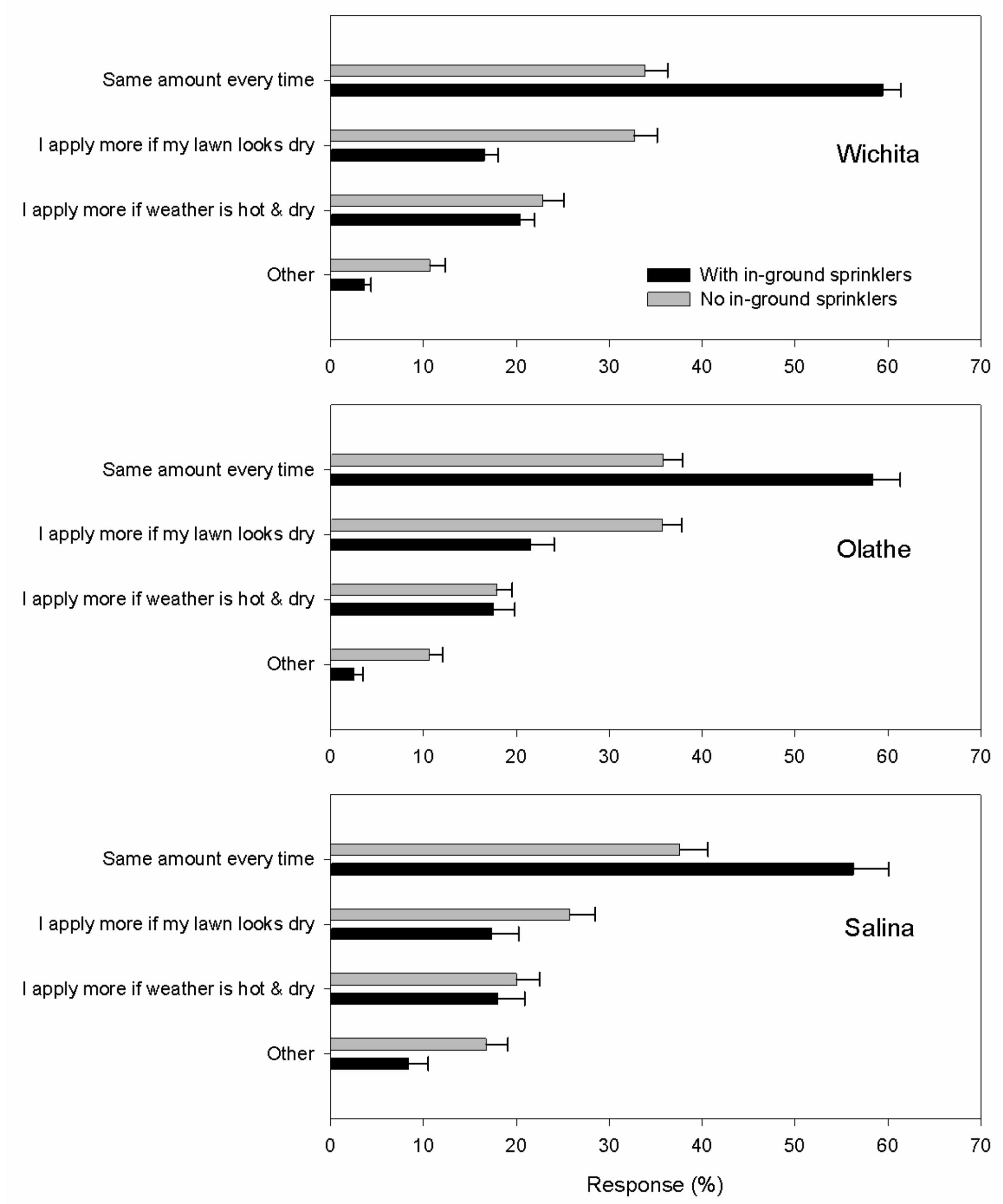

Figure 3. Responses of residential homeowners with and without in-ground irrigation systems in three urban areas in Kansas to the survey question, “How do you decide how much to water your lawn?” Error bars denote the standard error.

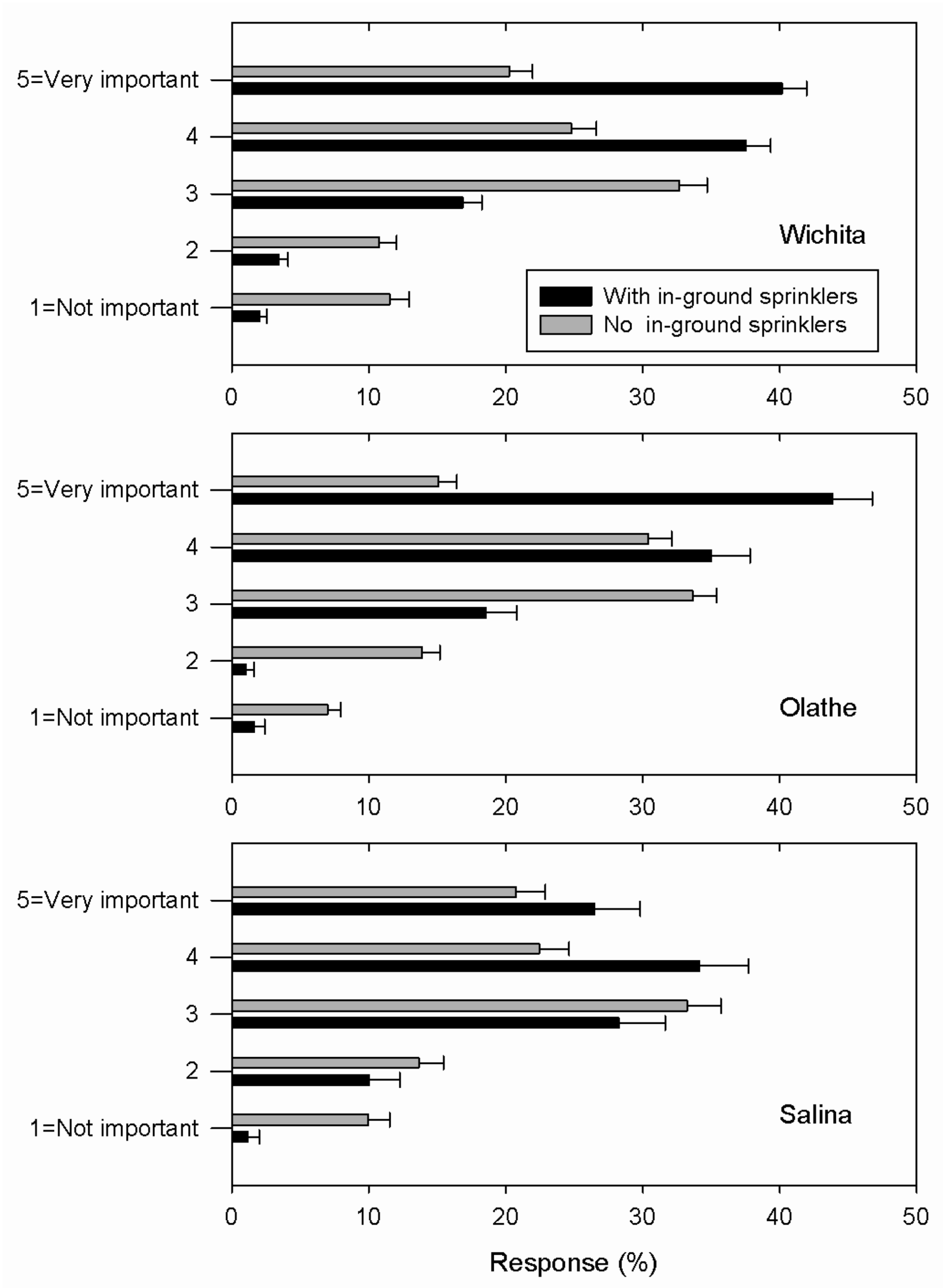

Figure 4. Responses of residential homeowners with and without in-ground irrigation systems in three urban areas in Kansas to the statement, "I like my lawn to look green all the time." Error bars denote standard errors.

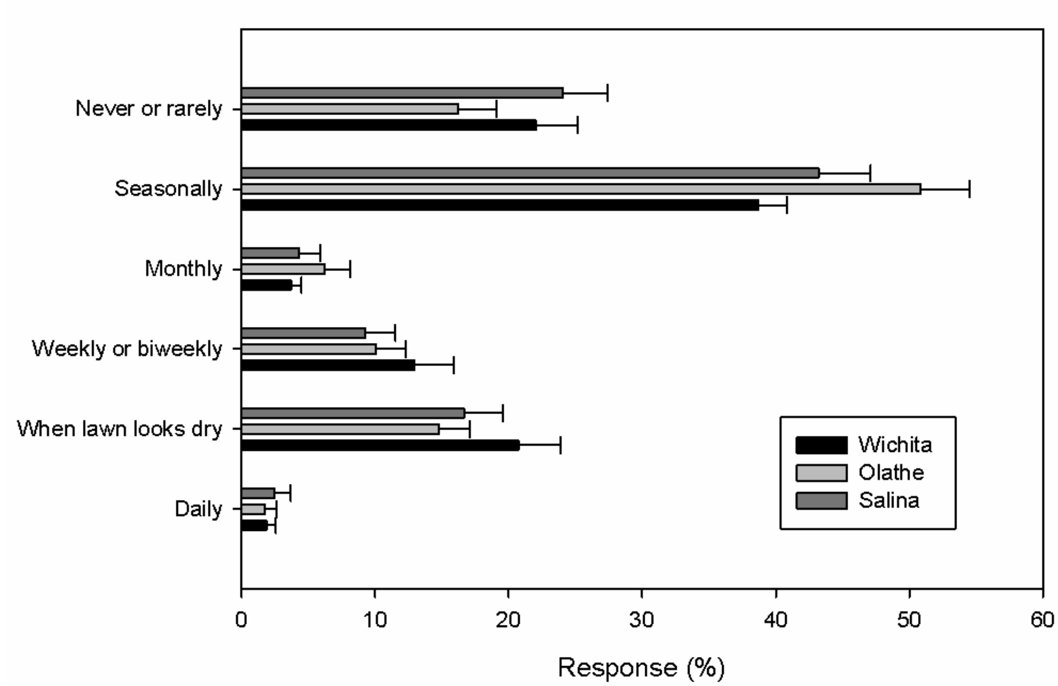

Figure 5. Responses of residential homeowners in three cities in Kansas who had in-ground sprinklers to the question, "How actively do you adjust your sprinkler timer?" Error bars denote standard errors.

Evapotranspiration and Performance Among Turfgrass and Ornamental Landscape Species in Response to Irrigation Deficit

Objectives: 1) Compare ET among two turfgrass species and two ornamental groundcover species under well-watered conditions, and 2) evaluate visual quality and plant water status of the same turfgrass and groundcover species under deficit irrigation

Investigators: Jacob C. Domenghini, Dale Bremer, Jack Fry, and Greg Davis

Sponsors: Kansas Turfgrass Foundation and the USDA National Integrated Water Quality Program (NIWQP)

Introduction

Competition for water resources is intensifying as the world's population grows. In 2005, turfgrass was estimated to cover up to 49 million acres of urbanized land, and that area is increasing rapidly along with urbanization. Turfgrasses have been singled out for replacement with what are presumed to be more water-efficient plant species to reduce the amount of turf and save water; for example, in 2006 the United States Environmental Protection Agency (EPA) created a voluntary program called WaterSense to promote water efficiency. The program outlined criteria that builders must follow to market a home as WaterSense-approved. At the inception of WaterSense, one of the options for the outdoor water efficiency component of the program required a reduction in the area of turfgrass in the landscape.

Although replacing turfgrass with ornamental vegetation is often recommended to conserve water, research is limited on the comparative water use between popular turfgrass species and other landscape plants. To our knowledge, no field studies have been conducted to compare water use between turfgrass and ornamental species. Substantial research has been conducted to compare evapotranspiration (ET) among turfgrass species as well among cultivars within a number of turfgrass species. Field research is needed to compare water use and drought performance between landscape ornamentals and turfgrasses.

Methods

Field plots were established under a rainout shelter (Figure 1) in June 2009 at the Rocky Ford Turfgrass Research Center near Manhattan, Kan. The rainout shelter shielded plots from any natural precipitation events during data collection. Two treatment factors were arranged in a randomized complete block design, including: 1) species [two turfgrass species (*Buchloe dactyloides* (Nutt.) Engelm. 'Sharps Improved' and *Festuca arundinacea* Schreb.) and two ornamental groundcover species (*Ajuga reptans*

L. 'Bronze Beauty' and *Vinca minor* L.)], and 2) irrigation (100%, 60%, and 20% ET replacement). Data collection for this study occurred from June 28 through October 4, 2010, and from June 20 through September 12, 2011.

Lysimeters were used to measure ET among species under well-watered conditions and to determine irrigation requirements (i.e., ET replacement) for the field plots. Each lysimeter was irrigated according to its respective ET loss to replenish the soil profile. For each species, proportionate amounts of water were applied to plots according to their assigned irrigation treatment (100%, 60%, and 20% ET replacement).

Visual quality was evaluated using a scale of 1 to 9 (1 = dead/dormant, 6 = minimally acceptable, and 9 = highest quality). This scale is the standard for evaluating turfgrass quality in the National Turfgrass Evaluation Program (NTEP). To maintain as much consistency as possible in quality ratings among ornamental and turfgrass species, the standard scale used for turfgrass by NTEP was adapted to ornamentals. Using this method, quality was determined in each species based on plant density and uniformity across the plot; plots receiving 100% ET irrigation generally received a rating of nine. In deficit irrigation plots, the amount of wilt or leaf firing also affected the quality ratings, with greater wilt or leaf firing resulting in lower quality.Visual quality of plants was recorded twice per week and leaf water potential (Ψ_{leaf}), electrolyte leakage (EL), and stomatal conductance (g_s) were measured every two weeks during both studies. The Ψ_{leaf} of each species was measured with a water potential meter (WP4-T PotentiaMeter, Decagon Devices, Pullman, Wash.). Electrolyte leakage was measured to determine the percentage of electrolytes that leaked due to drought stress. Stomatal conductance was measured using a steady state diffusion porometer (Model SC-1 Leaf Porometer, Decagon Devices). Volumetric soil water content (θ_v) was measured at 0 to 20 cm twice per week using time domain reflectometry (TDR). Plant materials from lysimeters were destructively harvested at the conclusion of each study to determine green leaf area index (LAI), aboveground green biomass, and leaf water content (LWC).

Results

Vinca minor data were collected only through week four due to damage from a severe fungus infestation (*Phoma exigua*) during both studies. All comparisons of *V. minor* with other species are included in the following section on an equivalent time frame (i.e., beginning of study through week four). Thereafter, only data from the entire study (12–14 weeks) are presented for *A. reptans*, *B. dactyloides*, and *F. arundinacea*. During the first four weeks of the study, *V. minor* maintained quality ratings above minimal acceptability for four weeks in all three ET treatments, which was similar to patterns in the other three species. Soil moisture likely had not declined enough during that period to adversely affect visual quality among species (Figure 2); therefore, only data from 100% plots are presented during that period to evaluate ET and g_s among species.

Well-Watered Plots: The First Four Weeks

Water use of *A. reptans* and *F. arundincacea* was similar and greater than that in the other two species in both years (Table 1). In 2010, ET of *V. minor* was similar to *B. dactyloides*, but in 2011, ET was greater in *V. minor* than in *B. dactyloides*. The g_s of *V. minor* in 2010 and of both ornamental species (*A. reptans* and *V. minor*) in 2011 was greater than the g_s of the two turfgrass species (*B. dactyloides* and *F. arundinacea*)

(Table 1). Presumably, greater g_s would result in greater ET among species; however, despite having a g_s similar to *A. reptans* and greater g_s than *F. arundinacea*, ET of *V. minor* was less than both of those species. Green LAI perhaps was less in *V. minor* than in *A. reptans* and *F. arundinacea*, which could have reduced overall ET from a relatively smaller *V. minor* canopy. Unfortunately, measurements of green LAI were not available from *V. minor* because a fungus infestation destroyed the canopy.

Well-Watered Plots: The Entire Study

The average ET of *B. dactyloides* was consistently lower than the other two species evaluated for the full length of each study, averaging 32 to 40% less across both studies (Table 2). Average water use was similar between *A. reptans* and *F. arundinacea* in both years (Table 2). Greater ET in *A. reptans* and *F. arundinacea* may be attributed to their green LAI, which was 1.6 to 2.6 times greater than in *B. dactyloides* in both studies (Table 2). In addition, g_s was greater in *A. reptans* in both years and greater in *F. arundinacea* than in *B. dactyloides* in 2010 (Table 3), which likely contributed to greater ET rates in *A. reptans* and *F. arundinacea*. Green LAI was positively correlated with ET in all three species in 2010 ($r^2 = 0.61$) and 2011 ($r^2 = 0.68$), illustrating the effects of green, transpiring leaf area on ET rates (data not shown).

Irrigation Deficit Effects

Throughout both studies, visual quality in 100% ET plots never declined below a rating of 8 among species (Figure 3 A and B). All three species maintained visual quality at or above minimal acceptability (rating of 6 or higher) in both 100% and 60% ET treatments (Figure 3 A–D). This result indicates that *A. reptans*, *B. dactyloides*, and *F. arundinacea* can be irrigated at 60% of their ET replacement requirements and still maintain an acceptable level of quality. Near the end of each study, the quality of *B. dactyloides* was greater than the other two species in 20% ET (Figure 3 E and F). Quality of *A. reptans* and *F. arundinacea* generally declined faster than that of *B. dactyloides* in the irrigation-deficit treatments, particularly in 20% ET. The ability of *B. dactyloides* to maintain higher visual quality than *A. reptans* and *F. arundinacea* when receiving minimal irrigation indicates greater drought resistance in *B. dactyloides*.

A. reptans consistently had lower θ_v in 2010, indicating that it used more water in the 0–20-cm soil profile than the other two species (Figure 2 A, C, and E). Throughout 2010, the θ_v of *B. dactyloides* and *F. arundinacea* generally remained similar to one another among all three ET treatments. In 2011, however, θ_v was lower in both *A. reptans* and *B. dactyloides* than *F. arundinacea* (Figure 2 D and F), suggesting that *A. reptans* and *B. dactyloides* used more water in the 0- to 20-cm soil profile than *F. arundinacea*. The roots of *B. dactyloides* likely were more developed at 0- to 20-cm by the second year of the study, thus allowing them to extract more water at that depth than during the previous year.

Electrolyte Leakage, Leaf Water Potential, and Stomatal Conductance

Deficit irrigation treatments did not affect EL among species with the exception of *A. reptans* at 20% ET in 2011 (Table 4). On DOT 85 in 2010 and on the last three measurement days of 2011 (DOT 57, 71, and 85), EL in *A. reptans* was as much as 50% higher in 20% ET than in other irrigation treatments (data not shown). This suggests a greater injury to cell membranes of *A. reptans* among species under severe drought although the quality of *A. reptans* remained similar to *F. arundinacea* at the end of the 2011 study (Figure 3).

In 2011, the season-long average of Ψ_{leaf} was lower in 20% ET than 100% ET plots in all three species; a similar pattern was observed in *B. dactyloides* in 2010 (Table 5). With the exception of *A. reptans* in 2010, Ψ_{leaf} was 34 to 90% lower in the 20% ET than in the 100% ET treatment by DOT 85 (data not shown). This result illustrates the effects of increasing drought intensity on Ψ_{leaf} as the season progressed.

Water deficit had no effect on g_s in *F. arundinacea* in either study (Table 3). The typically extensive, deep root system of *F. arundinacea* combined with deep soils at the research site probably allowed *F. arundinacea* to draw water from deeper in the soil profile than the other species. In 2010, season-long g_s in *B. dactyloides* was 25% less under 20% ET irrigation than 100% ET irrigation; however, deficit irrigation had no effect on season-long g_s in *B. dactyloides* in 2011. The root system in *B. dactyloides* could have developed more by the second year of the study, thus allowing the plants to mine more water from the soil profile. A deep root system probably helped to maintain high g_s in *F. arundinacea* in both years, and *B. dactyloides* in 2011, even under water deficit. The average, season-long g_s of *A. reptans* was 39% to 52% less in 60% and 20% ET than in 100% ET plots (Table 3). This result indicates the g_s of *A. reptans* was more sensitive to drought than the other two species in the study. Soil moisture in the 0–20-cm profile was generally depleted more in *A. reptans* than *F. arundinacea* in both years and *B. dactyloides* in 2010 (Figure 2).

Conclusions

To reduce water inputs in residential and commercial landscapes, the recommendation should not necessarily be to replace turfgrass with ornamental landscape species. Results indicate that *B. dactyloides* is a good choice for landscapes where water is limited because of its lower water use rate and its ability to maintain plant quality above minimal acceptability for more than 10 weeks when receiving 20% ET replacement. Conversely, use of groundcovers to reduce water requirements of landscapes requires careful species selection. *A. reptans* may be a less appealing choice for landscapes where water conservation is of concern given its high ET rate, plant quality ratings which were deleteriously affected by irrigation-deficit treatments, and lower plant water status during drought. Water use of *F. arundinacea* was also high, and plant quality was reduced by water deficit treatments; however, physiological responses to irrigation-deficit treatments were least affected in *F. arundinacea*, likely because of the deep root system of *F. arundinacea* and the deep soils at the Rocky Ford Turfgrass Research Center. This result indicates good drought resistance in *F. arundinacea* where soils are deep.

V. minor used less water than *A. reptans* and *F. arundinacea* in both years but more water than *B. dactyloides* in 2011, although only four weeks of data were evaluated for *V. minor* due to a fungus infestation (*Phoma exigua*) that damaged all *V. minor* plots in both studies. Research continues to be limited on the comparative water use between popular turfgrass species and other landscape plants; therefore, more field research is needed to evaluate the water use and drought resistance in other landscape plants.

Table 1. Average evapotranspiration (ET) and stomatal conductance (g_s) among each species in the well-watered plots over the first four weeks in 2010 and 2011

	ET[1] mm/day		g_s (mmol/m²/sec)[2]	
Species	2010	2011	2010	2011
Ajuga reptans	4.46 A[3]b[4]	5.61 Aa	404.2 ABa	527.5 Aa
Buchloe dactyloides	2.86 Bb	3.40 Ca	227.9 Ba	256.4 Ba
*Festuca arundinace*a	4.49 Ab	5.33 Aa	355.8 Ba	269.3 Ba
Vinca minor	3.58 Ba	4.37 Ba	656.8 Aa	643.6 Aa

[1] Averaged from seven measurement dates each in 2010 and 2011.
[2] Averaged from three measurement dates each in 2010 and 2011.
[3] Within a column, means followed by the same uppercase letter are not statistically different according to least significant difference (LSD) ($P = 0.05$).
[4] Within a row, within each category, means followed by the same lowercase letter are not statistically different according to LSD ($P = 0.05$).

Table 2. Average evapotranspiration (ET), green leaf area index (LAI), aboveground green biomass, and leaf water content (LWC) of the lysimeters in well-watered plots in 2010 and 2011

	ET[1] mm/day		Green LAI		Green biomass (g/m²)		LWC (%)	
Species	2010	2011	2010	2011	2010	2011	2010	2011
Ajuga reptans	4.00 A[2]b[3]	5.00 Aa	2.49 Aa	2.94 Aa	7.88 ABb	19.48 Ba	80.1 Aa	68.1 Ab
Buchloe dactyloides	2.68 Bb	3.42 Ba	0.95 Bb	1.30 Ca	4.51 Bb	15.21 Ca	47.7 Ba	35.6 Ca
Festuca arundinacea	4.44 Aa	4.99 Aa	1.98 Aa	2.14 Ba	8.66 Ab	23.94 Aa	66.1 Aa	56.1 Bb

[1] Averaged from 28 measurement dates in 2010 and 24 measurement dates in 2011.
[2] Within a column, means followed by the same uppercase letter are not statistically different according to least significant difference (LSD) ($P = 0.05$).
[3] Within a row, within each category, means followed by the same lowercase letter are not statistically different according to LSD ($P = 0.05$).

Table 3. Average, season-long stomatal conductance (g_s) among species within each irrigation treatment for 2010 and 2011

	g_s (mmol/m²/sec)[1]					
	2010[2]			2011		
Species	100% ET	60% ET	20% ET	100% ET	60% ET	20% ET
Ajuga reptans	475.3 A[3]a[4]	261.6 ABb	227.3 Ab	448.5 Aa	274.0 Ab	253.6 Ab
Buchloe dactyloides	201.5 Ba	164.7 Bab	151.6 Ab	186.9 Ba	175.4 Aa	163.3 Ba
Festuca arundinacea	360.9 Aa	309.1 Aa	292.5 Aa	257.3 Ba	229.0 Aa	264.5 Aa

[1] Averaged from seven measurement dates each in 2010 and 2011.
[2] 2010 means do not include data from day of treatment (DOT) 99 because of freezing temperatures on DOT 98 and 99.
[3] Within a column, means followed by the same uppercase letter are not statistically different according to least significant difference (LSD) ($P = 0.05$).
[4] Within a row, within each year, means followed by the same lowercase letter are not statistically different according to LSD ($P = 0.05$).

Table 4. Average, season-long electrolyte leakage (EL) among species within each irrigation treatment for 2010 and 2011

	EL (%)[1]					
	2010[2]			2011		
Species	100% ET	60% ET	20% ET	100% ET	60% ET	20% ET
Ajuga reptans	20.66 B[3]a[4]	20.54 Ba	25.88 Aa	21.73 Bb	24.54 Bb	34.78 Aa
Buchloe dactyloides	27.17 Aa	24.72 Aa	23.11 Aa	40.18 Aa	35.37 Ab	35.90 Aab
Festuca arundinacea	10.69 Ca	11.66 Ca	12.26 Ba	13.21 Ca	13.85 Ca	15.30 Ba

[1] Averaged from seven measurement dates each in 2010 and 2011.
[2] 2010 means do not include data from day of treatment (DOT) 99 because of freezing temperatures on DOT 98 and 99.
[3] Within a column, means followed by the same uppercase letter are not statistically different according to least significant difference (LSD) ($P = 0.05$).
[4] Within a row, within each year, means followed by the same lowercase letter are not statistically different according to LSD ($P = 0.05$).

Table 5. Average season-long leaf water potential (Ψ_{leaf}) among each species within each irrigation treatment for 2010 and 2011

	Ψ_{leaf} (MPa)[1]					
	2010[2]			2011		
Species	100% ET	60% ET	20% ET	100% ET	60% ET	20% ET
Ajuga reptans	-4.52 B[3]a[4]	-4.78 Ba	-5.30 Ca	-3.02 Ca	-3.14 Ba	-4.43 Bb
Buchloe dactyloides	-3.48 ABa	-4.18 Bab	-4.36 Bb	-2.60 Ba	-3.58 Bb	-4.13 Bb
Festuca arundinacea	-2.79 Aab	-2.62 Aa	-3.17 Ab	-2.08 Aa	-2.21 Aab	-2.55 Ab

[1] Averaged from seven measurement dates each in 2010 and 2011.
[2] 2010 means do not include data from day of treatment (DOT) 99 because of freezing temperatures on DOT 98 and 99.
[3] Within a column, means followed by the same uppercase letter are not statistically different at $P = 0.05$.
[4] Within a row, within each year, means followed by the same lowercase letter are not statistically different according to least significant difference (LSD) ($P = 0.05$).

Figure 1. Well-watered plots under the rainout shelter at the beginning of the study (June 26, 2010) before the deficit irrigation treatments were initiated.

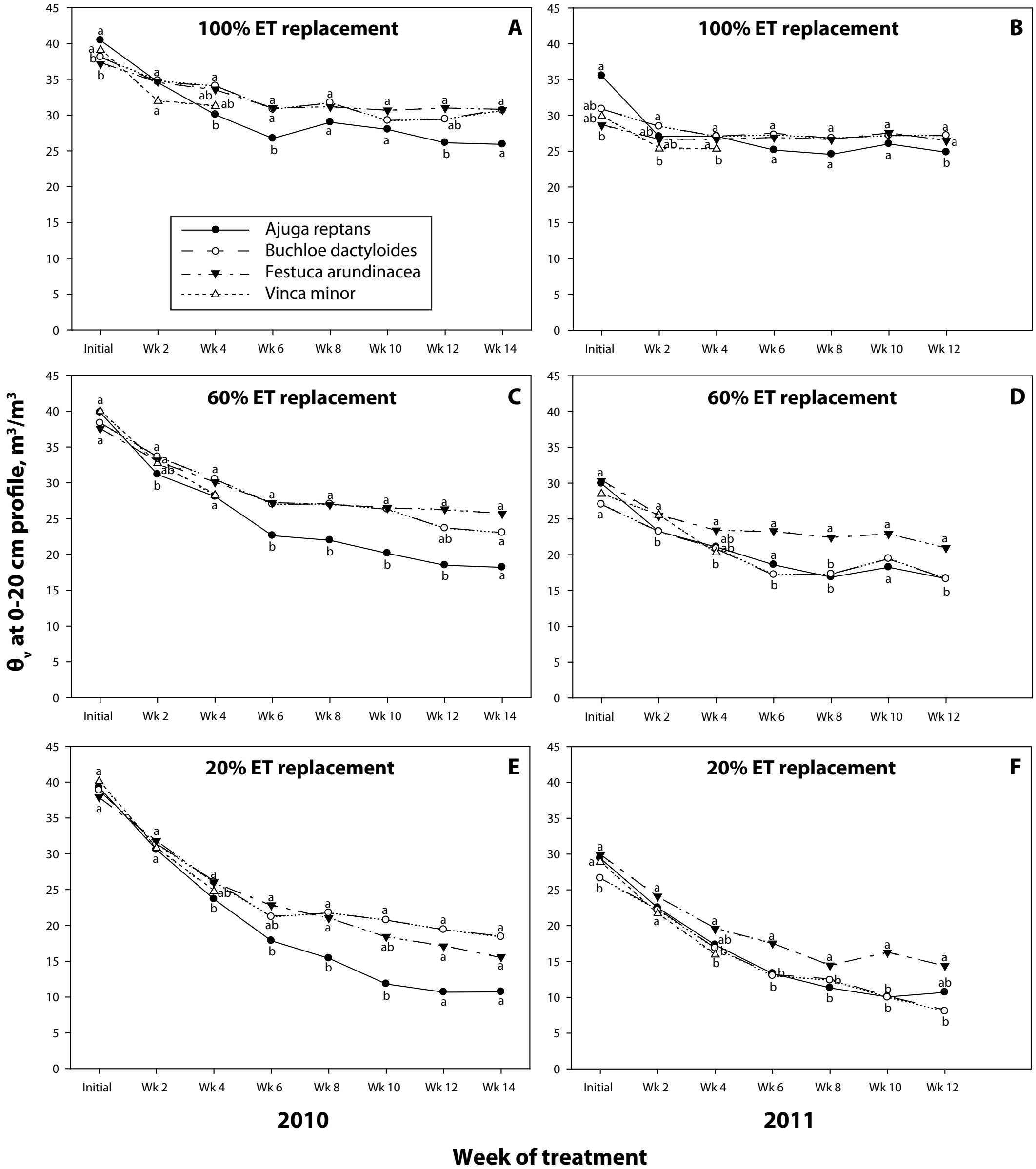

Figure 2. Effects on volumetric soil water content (θ_v) of: 100% ET in 2010 (A) and 2011 (B), 60% ET in 2010 (C) and 2011 (D), and 200% ET in 2010 (E) and 2011 (F) from June 28 through October 4, 2010, and from June 20 through September 12, 2011. *V. minor* data is shown only through week four due to damage from a fungus infestation (*Phoma exigua*) after four weeks during both studies. Means followed by the same letter on the first measurement day (initial) and biweekly averages thereafter are not significantly different ($P = 0.05$).

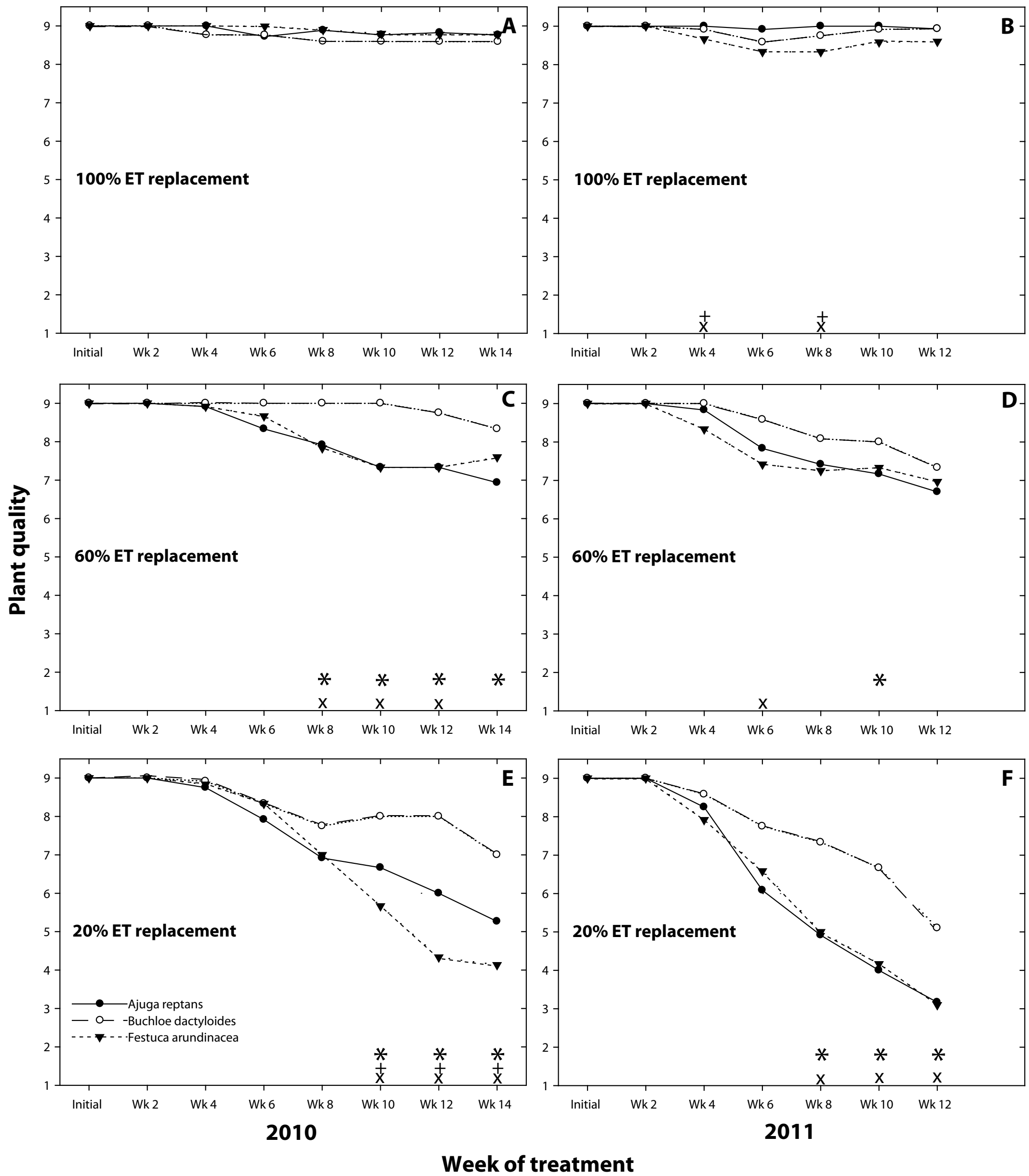

Figure 3. Effects on visual plant quality of: 100% ET in 2010 (A) and 2011 (B), 60% ET in 2010 (C) and 2011 (D), and 20% ET in 2010 (E) and 2011 (F) from June 28 through October 4, 2010, and from June 20 through September 12, 2011. The horizontal dashed line indicates minimal acceptability (quality of 6). Symbols along the abscissa of each graph indicate significant differences ($P = 0.05$) between: *A. reptans* and *B. dactyloides* (*); *B. dactyloides* and *F. arundinacea* (x); and *F. arundinacea* and *A. reptans* (+) on the initial measurement and biweekly averages.

Responses of Turfgrass and Ornamental Landscape Species to Prolonged Drought Stress

Objectives: 1) Evaluate visual quality and water status of one turfgrass and eight non-turf ornamental landscape species during a severe drydown, and 2) evaluate visual quality of the same species during recovery from the severe drydown.

Investigators: Jacob C. Domenghini, Dale Bremer, Jack Fry, and Greg Davis

Sponsors: Kansas Turfgrass Foundation and the USDA National Integrated Water Quality Program (NIWQP)

Introduction

Water resources continue to be depleted as the world's population grows. American families can use up to 400 gallons of water per day, and more than 50% may be used outdoors. Urbanization has been predicted to increase by as much as 80% between 2004 and 2025,[1] indicating that more land will be used for residential and commercial landscapes. This statistic illustrates a need for conserving water in the lawn and landscape. Selection of drought-tolerant species for use in the landscape may be one solution.

Water municipalities often impose water restrictions on residential landscapes, which can cause plants to experience drought stress. Including plants in the landscape that have the ability to maintain their quality longer or experience dormancy during and recover after a drought would be beneficial in areas with water restrictions.

Turfgrasses are often singled out for replacement by presumably more water-efficient plant species to save water. Research is needed, however, to either validate or refute claims that turfgrass uses more water or is less drought-resistant than ornamentals (see "Evapotranspiration and Performance Between Turfgrass and Ornamental Landscape Species in Response to Irrigation Deficit," page 101).

Methods

Two studies were conducted to evaluate performance among species during severe drydowns in the spring/summer and a second in the fall of 2010. Plant species were established in nursery containers in the Throckmorton Plant Sciences Center greenhouse complex in Manhattan, Kan. One turfgrass species, *P. pratensis* 'Apollo,' and eight commonly used ornamental landscape species were selected for the study. The ornamental species were *Achillea millifolium, Ajuga reptans* 'Bronze Beauty,' *Liriope muscari, Pachysandra terminalis, Sedum album, Thymus serpyllum, Vinca major,* and *Vinca minor.* Continuous measurements of air temperature, relative humidity, and

[1] Alig, R.J., J.D. Kline, and M. Lichtenstein. 2004. Urbanization on the US landscape: Looking ahead in the 21st century. Landscape and Urban Planning 69:219-234.

photosynthetically active radiation (PAR) were recorded at canopy height in the same vicinity as the containers during establishment and throughout each study.

When plants were established, containers were arranged in the greenhouse in a randomized complete block design with three replications (Figure 1). To begin the severe drought, irrigation of the containers ceased on May 18, 2010, for the spring/summer study and September 27, 2010, for the fall study. No irrigation was applied during the drydowns. Plant visual quality (1 = brown/dead, 6 = minimally acceptable for home landscape, and 9 = highest quality), container weight, volumetric soil water content (θ_v), leaf water potential (Ψ_{leaf}), and stomatal conductance (g_s) were measured until the plants were either dormant or dead. Irrigation was then applied to the container and percentage of plant density was evaluated for 60 days to determine the level of recovery, if any, from the severe drought.

Results

Visual Plant Quality

During the drydown, several species deteriorated faster than others to the lowest quality rating of one. *S. album* persisted two to three times longer than the next best performing species during drought; *S. album* required 266 days in the spring/summer and 241 days in the fall to decline to a quality rating of 1 (Figure 2). The quality of *L. muscari* and *P. terminalis* also declined slower than the remainder of species in the spring/summer, taking 122 days and 62 days, respectively, to decline to a rating of 1. In the spring/summer, the fastest decline to a quality of 1 among species was in *A. reptans*, *A. millifolium*, and *P. pratensis* (39 days each), and in *T. serpyllum* (42 days) (Figure 2). In the fall, *T. serpyllum* declined the fastest, followed by *A. millifolium*, *P. pratensis*, and *V. minor*. Thus, in both studies the persistence in quality during drought was generally least in *T. serpyllum*, *A. millifolium*, and *P. pratensis*.

Only three species recovered from the drought during the spring/summer: *P. pratensis* [46% Pot Cover (PC)]; *S. album* (38% PC); and *V. major* (35% PC) (Figure 3). The recovery in *P. pratensis*, which was the greatest among species at the end of the 60-day recovery period, indicates its capacity to recover well from complete dormancy. None of the species recovered from prolonged drought in the fall, probably because of a 51% increase in vapor pressure deficit (VPD) that was caused, in part, by artificial lights (Figure 4). We speculate that greater VPD caused plants to dry rapidly, disrupting the normal physiological breakdown of chlorophyll in the leaves. This resulted in the leaves retaining green pigment longer, even after the leaves were completely desiccated. The delayed loss of green pigment in the fall probably delayed the time when most species received a rating of 1 compared with the spring/summer study.

Volumetric Soil Water Content, Leaf Water Potential, and Stomatal Conductance

The decline in θ_v was more rapid in the fall than in the spring/summer, illustrating the effects of greater VPD on evapotranspiration rates in the fall (Figures 4 and 5). By week six in the spring/summer, θ_v of *S. album*, *P. terminalis*, and *L. muscari* was greater than 12% and significantly higher than the other species, with the exception of *P. terminalis*, which was similar to *A. reptans* (Figure 5).

As a general trend in the spring/summer study, Ψ_{leaf} declined slowly as Ψ_{soil} declined (Figure 6). This decline in Ψ_{leaf} illustrates the effects of drought stress as the drydown progressed. *P. terminalis* consistently had lower Ψ_{leaf} during the spring/summer study than other species. The average Ψ_{leaf} of *P. terminalis* overall measurements was -14.9 MPa (spring/summer) and -25.9 MPa (fall). This is over two and a half times lower in the spring/summer, and about four times lower in the fall, than the combined average Ψ_{leaf} of the other species' overall measurements at -5.4 MPa (spring/summer) and -6.2 MPa (fall).

Stomatal conductance was highest among species early in both studies and generally began to decline around day 10 in the spring/summer and day five in the fall as the soil dried (Figure 7). Stomatal closure may have helped the plants maintain leaf water status, as evidenced by the slow decline in Ψ_{leaf} of most species (Figure 6). In the spring/summer, the increase in g_s on the second measurement day (DOT 7) was probably caused by a corresponding increase in PAR from 472 to 697 µmol/m^2/second.

Conclusions

Results indicate *S. album*, *L. muscari*, and *P. terminalis* may be more successful in landscapes where severe drought may occur than the other species evaluated because of their ability to maintain greater plant quality and θ_v for a longer period during a drought. *V. major* and *V. minor* may also be good selections in landscapes with intermittent or less severe droughts. *P. pratensis* may be a good selection as well if periods of dormancy are acceptable to homeowners. *A. millifolium*, *A. reptans*, and *T. serpyllum* appeared least adaptable to severe drought.

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

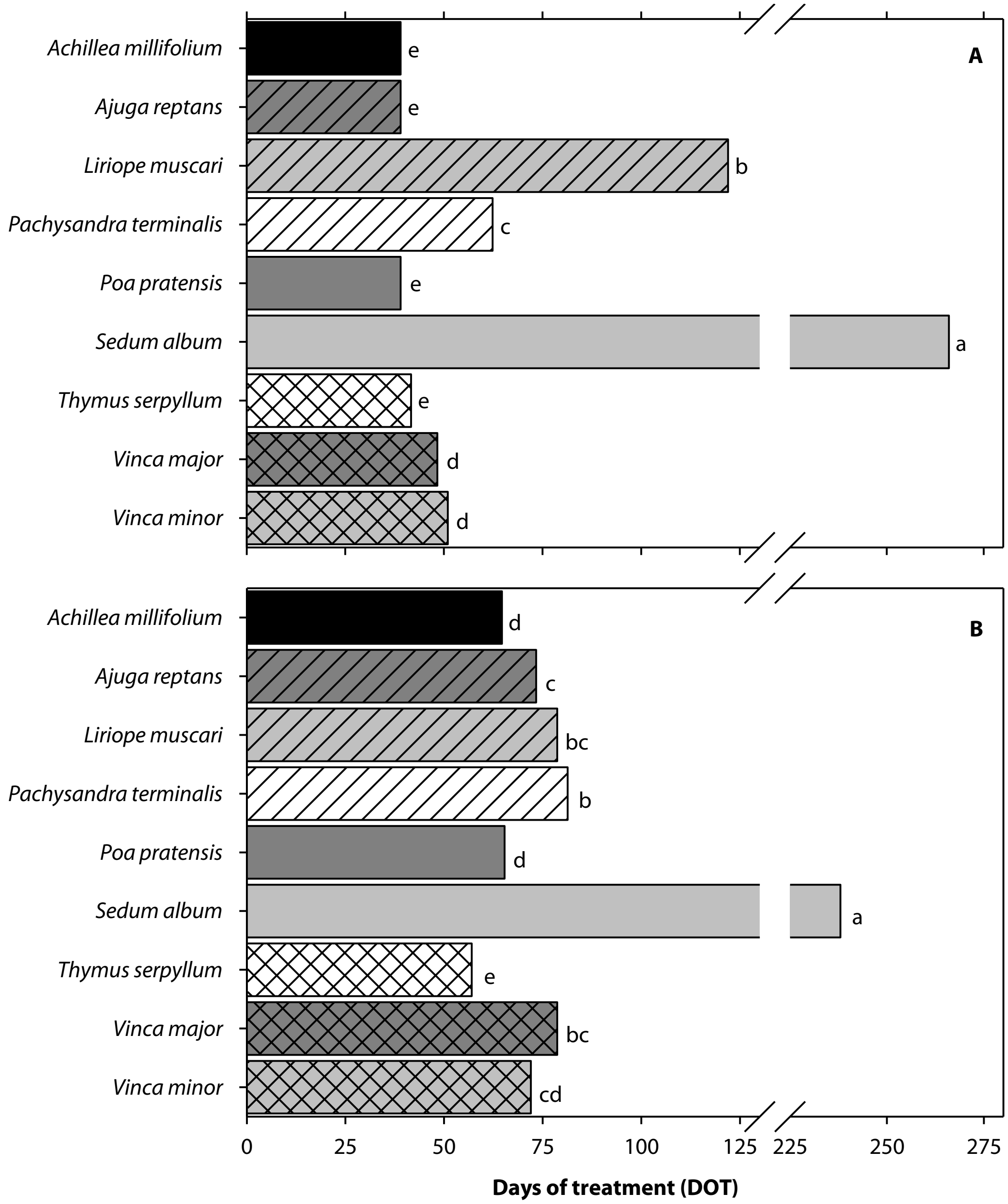

Figure 2. Number of days to decline to a quality rating of one among species during the spring/summer (A) and fall (B). Means followed by the same letter within each study period are not significantly different ($P = 0.05$).

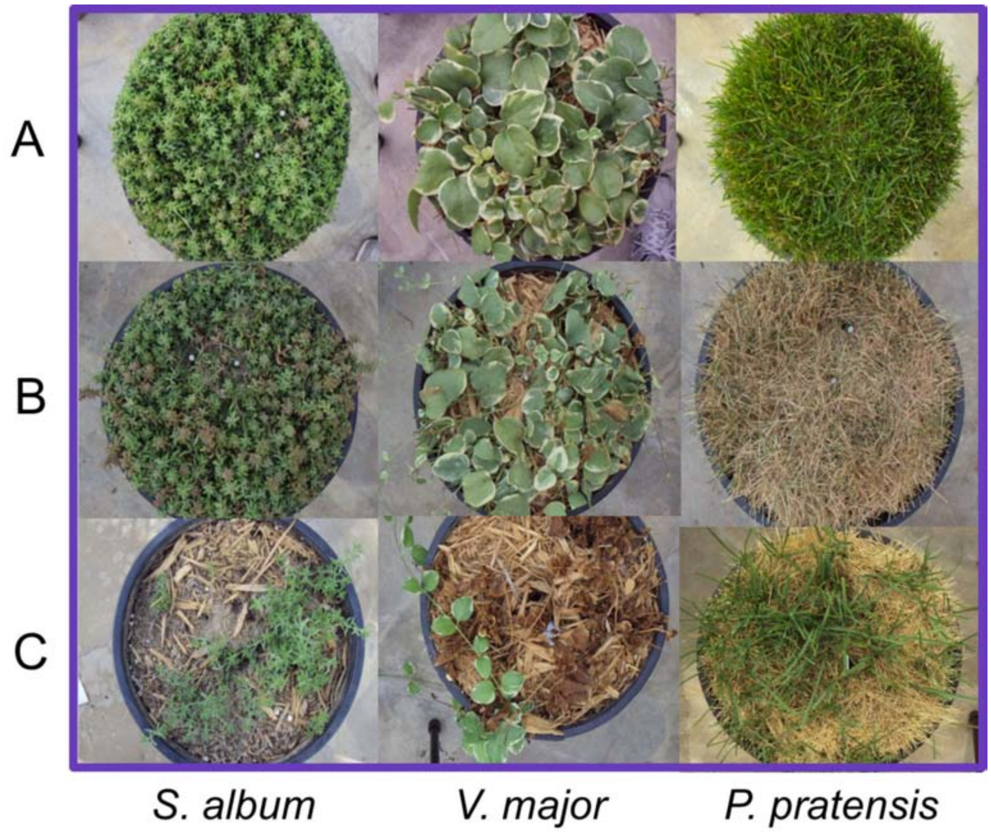

Figure 3. Well-watered containers at the beginning of the severe drydown (A), at week 6 (B), and after 60 days of recovery (C) during the spring/summer study.

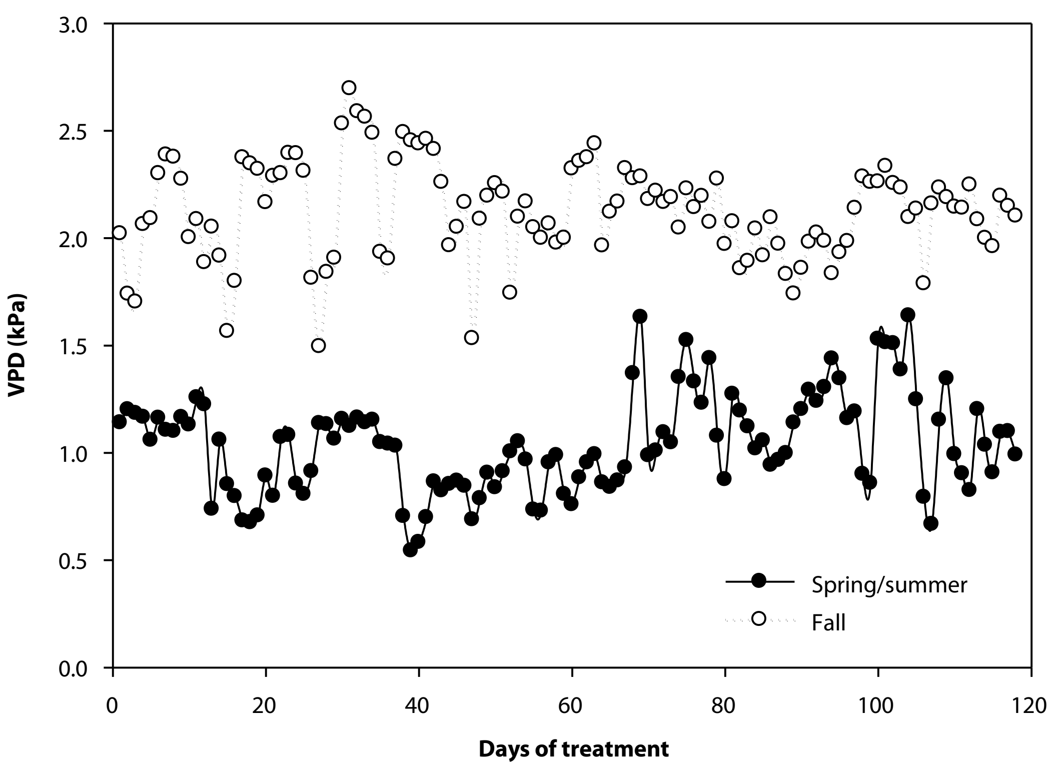

Figure 4. Daytime (6:00 a.m. through 8:00 p.m. CST) vapor pressure deficit (VPD) of the greenhouse environment in the spring/summer and fall studies.

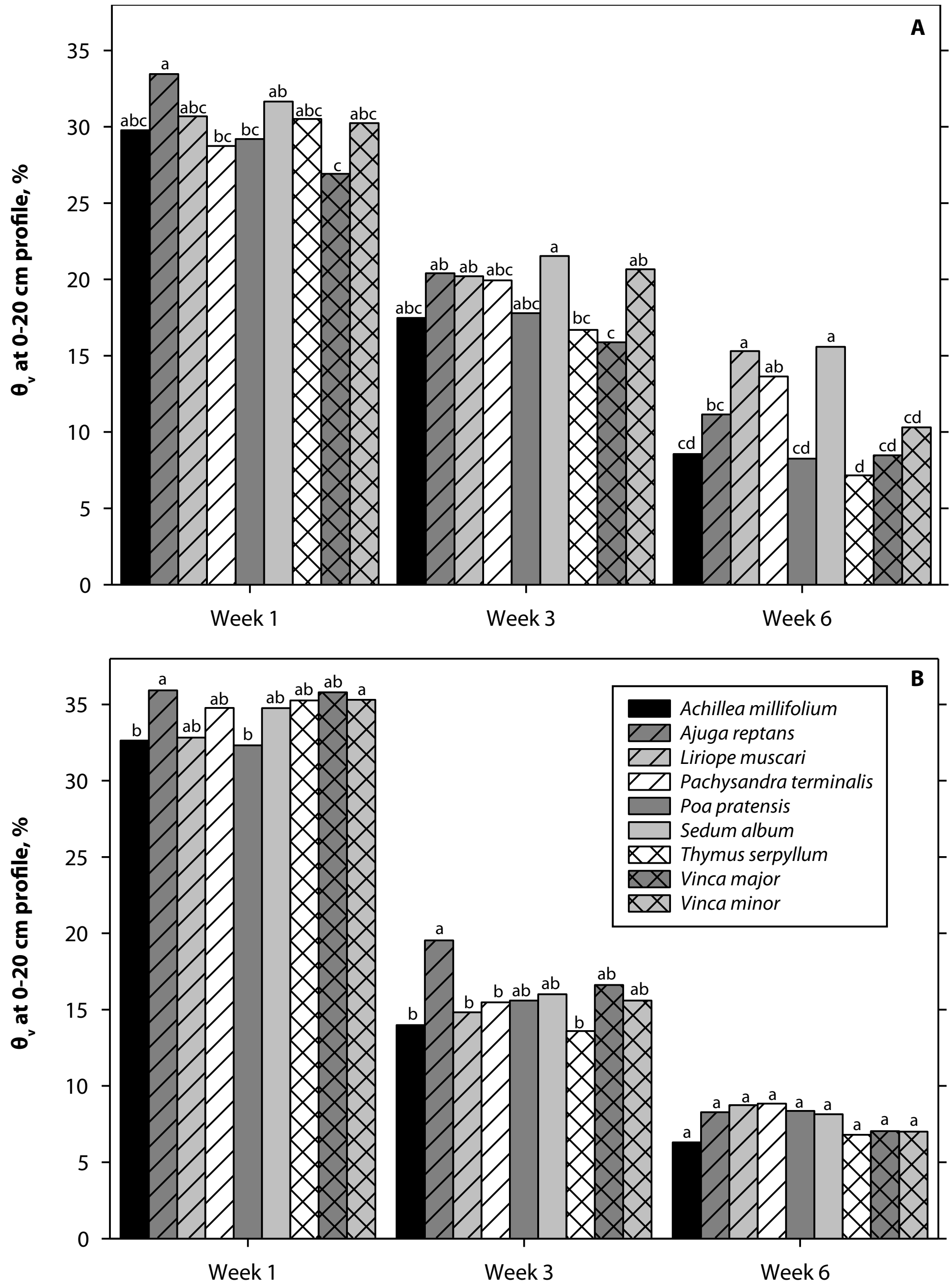

Figure 5. Volumetric soil water content (θ_v) of each species for weeks 1, 3, and 6 of the spring/summer (A) and the fall (B) drydown. Means followed by the same letter within each week are not significantly different (*P* = 0.05).

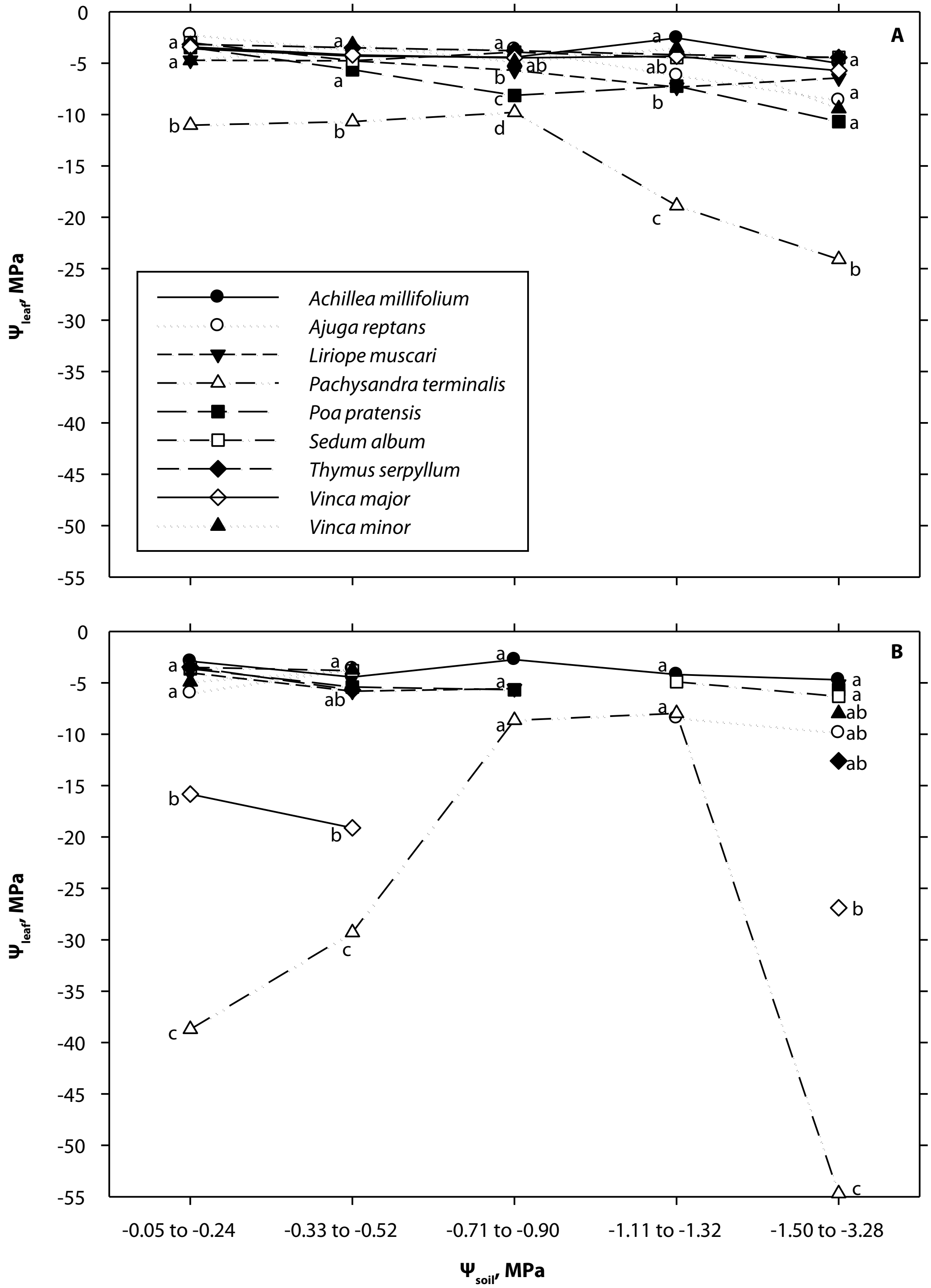

Figure 6. Changes in leaf water potential (Ψ_{leaf}) among species as the soils dried (i.e., Ψ_{soil} became more negative) during the spring/summer (A) and the fall (B) drydown. Means followed by the same letter within each Ψ_{soil} range are not significantly different ($P = 0.05$).

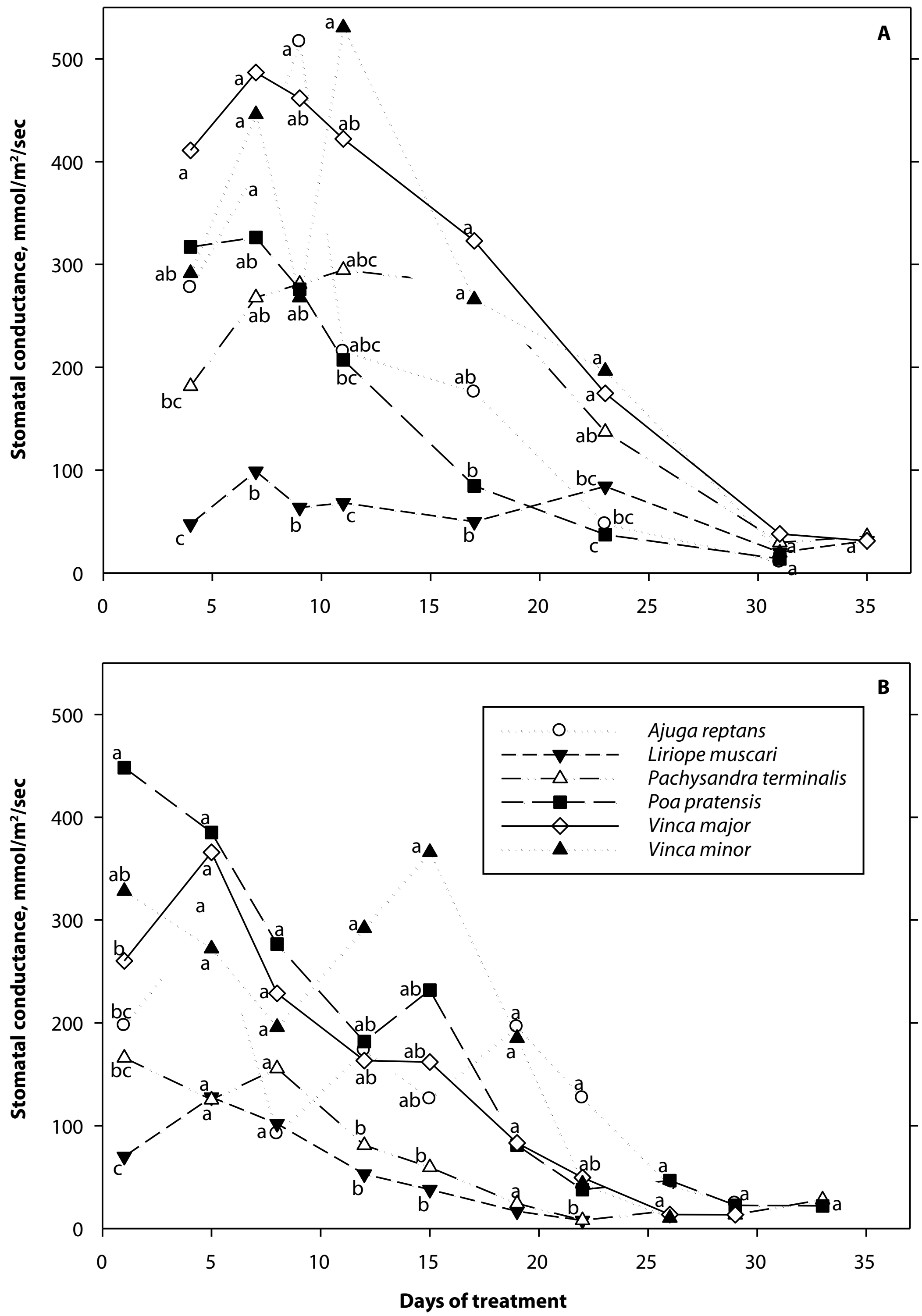

Figure 7. Changes in stomatal conductance (g_s) among species as the soils dried during the spring/summer (A) and the fall (B) drydown. Means followed by the same letter within each measurement day are not significantly different ($P = 0.05$).

Assessing Student Learning with Surveys and a Pre-/Post-Test in a New Online Course

Objectives: 1) Evaluate the level of student learning in a new online course using a pre-/post-test, and 2) evaluate the role of sense and meaning as they relate to student learning in the course.

Investigators: Cody Domenghini, Dale Bremer, Steve Keeley, Jack Fry, Cathie Lavis, and Steve Thien

Sponsor: USDA National Integrated Water Quality Program (NIWQP)

Introduction

Developments in technology have allowed distance education programs to expand in recent years, tremendously increasing the number of courses offered online. Whether a course is taught online or face-to-face, effective teaching is related to process and content. Most instructors know their content very well; however, the process of teaching content to students in a manner that facilitates learning and retention can be a challenge. Teachers should understand the teaching methods that result in the most effective learning experience for their students.

Previous research has found both sense and meaning to be important for student learning. If a concept is presented to a learner in a manner that makes sense to the student and has meaning for the student, the probability of the learner storing the concept in long-term memory is very high (Figure 1). The difference between sense and meaning can be illustrated with this example: A 15-year-old student hears that the minimum age to obtain a driver's license in his state is 16 and the minimum age is 17 in a neighboring state. If the student understands the information, we say it makes *sense* to him. Knowing the minimum age in his own state is more relevant to him because that is the state where he will apply for his license indicates the information also has *meaning* to the student. In other words, sense refers to the level of understanding and meaning refers to the level of significance the information has for a person. Researchers have reported that when instructors made a conscious effort to teach with sense and meaning, they reported an increase in student learning; therefore, the objectives of this research were to evaluate: 1) the level of student learning in a new online course using a pre-/post-test, and 2) the role of sense and meaning as they relate to student learning in the course. We hypothesized that student learning would be greater in areas of the course where both sense and meaning were high.

Background of the Evaluated Course

Water Issues in the Lawn and Landscape is an online course first offered in the spring semester of 2010 that examines critical water issues related to irrigation in urbanizing watersheds, with an emphasis on water quality and quantity. The course was designed for students and industry professionals who want to enhance their knowledge and careers through distance education. Students enrolled in the course learn about the interrelatedness of correct irrigation practices with water quality and quantity, and how to protect water resources through application of science-based irrigation practices.

Methods

The class is co-taught by four professors, each contributing from his or her area of expertise. In addition to conveying relevant content to students, the professors focused on the process through which the material was presented. Specifically, they emphasized creating sense and meaning while developing each assignment, lecture, and exam. The course was designed with seven topical modules presented in developmental order: Module 1, homeowner perceptions (M1); Module 2, water availability and quality (M2); Module 3, relationship between irrigation practices and water quality (M3); Module 4, weather-based irrigation decision-making (M4); Module 5, low-water-use lawns and landscapes (M5); Module 6, auditing irrigation systems (M6); and Module 7, changing water users' habits (M7).

An evaluation was conducted over five semesters (summer and fall 2010 and spring, summer, and fall 2011) to measure learning in the course with a pre- and post-test. Each module included three to five student learning outcomes (SLOs) designed by the course instructors. The SLOs are statements that specify what the students should know or be able to do after completing a particular section of the course. The pre- and post-test used in this study contained 27 questions. Each question was linked to one of the 27 SLOs developed for the course.

Surveys were conducted at the completion of each module to evaluate sense and meaning. Specifically, our objectives for the surveys were to separately evaluate the level of sense and meaning that each lecture, assignment, and exam had for the students. Surveys were available to the students for one week following completion of the module. Surveys were anonymous, allowing respondents to give their honest opinions about the contents of the module. Students were asked two questions about each specific content (lecture, assignment, or exam) in the module. Respondents were asked 1) if content X made *sense* to them, and 2) if content X had *meaning* for them. Respondents were asked to keep the following in mind about each question type. For each question, students responded using a Likert scale: "Definitely," "Yes," "Somewhat," "No," and "Not at all."

Results

Pre- and Post-Test: Student Learning

Student performance increased 10% from the pre-test (79%) to the post-test (89%) (Table 1), indicating that students learned concepts presented in the modules as guided by the SLOs. Mean scores increased significantly from the pre-test to the post-test for all modules with the exception of M7. The mean scores of SLOs 1.3, 2.4, 3.2, 4.1, 5.1, and 6.2 increased from the pre-test to the post-test (Table 1). Scores for each of these SLOs increased by 11 to 37%, to an overall score of 94% or higher (above average, equivalent to an A) on the post-test, with the exception of SLO 3.2, which had a score of 86% on the post-test. Four of these SLOs (2.4, 4.1, 5.1, and 6.2) received high scores on the pre-test (80 to 89%), meaning 80 to 89% of the students got these questions correct on the pre-test. The remaining two SLOs (1.3 and 3.2) received relatively low scores on the pre-test, 71% (SLO 1.3) and 49% (SLO 3.2).

Surveys: Sense and Meaning

For the purposes of discussion, survey responses of "Definitely" or "Yes" were considered favorable, and responses of "Somewhat," "No," or "Not at all" were considered unfavorable. A response of "Somewhat" could be considered acceptable, but because we were measuring the level of student learning for specific lectures, assignments, and exams, we reasoned that an average understanding of the course content was not desirable.

More than 83% of all responses (both sense and meaning questions combined) were favorable (Tables 2 and 3), indicating that the majority of students felt the lectures, assignments, and exams made sense and had meaning. Approximately 16% of all survey responses were unfavorable, but only 2% of responses were "No" or "Not at all." These results show that a majority of the students felt sense and meaning were present in the course content. As mentioned previously, instructors of this course made a conscious effort to include both sense and meaning in the content as the course was developed. Based on these results, the goals appear to have been met.

Overall, we received more favorable responses for sense questions than for meaning questions (Table 3). The sum of favorable ("Definitely" and "Yes") responses was 3.3% greater for the sense questions (43.5%) than for meaning questions (40.2%). Conversely, the sum of unfavorable ("Somewhat," "No," and "Not at all") responses was 3.3% greater for meaning questions (9.8%) than for sense questions (6.5%). This result indicates that sense was present in lectures, assignments, and exams more often than meaning for the students surveyed.

Relating Sense and Meaning to Student Learning

Within the favorable responses of the surveys (i.e., "Definitely" or "Yes"), student learning was greater when both sense and meaning were high. In general, post-test scores declined among modules as the difference between sense and meaning increased ($r = -0.82$, $P = 0.03$; Figure 2). The highest scores for individual modules on the post-test, which indicated greater learning, were 97% and 94% for M2 and M6, respectively (Table 1). Among favorable responses, the sense questions were only 1.2 to 3.1% higher than the meaning questions for these two modules (Figure 2 and Table 3). In contrast, M1 and M7 had the lowest scores among modules on the post-test at 77% and 79%, respectively. In the favorable responses for M1 and M7, the sense questions were 5.7% (M7) and 8.6% (M1) greater than the meaning questions. Although statistical differences between the sense and meaning responses could not be determined, these results imply the importance that both sense and meaning be present to achieve student learning. These findings support the model illustrated in Figure 1[1] and support our hypothesis that student learning is greater where both sense and meaning are high.

Modules with the greatest student learning (i.e., post-test scores) were also high in both sense and meaning among favorable responses. Conversely, in modules with the lowest post-test scores, responses were lower in the meaning questions than the sense questions. Results indicate the survey method developed is a useful tool to evaluate sense and meaning in this online class. Future research is needed to test this assessment tool in other courses, including online and traditional face-to-face class formats.

[1] Sousa, D. A. 2006. How the Brain Learns, Third Edition. Corwin Press, Thousand Oaks, CA.

Table 1. Overall, module, and student learning outcome (SLO) mean scores of the pre- and post-test

	Pre-test	Post-test				Pre-test	Post-test		
	Score (%)		Sig.[1]	Diff.[2] (%)		Score (%)		Sig.[1]	Diff.[2] (%)
Overall	79	89	*	10	Module 4	82	91	*	9
					SLO 4.1	86	100	*	14
Module 1	67	77	*	10	SLO 4.2	89	94	NS	5
SLO 1.1	26	40	NS	14	SLO 4.3	91	97	NS	6
SLO 1.2	69	80	NS	11	SLO 4.4	63	74	NS	11
SLO 1.3	71	94	*	23	Module 5	83	91	*	8
SLO 1.4	100	94	NS	6	SLO 5.1	86	100	*	14
Module 2	91	97	*	6	SLO 5.2	83	94	NS	11
SLO 2.1	82	91	NS	9	SLO 5.3	69	74	NS	5
SLO 2.2	91	97	NS	6	SLO 5.4	94	97	NS	3
SLO 2.3	100	100	NS	0	Module 6	82	94	*	12
SLO 2.4	89	100	*	11	SLO 6.1	89	97	NS	8
Module 3	78	91	*	13	SLO 6.2	80	97	*	17
SLO 3.1	89	97	NS	8	SLO 6.3	77	89	NS	12
SLO 3.2	49	86	*	37	Module 7	72	79	NS	7
SLO 3.3	86	94	NS	8	SLO 7.1	94	97	NS	3
SLO 3.4	83	94	NS	11	SLO 7.2	88	86	NS	-2
SLO 3.5	83	83	NS	0	SLO 7.3	43	54	NS	11

[1] Nonsignificant (NS) or significant (*) differences between pre- and post-test scores at $P=0.05$.

[2] Difference in scores from pre-test to post-test.

Table 2. Percentage of participants' responses to level of sense and meaning for each module and for the course overall

	Definitely[1]	Yes	Somewhat	No	Not at all
Module 1[2]					
Sense	17.8	28.4	3.5	0.3	0.0
Meaning	15.7	21.9	11.1	1.3	0.0
Module 2					
Sense	14.4	30.1	5.4	0.1	0.0
Meaning	15.5	25.9	8.5	0.1	0.0
Module 3					
Sense	20.0	27.0	2.2	0.8	0.0
Meaning	16.5	27.5	5.0	1.0	0.0
Module 4					
Sense	17.8	25.8	5.9	0.5	0.0
Meaning	17.0	25.6	6.6	0.7	0.1
Module 5					
Sense	17.0	25.5	5.5	1.6	0.4
Meaning	16.4	26.1	5.3	1.8	0.4
Module 6					
Sense	10.7	25.2	11.5	2.3	0.3
Meaning	11.7	23.0	14.0	1.0	0.3
Module 7					
Sense	13.1	30.1	6.8	0.0	0.0
Meaning	11.0	26.5	10.6	1.7	0.2
Overall[3]					
Sense	16.0	27.5	5.7	0.7	0.1
Meaning	15.1	25.1	8.6	1.1	0.1

[1] Five-point Likert-type scale used for responses: "Definitely," "Yes," "Somewhat," "No," and "Not at all."
[2] The sum of all percentages in each module rows (sense and meaning combined) equals 100%.
[3] Overall is a report of the responses for all seven modules combined.

Table 3. Percentage of favorable and unfavorable sense and meaning responses for each module and for the course overall

		Favorable[1]	Unfavorable[2]
Module 1	Sense	46.2	3.8
	Meaning	37.6	12.4
	Sum[3]	83.8	16.2
	Difference[4]	8.6	-8.6
Module 2	Sense	44.5	5.5
	Meaning	41.4	8.6
	Sum	85.9	14.1
	Difference	3.1	-3.1
Module 3	Sense	47.0	3.0
	Meaning	44.0	6.0
	Sum	91.0	9.0
	Difference	3.0	-3.0
Module 4	Sense	43.6	6.4
	Meaning	42.6	7.4
	Sum	86.2	13.8
	Difference	1.0	-1.0
Module 5	Sense	42.5	7.5
	Meaning	42.5	7.5
	Sum	85.0	15.0
	Difference	0.0	0.0
Module 6	Sense	35.9	14.1
	Meaning	34.7	15.3
	Sum	70.6	29.4
	Difference	1.2	-1.2
Module 7	Sense	43.2	6.8
	Meaning	37.5	12.5
	Sum	80.7	19.3
	Difference	5.7	-5.7
Overall[5]	Sense	43.5	6.5
	Meaning	40.2	9.8
	Sum	83.7	16.3
	Difference	3.3	-3.3

[1] Favorable is the combination of "Definitely" and "Yes" survey responses.
[2] Unfavorable is the combination of "Somewhat," "No," and "Not at all" survey responses.
[3] Sum of the percentage sense and meaning responses in the favorable and unfavorable categories within each module.
[4] Difference between the percentage sense and meaning responses within each module (sense – meaning).
[5] Overall is a summary of the responses for all seven modules combined.

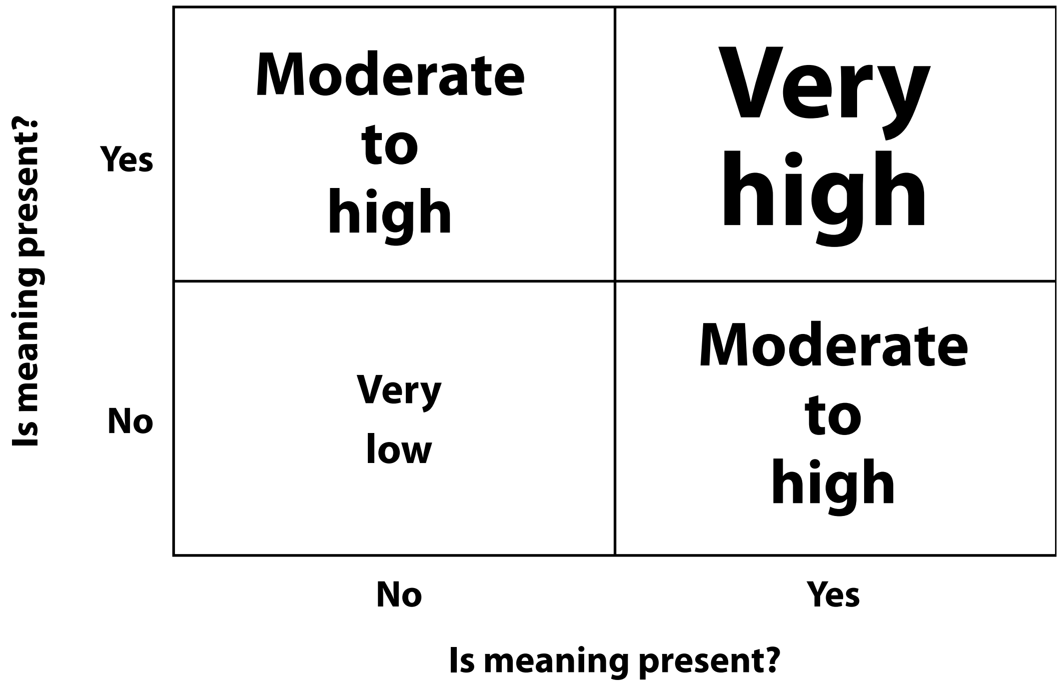

Figure 1. The probability of a student storing the information learned varies with the level of sense and meaning present.

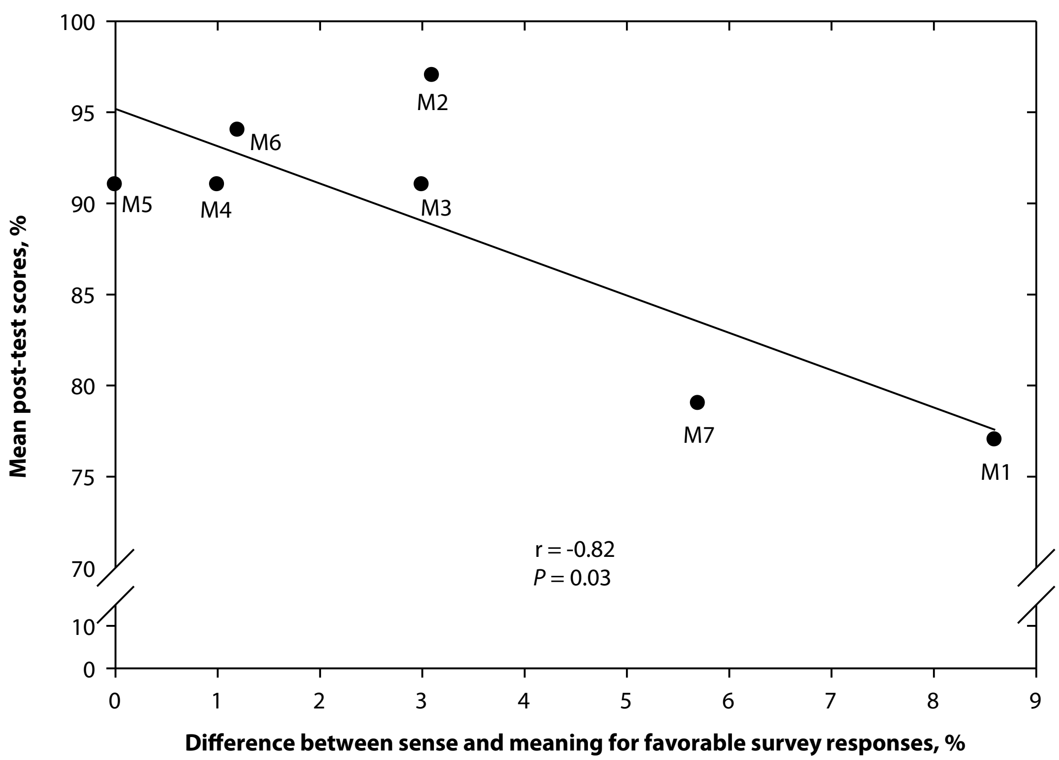

Figure 2. Regression model between mean post-test scores and the percentage difference between sense and meaning for favorable survey responses for Module 1 (M1), Module 2 (M2), Module 3 (M3), Module 4 (M4), Module 5 (M5), Module 6 (M6), and Module 7 (M7).

Irrigation Management Effects on Nitrate Leaching and Tall Fescue Mowing Requirements

Objective: To evaluate the effects of irrigation management on nitrate leaching and tall fescue mowing requirements

Investigators: Josh Chabon, Dale Bremer, and Jack Fry

Sponsor: Kansas Turfgrass Foundation

Introduction

Researchers have evaluated irrigation scheduling turf to determine effects on water consumption and nitrogen leaching; however, most of these studies have incorporated predetermined irrigation times in an attempt to minimize water usage and maximize efficiency of use. Little information is available on the impact of using soil water sensors to schedule irrigation and its potential effects on nitrogen leaching.

Materials and Methods

Nitrate Leaching Study

Research was conducted at the Rocky Ford Turfgrass Research Center, Manhattan, Kan., from September 22 through November 14, 2011. The experimental design was a split plot, with irrigation scheduling as the whole plot and nitrogen source and application rate as the subplots. Irrigation whole plot treatments were: 1) routine irrigation to apply 1.13 in. of water three times per week, and 2) irrigation with 1 in. of water when a predetermined volumetric soil water content was reached. Whole plots measured 30 ft × 90 ft. An in-ground irrigation system with lines running on the north and south side of the plots was utilized. Irrigation heads were Hunter I-20s set on a 30-ft spacing. In soil-sensor whole plots, Acclima sensors were installed next to the central most lysimeter subplot within each soil-sensor whole plot at a 10-cm depth. To elucidate predetermined soil water contents at which irrigation would occur, turf was monitored until wilt was first observed, and soil water content was recorded for that particular whole plot. The average soil water content that resulted in wilt was determined across the three whole plots. In-ground irrigation was then operated by the Acclima SC6 controller to deliver approximately 1 in. of water at one time in the early morning hours the next day.

Subplots within each whole plot measured 3.8 ft × 6.4 ft and contained the following treatments: 1) untreated, 2) 2.5 lb N/1,000 ft^2 per year from urea (46-0-0 N-P-K), 3) 2.5 lb N/1,000 ft^2 per year from a polymer coated urea (PCU; 41-0-0), and 4) 5.0 lb N/1,000 ft^2 per year from urea; and 5) 5.0 lb N/1,000 ft^2 per year Polyon (41-0-0). Water will be suctioned from lysimeters and be taken monthly throughout the growing season to measure leachate levels. Water meters were installed at each zone to measure water usage. The turf surrounding each lysimeter was mowed weekly at a height of 3.0 in. Visual quality was rated weekly.

Suction lysimeters were installed in the center of each subplot, with ceramic collection cups set at a 2.5-ft depth. Soil solution was extracted from the lysimeters on November 25, 2011, and April 30, 2012, using a vacuum that was applied to each lysimeter at approximately a pressure of 50 centibars for a period of 24 to 48 hours depending on the amount of moisture in the soil. Samples were analyzed in the Kansas State University soil testing lab for NO_3 levels (in ppm).

Mowing Study

This was a separate experiment on tall fescue using the same irrigation whole plots described for the nitrate leaching study above. Four subplots measuring 15 ft × 6 ft were established in each whole plot, including mowing at 1) 2 in., 2) 3.5 in., 3) 2 in. with Primo, and 4) 3.5 in. with Primo. Primo was applied at 0.75 fl oz./1,000 ft^2 on September 15 and October 26. Mowing was done on all subplots to follow the one-third rule. Within each irrigation whole plot, subplots were measured on Mondays, Wednesdays, and Fridays to determine the current height. When two of the three replicates of mowing subplots had exceeding the height to trigger mowing based upon the one-third rule, all three were then mowed to their respective height. Data were collected on total water application and number of mowings, and turf quality was rated once weekly on a 1 to 9 scale.

Results

Water Use (Both Studies)

The average usage for 2011 of the fixed irrigation schedule types was approximately 0.36 ac-in. (222.2 gal/1,000 ft^2), and the average usage of sensor irrigation types was approximately 0.10 ac-in. (61.7 gal/1,000 ft^2).

Nitrate Leaching Study

Nitrate levels did not differ in leachate extracted from lysimeters in the two irrigation treatments in November 2011 or April 2012; furthermore, nitrate levels did not differ among nitrogen sources and rates. When leachate was collected from lysimeters, almost all of the samples contained <0.01 ppm nitrate. Nitrogen fertilizer treatments did not influence turf quality.

Mowing Study

Because of the limited amount of time that this study was conducted in 2011, irrigation management had no influence on mowing, and there were no differences among mowing treatments for number of mowings. We observed some significant difference in the quality ratings of the mowing plots early in the season due to the hot weather when the trial began and the difficulties of isolating the sensor irrigation controller from the main controller at the Rocky Ford Turfgrass Research Center (Table 1). As the season progressed, however, quality ratings became no longer significantly different.

Table 1. Influence of mowing height, with or without Primo, on turfgrass quality; data are averaged over irrigation treatments

Mowing height	Sept. 22	Sept. 28	Oct. 6	Oct. 13	Oct. 28	Oct. 27	Nov. 3	Nov. 10
3.5 in., no Primo	7.0 a[1]	6.8 a	6.8 a	6.8 a	6.8 a	6.7 a	6.7 a	6.7 a
3.5 in. w/ Primo	6.7 a	6.3 a	6.5 a	6.5 ab	6.5 ab	6.5 a	6.5 a	6.5 a
2.0 in., no Primo	4.7 b	4.7 b	4.7 b	5.2 b	5.2 b	5.7 a	5.7 a	5.7 a
2.0 in. w/ Primo	4.7 b	4.5 b	4.5 b	5.0 b	5.0 b	5.5 a	5.5 a	5.5 a

[1] Means followed by the same letter in a column are not significantly ($P < 0.05$) different based on pairwise comparisons.

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