2007

# K-State Turfgrass Research 2007

Kansas State University. Agricultural Experiment Station and Cooperative Extension Service

K-STATE
Kansas State University

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and Cooperative Extension Service

# K-STATE TURFGRASS RESEARCH

## 2007

Report of Progress 981

# FOREWORD

***Turfgrass Research 2007*** contains results of projects done by K-State faculty and graduate students. Some of these results will be presented at the Kansas Turfgrass Field Day, August 2, 2007, at the Olathe Extension and Research Center. The enclosed articles 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 environmental stresses, turfgrass establishment and culture, and cultivar evaluations.

What questions can we answer for you? The K-State 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. In addition to the CD format, you can access this report, those from previous years, and all K-State Research and Extension publications relating to turfgrass on the Web at:

*http://ksuturf.com*

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Contribution number: 08-20-S

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**TITLE**: Evaluation of Turfgrass Quality and Green Leaf Area Index and Aboveground Biomass with Multispectral Radiometry

**OBJECTIVES:** 1. Compare correlations between canopy reflectance and visual ratings in four cool-season grasses; and 2. measure relationships between reflectance data and green leaf area index and biomass in seven turfgrass species.

**AUTHORS**: Hyeonju Lee, Dale Bremer, and Kemin Su

**SPONSORS**: The Scotts Co., Inc, Golf Course Superintendents Association of America, and the Kansas Turfgrass Foundation

**INTRODUCTION:**
Turfgrass quality is typically evaluated by visual observations of color, uniformity, density, and texture. Visual evaluations, however, are subjective and may vary among observers. Multispectral radiometry (MSR) may provide quantitative and objective evaluations of turfgrass quality and its responses to various stresses by measuring the reflectance of turfgrasses in the visible and near infrared part of the spectrum (Table 1). Normalized difference vegetation index (NDVI) and the ratio of near infrared to red (NIR/R) may be good predictors of green leaf area index (LAI) and aboveground biomass, although this has not been evaluated in turfgrasses.

**METHODS:**
*Study 1: Correlations between visual ratings of turfgrass quality and canopy reflectance. measurements*Research was conducted under a rainout shelter (12 x 12 m) at the Rocky Ford Turfgrass Research Center, Manhattan, KS, summer, 2005 and 2006 (Fig. 1A). Four cool-season turfgrasses were evaluated: Kentucky bluegrass (*Poa pratensis* L., 'Apollo'), tall fescue (*Festuca arundinacea* Schreb., 'Dynasty') and two hybrid bluegrasses, genetic crosses between *Poa arachnifera* Torr. and Kentucky bluegrass ('Thermal Blue' and 'Reveille'). Spectral reflectance was measured once weekly with a handheld multispectral radiometer (CropScan16, Inc., Rochester, MN) (Fig. 1B-1D). Turfgrass quality was rated visually on a scale from 1 to 9 (6=minimally acceptable for use in home lawns) and was compared with reflectance at each of 8 wavelengths as well as with the ratios NDVI (computed as [*R935-R661*] / [*R935+R661*]), *NIR/R* (*R935/R661*), *Stress 1* (*R706/R760*), and *Stress 2* (*R706/R935*).

*Study 2: Predicting green leaf area index and aboveground biomass with NDVI and NIR/R.*
Aboveground biomass samples (three 7.62 cm diam. PVC rings) were harvested from turfgrass canopies immediately after measurements with MSR on seven turfgrass cultivars. Green leaf area was measured with an area scanner and software (WinRhizo 2002C Reg). Green biomass was then dried and weighed separately from dead biomass at 78°C for 12 hours. Measurements of green LAI and aboveground biomass were correlated with NDVI and NIR/R to determine relationships between spectral reflectance and canopy properties.

**RESULTS:**
*Study 1: Correlations between visual ratings of turfgrass quality and canopy reflectance measurements.*
Relationships between turfgrass quality and MSR data were significant at ***R661*** *NDVI, IR/R* and *Stress1* showed strong correlations in cool-season grasses (Table 2). Our results indicated that reflectance measurements in these wavebands and ratios may be a good method for assessing turfgrass quality. Further research and data analyses are being conducted to develop predictive models to accurately estimate turfgrass visual quality using multispectral radiometry.

*Study 2:Predicting green leaf area index and aboveground biomass with NDVI and NIR/R.*
No relationships were evident between green LAI or biomass and reflectance data (Fig. 2). Data indicated that LAI in established turfgrasses may be above the “saturation point” of reflectance-based vegetation indices, suggesting limited use of MSR data in predicting LAI. Further research is needed to develop adequate models to predict LAI from reflectance data – e.g., hyperspectral radiometry or the refinement of vegetation indices from our MSR data may result in improved predictions from reflectance data of green LAI and biomass in turfgrasses.

**Table 1.** Wavelengths measured by Cropscan multispectral radiometer and the associated color and function in plant tissue at each wavelength.

| Wavebands | Color | Properties |
|---|---|---|
| $R_{507}$<br>$R_{559}$ | Green | Low absorbance by chlorophyll |
| $R_{613}$<br>$R_{661}$<br>$R_{706}$ | Red | High absorbance by chlorophyll |
| $R_{760}$<br>$R_{813}$<br>$R_{935}$ | Near infrared | High reflectance by air -water interfaces in leaf |

**Table 2.** Correlation coefficients for reflectance vs. turfgrass quality in four cool-season turfgrasses in 2005 and 2006.

| Wavelength or Ratio | Correlation | |
|---|---|---|
| | 2005 | 2006 |
| $R_{507}$ | -0.48 | -0.70 |
| $R_{559}$ | -0.64 | -0.61 |
| $R_{613}$ | -0.74 | -0.09 |
| $R_{661}$ | -0.80 | -0.73 |
| $R_{706}$ | -0.54 | -0.37 |
| $R_{760}$ | 0.76 | 0.55 |
| $R_{813}$ | 0.38 | 0.62 |
| $R_{935}$ | 0.40 | 0.54 |
| NDVI | 0.88 | 0.77 |
| IR/R | 0.83 | 0.68 |
| Stress1 | -0.84 | -0.68 |
| Stress2 | -0.70 | -0.70 |

**Figure 1**. (A) The rainout shelter shields turf plots from rainfall and allows for precise irrigation application. (B) Reflectance was measured using a Cropscan MSR 16. The sensor head of MSR 16 radiometer (C) and keypad (D) are shown.

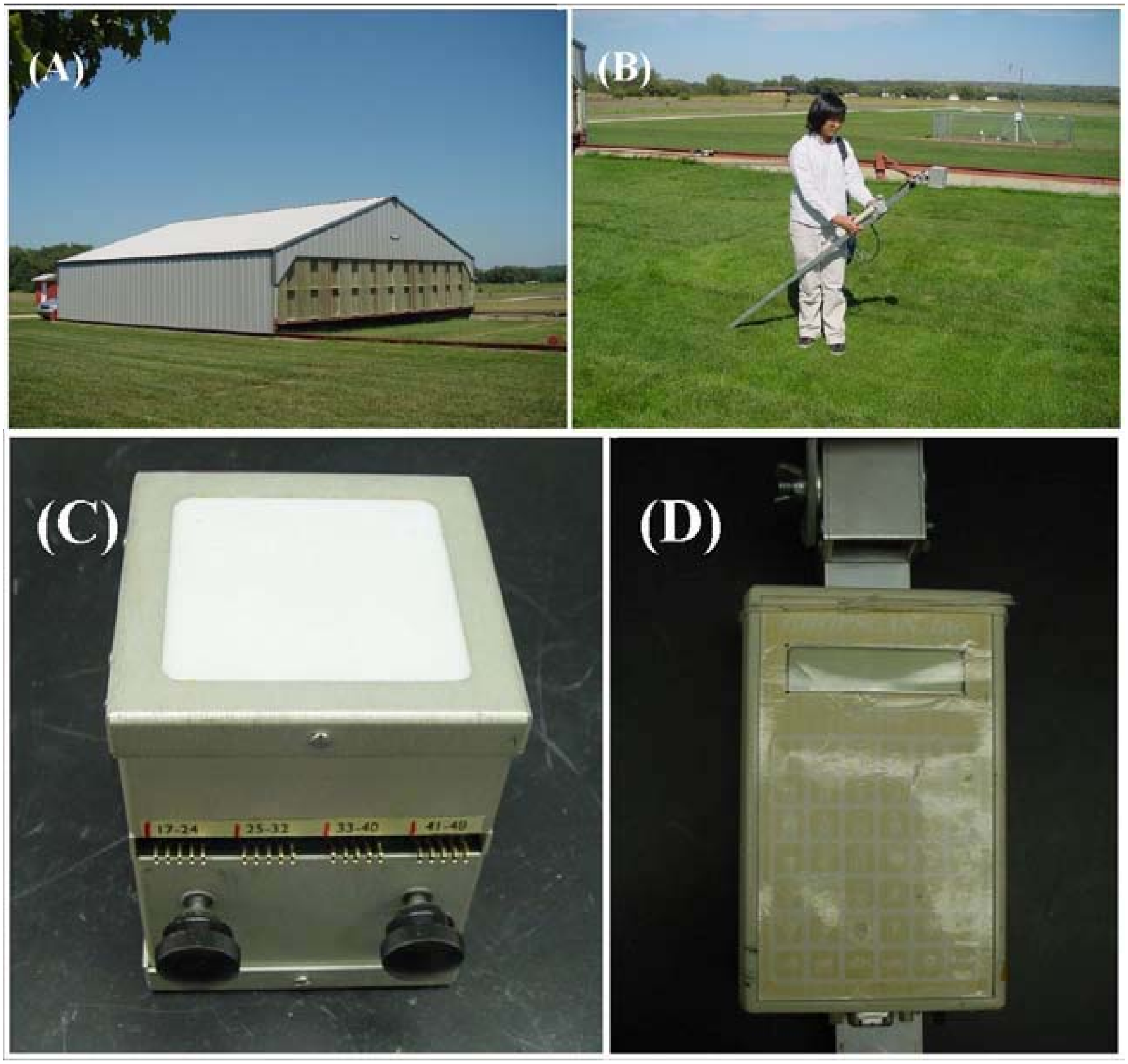
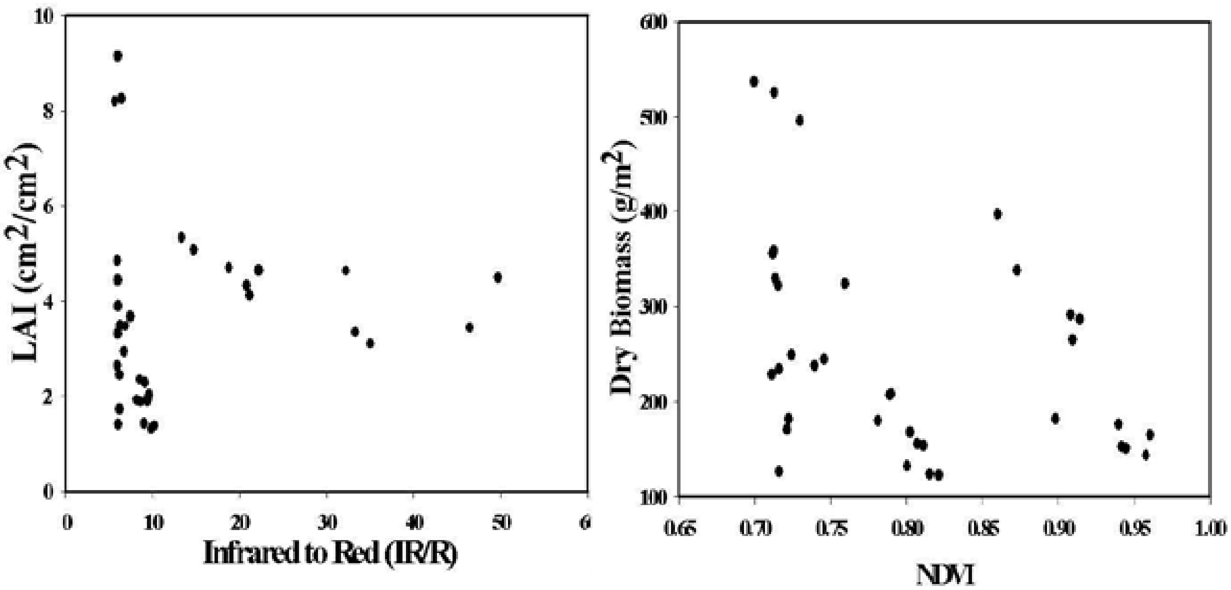


**Figure 2**. Relationship between IR/R and green LAI (left) and NDVI and green aboveground dry biomass and (right) in seven turfgrass cultivars.



**TITLE:** Lateral Spread of Tall Fescue Cultivars and Blends

**OBJECTIVE:** Compare lateral spread of tall fescue cultivars and blends with Kentucky bluegrass

**PERSONNEL:** Jack Fry, Dale Bremer, Steve Keeley, and Rodney St. John

**SPONSORS:** Kansas Turfgrass Foundation. Hummert International, Barenbrug USA, and Seed Research of Oregon provided seed

**INTRODUCTION:**

Some new tall fescue cultivars and blends have been advertised as being rhizomatous, resulting in faster establishment and recovery time. More research is needed to determine the extent of this rhizomatous nature in tall fescue. Barenbrug USA researchers reported that 'Labarinth' tall fescue produced more and longer rhizomes compared to several other tall fescue cultivars when evaluated 20 months after transplanting 2-month-old plants. Ohio State University researchers evaluated six tall fescue cultivars, including some that were purported to be rhizomatous, and found that the average number of plants producing a rhizome was 21 percent, and all were less than 3 cm long. More information is needed to evaluate the rhizomatous potential of tall fescue cultivars and its influence on lateral spread and recuperative potential.

**MATERIALS AND METHODS:**

Six different cultivars or blends were seeded into a silt loam soil in 5 x 5-ft. plots arranged in a randomized complete block design on September 14, 2005, at the Rocky Ford Turfgrass Research Center, Manhattan, KS. Each cultivar was replicated four times. Tall fescues evaluated included 'Grande', 'Regiment II', 'Barlexus', 'Water Saver RTF' tall fescue blend (39.84 'Labarinth'; 29.93 'Barlexus II'; 29.86 'Barrington'); and 'Kentucky-31'. SR2284 Kentucky bluegrass was also included. Tall fescue cultivars evaluated that are purported to be more prolific rhizome producers are Grande II, Regiment II, and Water Saver RTF blend (particularly the Lararinth cultivar in the blend). Tall fescue was seeded at 7 lbs/1,000 sq. ft. and Kentucky bluegrass at 2 lbs/1,000 ft$^2$. Seed was mixed with Milorganite to provide 1 lb. N/1,000 ft$^2$ at the time of seeding. Nitrogen from urea was applied at 1 lb./1,000 ft$^2$. in November 2005, and May and September 2006. Turf was irrigated to prevent drought stress and mowed at least once weekly at a 3 inches.

During autumn 2005, percentage of coverage during the establishment period was determined weekly through 9 weeks after seeding using a First Growth camera.

On July 28, 2006, four 4-inch-diameter x 4-inch-deep plugs were removed from the center of each plot. A uniform circle of 1-ft.-diameter x 4-inch-deep was cut in the center of each plot around the area where plugs were removed on August 1, 2006, and voids were filled with the same field soil to return to the original level. Plugs were planted in an adjacent area for another study in which lateral spread will be evaluated (data not presented here). Hand weeding within each circular void was done as needed. On August 31 and October 5, 2006, the number of emerging daughter plants arising from rhizomes within each void was counted. On August 31, the greatest distance from the circle's edge that a newly emerging daughter plant was observed was also recorded. Data were subjected to analysis of variance and means separated using an F-LSD ($P < 0.05$).

**RESULTS:**

*Establishment rate.* Kentucky bluegrass was slowest to establish following seeding in Fall 2005 (Figure 1). Among tall fescues, Kentucky-31 exhibited greater coverage three weeks after seeding than other cultivars, and was greater than at least one other tall fescue cultivar on all rating dates. Regiment II had lower levels of coverage than at least one cultivar other than Kentucky-31 at 2 to 5 weeks after seeding and 7 weeks after seeding. Coverage of other tall fescue cultivars and blends was intermediate between Regiment II and Kentucky-31.

*Lateral Spread into Voids.* Kentucky bluegrass had significantly more emerging daughter plants than any tall fescue cultivar or blend on each evaluation date (Table 1). Kentucky bluegrass had produced more than 11 daughter plants per 1 ft. diam. void on August 31 and more than 18 on October 5. The average number of daughter plants emerging in voids in tall fescue plots was less than 2 on both evaluation dates. The greatest distance from the circle's edge that a Kentucky bluegrass daughter plant emerged was about 8 cm. Tall fescue daughter plants emerged no greater than 1.5 cm from the circle's edge.

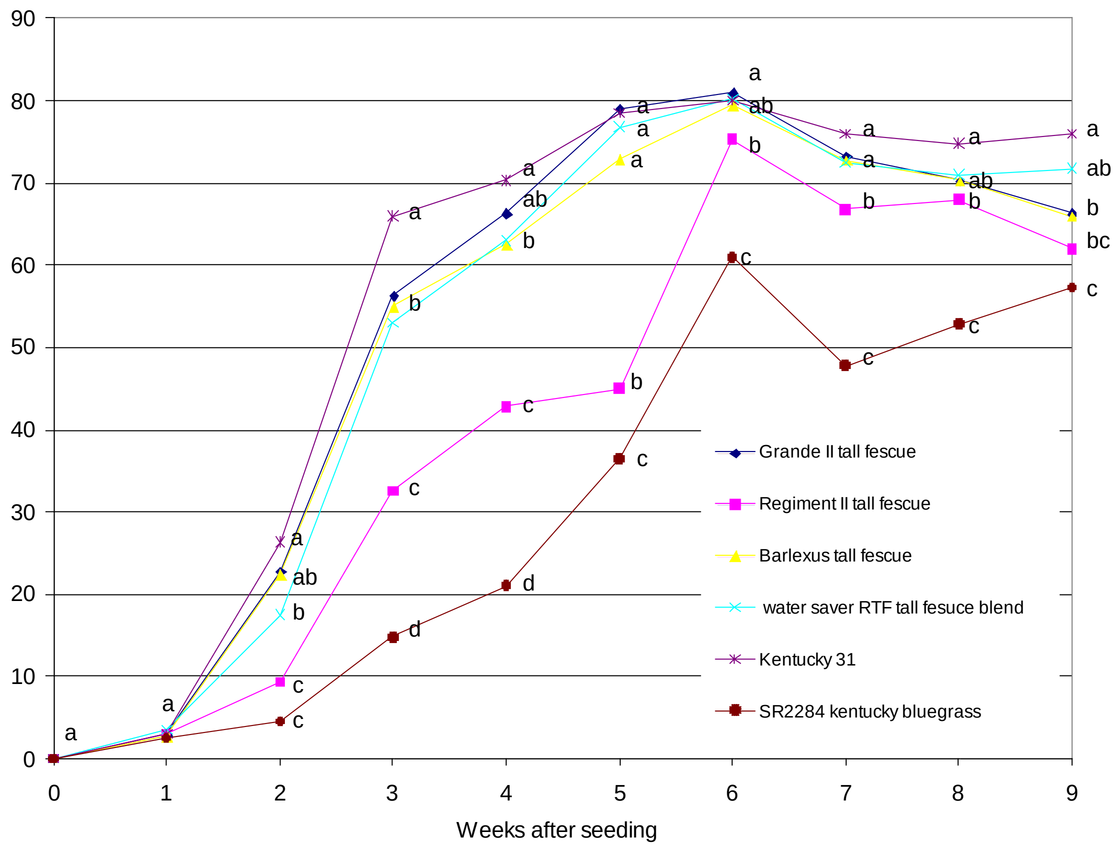
In summary, rhizomatous tall fescue cultivars and blends did not increase rate of coverage relative to non-rhizomatous types. By October 2006, plants were more than 24 months old. Research by Barenbrug USA indicated that plants needed to be at least 20 months old before rhizome production was substantial. Data collection will continue on these cultivars and blends.

**Table 1.** Daughter plants emerging in 1-foot-diameter circular voids in the center of tall fescue and Kentucky bluegrass plots, and the farthest distance away from the circle's edge that any one plant emerged. Voids were created on July 28, 2006.

| Cultivar or Blend | Reported to have improved recuperative potential? | Daughter plants (no.) | | Distance (cm) |
|---|---|---|---|---|
| | | Aug. 31 | Oct. 5 | Aug. 31 |
| Grande II tall fescue | Yes | 0.50 b* | 0.50 b | 1.25 b |
| Regiment II tall fescue | Yes | 2.00 b | 0.00 b | 2.25 b |
| Water saver RTF tall fescue blend | Yes | 0.25 b | 0.50 b | 0.25 b |
| Barlexus tall fescue | No | 1.50 b | 1.00 b | 1.50 b |
| Kentucky 31 | No | 1.25 b | 2.00 b | 1.00 b |
| SR2284 Kentucky bluegrass | - | 11.50 a | 18.75 a | 8.25 a |

*Means followed by the same letter on a date are not significantly different ($P$ < 0.05).

**Fig. 1**. Rate of coverage of tall fescue cultivars and blends and Kentucky bluegrass after seeding on September 14, 2005. Points represent the mean of four replicates. Points followed by the same letter in a week are not statistically different ($P < 0.05$).



**TITLE:** 2001 National Tall Fescue Test

**OBJECTIVE:** To evaluate tall fescue cultivars under Kansas conditions and submit data collected to the National Turfgrass Evaluation Program

**PERSONNEL:** Linda R. Parsons and Rodney St. John

**SPONSOR:** USDA National Turfgrass Evaluation Program

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

**MATERIALS AND METHODS:**
After incorporating 13-13-13 at a rate of 1 lb. NPK /1,000 $ft^2$ into 480 5- x 5- ft. study plots at the John C. Pair Horticultural Center, Wichita, KS, the area was seeded September 28, 2001, with 160 tall fescue cultivars and experimental numbers in a randomized complete block design at a rate of 4.4 lb. of seed per 1,000 $ft^{2.}$ Fertility was maintained at 0.25 to 0.5 lb. N/1,000 $ft^2$ per growing month. Plots were mowed weekly during the growing season at 2.5 in. and clippings removed. Irrigation was done as necessary to prevent stress. Weeds, insects, and disease were controlled only when they presented a threat to the trial.

During the course of the study, information was collected on spring green-up, genetic color, leaf texture, quality, and other measures when appropriate. Rating was done on a scale of 1=poorest, 6=acceptable, and 9=optimum measure.

**RESULTS:**
During the summer of 2006, data were collected on turf green up and quality. The growing season began by assessing spring green up. By April 12, the cultivars/ experimental numbers BE1, CAS-ED, and Tar Heel were among the greenest (Table 1). Fescue plots were rated monthly throughout the growing season for turf quality. Ratings were influenced by degree of coverage and weed infestation as well as turf color, texture, and density. Those that performed best overall were Escalade (01-ORU1), 2nd Millennium, BE1, Dynasty, and Finelawn Elite (DLSD).

In reviewing turf performance over the course of the study, Finelawn Elite (DLSD), Justice (RB2-01), Apache III (PST-5A1), and BE1 were rated as the best performers with the highest quality ratings (Table 2). Evaluation of the turf plots began in 2001, six weeks after seeding, by looking at percent ground cover as a measure of turf establishment rate. At that time, GO-RD4, PST-5NAS, Kentucky 31 with Endophytes, Elisa, and Falcon II were the best established, with 60 to 67 percent cover, respectively. Starting in 2003, spring green up was rated annually, with Blackwatch (Pick-OD3-01), CAS-ED, Gremlin (P-58), and Tar Heel earliest to green. Every year of the study from 2002 through 2005, genetic color and turf texture were rated. MRF 28, NA-TDD, Regiment II (SRX 805), MRF 210, and MRF 211 were among the darkest green. ATF 806, Inferno (JT-99), JT-12, and Wellington had the finest texture.

More information on the National Turfgrass Evaluation Program and the complete results of the nationwide 2001 National Tall Fescue Test can be found at http://www.ntep.org/.

**Table 1.** 2006 performance of tall fescue cultivars at Wichita, KS.[1]

| Cultivar/ Experimental Number | Spring Green up | Quality Apr. | May | Jun. | Jul. | Aug. | Sep. | Avg. |
|---|---|---|---|---|---|---|---|---|
| Escalade (01-ORU1)*[2] | 5.7 | 5.7 | 6.3 | 5.7 | 6.0 | 6.0 | 5.7 | 5.9 |
| 2nd Millennium* | 5.3 | 5.0 | 5.7 | 6.3 | 6.0 | 6.0 | 6.3 | 5.9 |
| BE1 | 6.7 | 5.7 | 5.7 | 6.0 | 5.7 | 6.0 | 6.0 | 5.8 |
| Dynasty* | 6.0 | 5.7 | 6.7 | 5.7 | 6.7 | 5.3 | 5.0 | 5.8 |
| Finelawn Elite (DLSD)* | 5.7 | 5.7 | 6.0 | 6.0 | 5.7 | 5.7 | 6.0 | 5.8 |
| Falcon IV (F-4)* | 6.0 | 5.7 | 6.0 | 5.7 | 5.3 | 5.3 | 6.3 | 5.7 |
| Wolfpack* | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 6.0 | 5.7 |
| Cochise III (018)* | 5.7 | 5.7 | 6.3 | 5.3 | 5.0 | 5.7 | 5.7 | 5.6 |
| CAS-ED | 6.7 | 6.0 | 6.0 | 5.0 | 5.7 | 5.0 | 6.0 | 5.6 |
| Justice (RB2-01)* | 6.3 | 4.7 | 6.0 | 6.0 | 6.7 | 5.0 | 5.0 | 5.6 |
| K01-E03 | 5.7 | 5.7 | 5.7 | 5.0 | 5.3 | 5.7 | 6.0 | 5.6 |
| Padre (NJ4)* | 5.3 | 5.0 | 5.7 | 6.0 | 5.7 | 5.7 | 5.3 | 5.6 |
| Watchdog* | 5.7 | 5.3 | 5.7 | 6.0 | 5.7 | 5.3 | 5.3 | 5.6 |
| Avenger (L1Z)* | 6.3 | 6.0 | 6.0 | 5.0 | 5.3 | 5.0 | 5.7 | 5.5 |
| Forte (BE-2)* | 6.0 | 5.3 | 5.3 | 6.0 | 6.0 | 5.0 | 5.3 | 5.5 |
| JT-13 | 5.0 | 5.3 | 5.3 | 5.7 | 6.0 | 5.3 | 5.3 | 5.5 |
| PST-5BAB | 5.7 | 5.3 | 5.3 | 6.0 | 5.3 | 5.3 | 5.7 | 5.5 |
| PST-5JM | 5.3 | 5.3 | 5.3 | 5.7 | 5.7 | 5.0 | 6.0 | 5.5 |
| Serengeti (GO-OD2)* | 6.0 | 5.3 | 5.3 | 5.0 | 6.0 | 5.7 | 5.7 | 5.5 |
| ATF 702 | 5.0 | 4.7 | 5.3 | 5.3 | 6.3 | 6.0 | 5.0 | 5.4 |
| Scorpion* | 6.0 | 5.3 | 5.7 | 5.7 | 5.3 | 5.3 | 5.3 | 5.4 |
| Silverado II (PST-578)* | 5.7 | 5.0 | 5.7 | 5.7 | 5.7 | 5.3 | 5.3 | 5.4 |
| Blackwatch (Pick-OD3-01)* | 6.0 | 5.3 | 5.7 | 5.3 | 5.0 | 5.0 | 6.3 | 5.4 |
| CIS-TF-67 | 5.3 | 5.0 | 5.7 | 5.3 | 5.3 | 5.7 | 5.7 | 5.4 |
| Cayenne* | 5.7 | 5.0 | 6.0 | 5.3 | 5.3 | 5.7 | 5.3 | 5.4 |
| Pick TF H-97 | 4.7 | 5.3 | 5.7 | 5.7 | 5.7 | 5.3 | 5.0 | 5.4 |
| Titanium (SBM)* | 5.3 | 5.0 | 5.3 | 5.3 | 6.0 | 5.7 | 5.3 | 5.4 |
| Apache III (PST-5A1)* | 6.0 | 6.0 | 6.0 | 5.0 | 5.0 | 5.0 | 5.3 | 5.4 |
| Fidelity (PST-5T1)* | 5.3 | 5.3 | 6.0 | 5.3 | 5.3 | 5.3 | 5.0 | 5.4 |
| MRF 26 | 5.7 | 5.3 | 5.3 | 5.3 | 5.7 | 5.0 | 5.7 | 5.4 |
| PST-5NAS | 5.3 | 5.3 | 5.3 | 5.0 | 5.7 | 5.7 | 5.3 | 5.4 |
| Tar Heel* | 6.7 | 5.3 | 4.7 | 5.7 | 5.7 | 5.3 | 5.7 | 5.4 |
| Ultimate (01-RUTOR2)* | 6.3 | 5.7 | 5.7 | 6.0 | 5.3 | 5.3 | 4.3 | 5.4 |
| Gremlin (P-58)* | 5.7 | 4.7 | 6.0 | 5.0 | 4.3 | 5.3 | 6.7 | 5.3 |
| Kalahari* | 5.0 | 5.3 | 5.7 | 5.7 | 4.7 | 5.3 | 5.3 | 5.3 |
| Laramie* | 5.0 | 5.0 | 5.3 | 5.0 | 6.0 | 5.3 | 5.3 | 5.3 |
| Lexington (UT-RB3)* | 5.3 | 5.3 | 5.3 | 4.7 | 5.3 | 6.0 | 5.3 | 5.3 |
| Millennium* | 5.7 | 5.3 | 5.7 | 5.3 | 5.0 | 5.7 | 5.0 | 5.3 |
| Rendition* | 5.7 | 5.3 | 5.3 | 5.7 | 5.3 | 4.7 | 5.7 | 5.3 |
| Tar Heel II (PST-5TR1)* | 5.7 | 5.3 | 5.7 | 5.0 | 5.0 | 5.7 | 5.3 | 5.3 |
| Olympic Gold* | 6.3 | 5.7 | 5.3 | 4.7 | 5.3 | 5.0 | 5.7 | 5.3 |
| DLF-J210 | 5.0 | 4.7 | 5.3 | 5.7 | 5.0 | 5.3 | 5.7 | 5.3 |
| Focus* | 5.3 | 4.7 | 5.3 | 5.3 | 5.3 | 5.3 | 5.7 | 5.3 |
| Jaguar 3* | 5.3 | 5.0 | 5.3 | 5.3 | 5.0 | 5.3 | 5.7 | 5.3 |
| PST-5S12 | 5.7 | 5.3 | 5.7 | 5.0 | 5.0 | 5.0 | 5.7 | 5.3 |
| R-4 | 5.3 | 5.3 | 5.0 | 5.0 | 5.3 | 5.3 | 5.7 | 5.3 |
| Riverside (ProSeeds 5301)* | 6.0 | 5.3 | 5.0 | 5.7 | 5.7 | 5.0 | 5.0 | 5.3 |
| Silverstar (PST-5ASR)* | 5.7 | 5.3 | 5.7 | 5.0 | 5.0 | 5.3 | 5.3 | 5.3 |
| UT-155 | 5.3 | 5.0 | 5.3 | 5.0 | 5.0 | 5.3 | 6.0 | 5.3 |
| Blade Runner (Roberts SM4)* | 5.7 | 5.3 | 5.3 | 5.0 | 5.0 | 5.3 | 5.3 | 5.2 |
| Coyote* | 5.3 | 5.3 | 4.7 | 5.7 | 5.3 | 4.7 | 5.7 | 5.2 |
| MA 127 | 5.3 | 4.7 | 5.3 | 5.3 | 5.7 | 5.0 | 5.3 | 5.2 |

| Cultivar/ Experimental Number | Spring Green up | Quality Apr. | May | Jun. | Jul. | Aug. | Sep. | Avg. |
|---|---|---|---|---|---|---|---|---|
| MRF 210 | 4.7 | 5.0 | 4.7 | 5.7 | 5.7 | 5.3 | 5.0 | 5.2 |
| MRF 27 | 6.0 | 5.3 | 5.0 | 5.7 | 5.3 | 4.7 | 5.3 | 5.2 |
| Matador GT (PST-5TUO)* | 5.7 | 5.0 | 6.0 | 5.3 | 5.7 | 5.0 | 4.3 | 5.2 |
| PST-5BZ | 5.7 | 5.0 | 5.7 | 6.0 | 5.7 | 4.7 | 4.3 | 5.2 |
| Rembrandt* | 5.7 | 5.0 | 5.7 | 5.0 | 5.0 | 5.3 | 5.3 | 5.2 |
| Tahoe (CAS-157)* | 5.3 | 5.0 | 5.3 | 5.3 | 5.0 | 5.0 | 5.7 | 5.2 |
| ATF 799 | 5.0 | 5.0 | 5.7 | 5.3 | 5.0 | 5.0 | 5.0 | 5.2 |
| Bravo* | 5.3 | 5.0 | 5.0 | 5.0 | 5.0 | 5.3 | 5.7 | 5.2 |
| Endeavor* | 5.3 | 5.0 | 5.7 | 4.7 | 5.0 | 5.3 | 5.3 | 5.2 |
| Five Point MCN-RC* | 6.0 | 5.0 | 5.0 | 5.7 | 5.0 | 5.0 | 5.3 | 5.2 |
| JT-15 | 5.0 | 5.0 | 5.0 | 5.7 | 6.3 | 4.0 | 5.0 | 5.2 |
| JT-9 | 4.3 | 5.3 | 5.3 | 6.0 | 4.0 | 4.7 | 5.7 | 5.2 |
| K01-8007 | 5.3 | 5.0 | 5.3 | 5.7 | 5.0 | 4.7 | 5.3 | 5.2 |
| MRF 28 | 5.7 | 5.0 | 5.3 | 5.3 | 5.7 | 4.7 | 5.0 | 5.2 |
| Magellan (OD-4)* | 5.0 | 5.3 | 6.0 | 4.3 | 4.3 | 5.7 | 5.3 | 5.2 |
| Masterpiece* | 5.7 | 5.3 | 5.0 | 5.7 | 5.0 | 5.0 | 5.0 | 5.2 |
| Mustang 3* | 5.7 | 5.0 | 5.3 | 5.7 | 4.7 | 5.0 | 5.3 | 5.2 |
| Picasso* | 6.0 | 5.0 | 5.0 | 5.0 | 5.7 | 5.3 | 5.0 | 5.2 |
| Pick ZMG | 5.7 | 4.7 | 5.3 | 4.7 | 4.7 | 5.3 | 6.3 | 5.2 |
| Prospect* | 5.0 | 5.0 | 6.7 | 5.0 | 4.7 | 4.7 | 5.0 | 5.2 |
| SR 8600* | 5.0 | 4.7 | 5.3 | 5.3 | 5.3 | 5.0 | 5.3 | 5.2 |
| Turbo (CAS-MC1)* | 6.0 | 5.3 | 5.7 | 5.3 | 5.3 | 4.3 | 5.0 | 5.2 |
| Constitution (ATF-593)* | 5.0 | 4.7 | 4.7 | 5.7 | 5.7 | 5.0 | 5.0 | 5.1 |
| Finesse II* | 5.0 | 4.7 | 5.3 | 5.0 | 5.0 | 5.0 | 5.7 | 5.1 |
| PST-53T | 4.7 | 5.0 | 5.7 | 5.3 | 5.3 | 5.0 | 4.3 | 5.1 |
| PST-5KU | 5.3 | 5.0 | 5.3 | 5.3 | 5.7 | 5.3 | 4.0 | 5.1 |
| Plantation* | 6.3 | 5.0 | 5.3 | 5.3 | 5.7 | 4.7 | 4.7 | 5.1 |
| BAR Fa 1CR7 | 4.7 | 4.7 | 5.0 | 5.3 | 6.0 | 5.0 | 4.7 | 5.1 |
| Barrera* | 5.7 | 5.0 | 5.0 | 6.0 | 5.0 | 5.0 | 4.7 | 5.1 |
| CIS-TF-77 | 5.3 | 5.3 | 5.0 | 5.3 | 5.7 | 4.7 | 4.7 | 5.1 |
| Dynamic (PST-57E)* | 4.7 | 5.0 | 5.3 | 5.3 | 5.3 | 4.7 | 5.0 | 5.1 |
| Grande II* | 5.7 | 5.0 | 5.0 | 5.3 | 5.7 | 5.3 | 4.3 | 5.1 |
| MRF 25 | 5.7 | 5.3 | 5.7 | 4.7 | 4.7 | 5.0 | 5.3 | 5.1 |
| SR 8550 (SRX 8BE4)* | 5.3 | 5.3 | 5.7 | 5.3 | 5.7 | 4.3 | 4.3 | 5.1 |
| Stonewall (JT-18)* | 4.7 | 5.3 | 5.3 | 6.0 | 4.7 | 4.7 | 4.7 | 5.1 |
| MA 138 | 5.0 | 4.7 | 5.3 | 5.7 | 5.3 | 4.7 | 4.7 | 5.1 |
| Raptor (CIS-TF-33)* | 4.7 | 5.0 | 5.3 | 4.3 | 4.3 | 6.0 | 5.3 | 5.1 |
| TF66* | 5.3 | 5.0 | 5.3 | 4.7 | 4.7 | 5.7 | 5.0 | 5.1 |
| Trooper (T1-TFOR3)* | 5.3 | 5.0 | 5.3 | 4.3 | 5.0 | 5.0 | 5.7 | 5.1 |
| Dominion* | 5.3 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.3 | 5.1 |
| K01-WAF | 5.3 | 5.3 | 5.7 | 5.0 | 4.3 | 4.7 | 5.3 | 5.1 |
| SR 8250* | 5.0 | 5.0 | 5.7 | 4.3 | 4.7 | 5.3 | 5.3 | 5.1 |
| ATF 806 | 5.3 | 5.0 | 5.3 | 5.7 | 5.0 | 5.3 | 3.7 | 5.0 |
| Biltmore* | 5.7 | 5.3 | 5.7 | 5.3 | 5.0 | 4.3 | 4.3 | 5.0 |
| EA 163 | 6.3 | 5.0 | 5.3 | 5.3 | 5.7 | 4.3 | 4.3 | 5.0 |
| Falcon II* | 5.0 | 4.7 | 4.7 | 4.7 | 5.0 | 5.7 | 5.3 | 5.0 |
| K01-8015 | 5.0 | 5.0 | 5.3 | 4.7 | 4.7 | 5.0 | 5.3 | 5.0 |
| MA 158 | 5.3 | 5.0 | 5.3 | 5.3 | 5.0 | 5.0 | 4.3 | 5.0 |
| PST-5LO | 5.0 | 5.0 | 5.7 | 4.0 | 4.0 | 5.3 | 6.0 | 5.0 |
| Quest* | 4.7 | 4.7 | 5.3 | 5.0 | 5.3 | 5.0 | 4.7 | 5.0 |
| B-7001 | 5.3 | 5.0 | 6.0 | 5.0 | 4.7 | 5.0 | 4.0 | 4.9 |
| JTTFF-2000 | 5.3 | 5.3 | 4.7 | 5.0 | 4.7 | 4.7 | 5.3 | 4.9 |
| PST-DDL | 5.3 | 5.0 | 5.7 | 5.0 | 5.3 | 4.0 | 4.7 | 4.9 |

| Cultivar/ Experimental Number | Spring Green up | Quality Apr. | May | Jun. | Jul. | Aug. | Sep. | Avg. |
|---|---|---|---|---|---|---|---|---|
| Bingo* | 5.7 | 4.7 | 5.0 | 5.3 | 5.7 | 4.7 | 4.3 | 4.9 |
| Davinci (LTP-7801)* | 5.3 | 4.7 | 5.7 | 5.0 | 5.3 | 4.3 | 4.3 | 4.9 |
| Legitimate* | 5.3 | 4.0 | 4.7 | 5.0 | 5.3 | 5.0 | 5.3 | 4.9 |
| PST-5FZD | 4.7 | 5.3 | 5.7 | 4.0 | 4.0 | 5.7 | 4.7 | 4.9 |
| Barlexas II* | 5.7 | 4.7 | 4.7 | 4.3 | 5.0 | 4.7 | 6.0 | 4.9 |
| JT-12 | 5.0 | 4.3 | 5.3 | 5.0 | 4.7 | 5.0 | 5.0 | 4.9 |
| Signia* | 5.7 | 5.0 | 5.3 | 4.7 | 5.0 | 4.7 | 4.3 | 4.8 |
| BAR Fa 1005 | 5.3 | 4.7 | 5.3 | 4.3 | 4.0 | 5.0 | 5.7 | 4.8 |
| Barrington* | 5.0 | 4.7 | 5.0 | 5.0 | 5.0 | 4.7 | 4.7 | 4.8 |
| Covenant (ATF 802)* | 5.0 | 5.0 | 5.0 | 4.7 | 4.7 | 4.3 | 5.3 | 4.8 |
| DP 50-9082 | 5.0 | 5.0 | 5.0 | 4.7 | 4.7 | 5.0 | 4.7 | 4.8 |
| Daytona (MRF 23)* | 4.7 | 4.3 | 4.0 | 4.7 | 5.7 | 5.0 | 5.3 | 4.8 |
| Guardian-21 (Roberts DOL)* | 5.0 | 4.7 | 5.3 | 5.0 | 4.7 | 5.0 | 4.3 | 4.8 |
| Inferno (JT-99)* | 4.7 | 5.3 | 5.7 | 4.0 | 3.7 | 5.3 | 5.0 | 4.8 |
| MRF 29 | 5.0 | 4.7 | 6.0 | 5.7 | 5.0 | 4.0 | 3.7 | 4.8 |
| Ninja 2 (ATF-800)* | 5.0 | 5.0 | 5.3 | 4.0 | 5.0 | 4.7 | 5.0 | 4.8 |
| Rebel Sentry* | 5.0 | 5.0 | 5.3 | 5.3 | 5.0 | 4.3 | 4.0 | 4.8 |
| ATF 586 | 5.0 | 4.3 | 4.7 | 5.0 | 5.0 | 4.7 | 5.0 | 4.8 |
| DP 50-9226 | 5.3 | 4.0 | 4.7 | 5.0 | 5.7 | 4.7 | 4.7 | 4.8 |
| Firebird (CIS-TF-65)* | 5.0 | 4.3 | 5.3 | 5.0 | 4.0 | 5.0 | 5.0 | 4.8 |
| GO-RD4 | 4.7 | 4.7 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.8 |
| JT-6 | 5.0 | 4.7 | 5.0 | 4.7 | 4.0 | 5.3 | 5.0 | 4.8 |
| Southern Choice II* | 5.0 | 4.7 | 5.0 | 5.3 | 4.7 | 4.7 | 4.3 | 4.8 |
| Tempest* | 5.3 | 4.7 | 5.0 | 4.7 | 4.7 | 5.0 | 4.7 | 4.8 |
| Titan Ltd.* | 5.3 | 5.3 | 4.7 | 4.7 | 4.7 | 4.3 | 5.0 | 4.8 |
| ATF 707 | 4.7 | 4.7 | 5.0 | 4.7 | 4.3 | 4.3 | 5.3 | 4.7 |
| BAR Fa 1003 | 5.7 | 4.7 | 5.7 | 4.7 | 4.0 | 4.7 | 4.7 | 4.7 |
| Matador* | 5.3 | 5.0 | 5.3 | 4.3 | 4.0 | 5.0 | 4.7 | 4.7 |
| Rebel Exeda* | 5.3 | 5.0 | 5.3 | 4.7 | 4.3 | 4.7 | 4.3 | 4.7 |
| Barlexas* | 4.7 | 4.7 | 5.3 | 5.0 | 4.7 | 4.0 | 4.3 | 4.7 |
| Pick-00-AFA | 4.7 | 5.0 | 5.0 | 5.3 | 4.7 | 4.3 | 3.7 | 4.7 |
| Pure Gold* | 4.7 | 4.7 | 5.0 | 4.7 | 4.3 | 5.0 | 4.3 | 4.7 |
| CIS-TF-60 | 5.0 | 4.7 | 5.0 | 5.0 | 4.7 | 4.3 | 4.0 | 4.6 |
| CIS-TF-64 | 5.7 | 5.0 | 5.3 | 4.3 | 4.3 | 5.3 | 3.3 | 4.6 |
| K01-E09 | 5.3 | 5.0 | 5.3 | 4.7 | 4.3 | 4.3 | 4.0 | 4.6 |
| Tulsa II (ATF 706)* | 5.7 | 4.7 | 5.0 | 5.0 | 4.3 | 4.3 | 4.3 | 4.6 |
| ATF 704 | 4.7 | 4.3 | 5.0 | 5.0 | 4.3 | 4.3 | 4.3 | 4.6 |
| Regiment II (SRX 805)* | 4.7 | 4.3 | 4.7 | 4.0 | 4.0 | 5.0 | 5.3 | 4.6 |
| South Paw (MRF 24)* | 5.3 | 4.7 | 5.0 | 5.0 | 4.7 | 4.0 | 4.0 | 4.6 |
| Expedetion (ATF-803)* | 4.7 | 4.3 | 4.3 | 4.7 | 4.7 | 4.3 | 4.7 | 4.5 |
| MRF 211 | 4.7 | 4.3 | 4.7 | 5.0 | 4.3 | 5.0 | 3.7 | 4.5 |
| PST-5KI | 5.0 | 5.0 | 5.3 | 4.0 | 3.3 | 4.7 | 4.7 | 4.5 |
| Kitty Hawk 2000* | 5.0 | 4.7 | 5.0 | 4.0 | 4.3 | 4.3 | 4.3 | 4.4 |
| Stetson* | 5.0 | 4.0 | 4.7 | 4.0 | 4.3 | 5.0 | 4.7 | 4.4 |
| Tracer* | 4.3 | 4.7 | 5.3 | 4.0 | 3.3 | 4.7 | 4.7 | 4.4 |
| NA-TDD | 5.3 | 5.3 | 4.7 | 4.7 | 3.7 | 4.3 | 3.7 | 4.4 |
| Tomahawk GT* | 4.7 | 4.0 | 5.0 | 4.3 | 4.7 | 4.3 | 4.0 | 4.4 |
| Elisa* | 4.7 | 4.0 | 4.3 | 4.3 | 5.3 | 4.0 | 4.3 | 4.4 |
| Floridian (GO-FL3)* | 5.7 | 4.3 | 4.7 | 4.0 | 4.7 | 4.3 | 4.0 | 4.3 |
| Lancer* | 5.0 | 4.3 | 5.0 | 4.3 | 4.0 | 4.3 | 4.0 | 4.3 |
| T991 | 4.0 | 4.0 | 5.0 | 4.7 | 3.7 | 5.0 | 3.7 | 4.3 |
| GO-SIU2 | 5.0 | 4.3 | 4.3 | 4.0 | 4.7 | 4.0 | 4.3 | 4.3 |

| Cultivar/ Experimental Number | Spring Green up | Quality Apr. | May | Jun. | Jul. | Aug. | Sep. | Avg. |
|---|---|---|---|---|---|---|---|---|
| Wyatt* | 4.7 | 4.7 | 4.7 | 4.0 | 4.3 | 4.3 | 3.7 | 4.3 |
| Bonsai* | 4.7 | 4.0 | 5.0 | 4.3 | 4.7 | 3.7 | 3.0 | 4.1 |
| Ky-31 E+* | 5.0 | 3.3 | 3.3 | 3.0 | 3.7 | 3.3 | 3.3 | 3.3 |
| *LSD*[3] | *1.5* | *1.4* | *1.2* | *2.1* | *3.6* | *1.8* | *2.1* | *0.9* |

[1] Ratings based on a scale of 1–9 with 9=best measure.
[2] Cultivars marked with "*" became commercially available in 2005.
[3] Least Statistical Difference. To determine statistical differences among entries, subtract one entry's mean from another's. If the result is larger than the corresponding LSD value, the two are statistically different.

**Table 2.** Performance summary of tall fescue cultivars at Wichita, KS, for the years 2001 through 2006.[1]

| Cultivar/ Experimental Number | % Cover 2001 | Avg. Green up | Avg. Genetic Color | Avg. Texture | Average Monthly Quality 2002–2006 Apr. | May | Jun. | Jul. | | Sep. | Oct. | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Finelawn Elite (DLSD)*[2] | 40.0 | 5.9 | 6.2 | 6.5 | 5.3 | 5.5 | 5.6 | 5.6 | 5.5 | 5.1 | 5.8 | 5.5 |
| Justice (RB2-01)* | 51.7 | 5.9 | 6.4 | 6.3 | 4.9 | 5.5 | 5.7 | 5.9 | 5.3 | 5.3 | 5.8 | 5.5 |
| Apache III (PST-5A1)* | 48.3 | 5.8 | 6.4 | 6.5 | 5.4 | 5.5 | 5.2 | 5.5 | 5.4 | 5.4 | 5.5 | 5.4 |
| BE1 | 46.7 | 6.0 | 6.1 | 6.2 | 4.7 | 5.3 | 5.3 | 5.7 | 5.7 | 5.3 | 5.5 | 5.4 |
| CAS-ED | 46.7 | 6.1 | 6.8 | 5.9 | 5.2 | 5.5 | 5.2 | 5.6 | 5.3 | 5.3 | 5.3 | 5.3 |
| Dynasty* | 48.3 | 6.0 | 5.9 | 6.7 | 5.0 | 5.7 | 5.4 | 5.7 | 5.3 | 4.8 | 5.2 | 5.3 |
| Avenger (L1Z)* | 53.3 | 5.9 | 6.8 | 6.6 | 4.9 | 5.5 | 5.2 | 5.5 | 5.4 | 5.1 | 5.4 | 5.3 |
| MRF 26 | 35.0 | 5.6 | 7.6 | 6.1 | 4.9 | 5.1 | 5.5 | 5.7 | 5.1 | 5.2 | 5.3 | 5.3 |
| Cochise III (018)* | 50.0 | 5.8 | 6.4 | 6.3 | 5.3 | 5.7 | 5.3 | 5.4 | 5.4 | 4.7 | 5.2 | 5.3 |
| Falcon IV (F-4)* | 41.7 | 5.9 | 6.4 | 6.6 | 5.0 | 5.3 | 5.1 | 5.4 | 5.1 | 5.3 | 5.6 | 5.3 |
| Millennium* | 53.3 | 5.8 | 6.2 | 6.3 | 4.9 | 5.5 | 5.3 | 5.5 | 5.5 | 5.0 | 5.2 | 5.3 |
| Escalade (01-ORU1)* | 41.7 | 5.8 | 6.4 | 6.6 | 5.1 | 5.4 | 5.1 | 5.5 | 5.5 | 4.9 | 5.3 | 5.3 |
| JT-9 | 41.7 | 5.4 | 6.4 | 6.5 | 4.7 | 5.4 | 5.6 | 5.3 | 5.4 | 5.1 | 5.1 | 5.2 |
| Riverside (ProSeeds 5301)* | 45.0 | 6.0 | 6.5 | 6.3 | 5.0 | 5.1 | 5.5 | 5.7 | 5.2 | 5.0 | 5.3 | 5.2 |
| Wolfpack* | 45.0 | 5.5 | 5.8 | 6.0 | 5.1 | 5.3 | 5.1 | 5.4 | 5.3 | 5.2 | 5.4 | 5.2 |
| Watchdog* | 48.3 | 5.9 | 6.0 | 6.3 | 5.1 | 5.1 | 5.4 | 5.4 | 5.3 | 5.2 | 5.2 | 5.2 |
| Scorpion* | 45.0 | 5.8 | 6.4 | 6.5 | 4.7 | 5.3 | 5.3 | 5.4 | 5.5 | 5.0 | 5.3 | 5.2 |
| 2nd Millennium* | 43.3 | 5.8 | 6.3 | 6.6 | 4.6 | 5.0 | 5.4 | 5.5 | 5.3 | 5.2 | 5.4 | 5.2 |
| Picasso* | 46.7 | 5.8 | 6.4 | 6.1 | 4.6 | 5.3 | 5.1 | 5.4 | 5.3 | 5.3 | 5.5 | 5.2 |
| EA 163 | 43.3 | 5.8 | 6.8 | 5.8 | 5.0 | 5.3 | 5.3 | 5.4 | 5.0 | 4.9 | 5.6 | 5.2 |
| Cayenne* | 46.7 | 5.3 | 5.9 | 6.1 | 4.3 | 5.6 | 5.3 | 5.3 | 5.3 | 5.1 | 5.1 | 5.2 |
| BAR Fa 1CR7 | 56.7 | 5.4 | 7.3 | 6.3 | 4.5 | 5.1 | 5.3 | 5.6 | 5.4 | 5.1 | 5.2 | 5.2 |
| Padre (NJ4)* | 41.7 | 5.5 | 6.2 | 5.9 | 4.5 | 5.3 | 5.3 | 5.2 | 5.4 | 5.3 | 5.0 | 5.2 |
| Ultimate (01-RUTOR2)* | 45.0 | 6.0 | 6.4 | 6.4 | 5.0 | 5.4 | 5.1 | 5.6 | 5.2 | 4.7 | 5.1 | 5.1 |
| JT-13 | 43.3 | 5.3 | 6.8 | 6.3 | 4.6 | 5.1 | 5.5 | 5.7 | 4.7 | 5.0 | 5.4 | 5.1 |
| Constitution (ATF-593)* | 40.0 | 5.4 | 6.4 | 5.8 | 4.4 | 5.1 | 5.5 | 5.5 | 5.3 | 4.9 | 5.3 | 5.1 |
| MA 127 | 43.3 | 5.6 | 6.6 | 5.8 | 4.8 | 5.3 | 5.3 | 5.5 | 4.7 | 5.3 | 5.2 | 5.1 |
| Blackwatch (Pick-OD3-01)* | 45.0 | 6.2 | 6.3 | 6.0 | 4.8 | 5.3 | 5.2 | 5.4 | 5.3 | 5.0 | 5.1 | 5.1 |
| ATF 702 | 51.7 | 5.4 | 7.4 | 5.9 | 4.4 | 5.3 | 5.2 | 5.6 | 5.3 | 4.7 | 5.2 | 5.1 |
| Coyote* | 45.0 | 5.5 | 6.5 | 6.2 | 4.8 | 5.1 | 5.3 | 5.5 | 5.0 | 4.9 | 5.3 | 5.1 |
| Gremlin (P-58)* | 40.0 | 6.1 | 6.1 | 6.1 | 4.3 | 5.3 | 5.2 | 5.3 | 5.2 | 5.1 | 5.3 | 5.1 |
| Titanium (SBM)* | 46.7 | 5.6 | 6.2 | 6.5 | 4.6 | 4.7 | 5.3 | 5.3 | 5.5 | 5.3 | 5.1 | 5.1 |
| MRF 210 | 50.0 | 5.4 | 7.8 | 5.9 | 4.7 | 5.1 | 5.4 | 5.3 | 5.1 | 5.1 | 5.0 | 5.1 |
| Grande II* | 41.7 | 5.8 | 6.4 | 6.5 | 4.8 | 5.1 | 5.1 | 5.2 | 5.2 | 5.1 | 5.3 | 5.1 |
| Masterpiece* | 45.0 | 5.8 | 6.3 | 6.0 | 4.8 | 5.0 | 5.1 | 5.3 | 5.4 | 5.0 | 5.1 | 5.1 |

| Cultivar/ Experimental Number | % Cover 2001 | Avg. Green up | Avg. Genetic Color | Avg. Texture | Average Monthly Quality 2002–2006 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Apr. | May | Jun. | Jul. | | Sep. | Oct. | Avg. |
| Silverado II (PST-578)* | 43.3 | 5.6 | 6.3 | 5.8 | 4.4 | 5.1 | 5.1 | 5.3 | 5.3 | 5.0 | 5.3 | 5.1 |
| CIS-TF-67 | 43.3 | 5.4 | 6.6 | 6.5 | 4.6 | 5.4 | 5.1 | 5.4 | 4.7 | 5.0 | 5.3 | 5.1 |
| Rembrandt* | 43.3 | 5.7 | 6.1 | 5.9 | 4.8 | 5.2 | 5.1 | 5.3 | 5.2 | 4.9 | 5.1 | 5.1 |
| PST-5NAS | 61.7 | 5.7 | 6.1 | 6.3 | 4.8 | 5.1 | 4.9 | 5.6 | 5.4 | 4.6 | 5.2 | 5.1 |
| SR 8550 (SRX 8BE4)* | 43.3 | 5.5 | 6.6 | 5.9 | 4.7 | 5.6 | 5.2 | 5.1 | 4.9 | 4.9 | 5.2 | 5.1 |
| Turbo (CAS-MC1)* | 43.3 | 5.9 | 6.7 | 6.0 | 4.8 | 5.3 | 5.3 | 5.1 | 5.2 | 4.7 | 5.2 | 5.1 |
| MRF 27 | 43.3 | 5.7 | 7.2 | 6.3 | 4.8 | 5.1 | 5.4 | 5.5 | 4.9 | 4.9 | 4.9 | 5.1 |
| PST-5JM | 40.0 | 5.4 | 6.6 | 6.2 | 4.8 | 5.2 | 5.1 | 5.2 | 4.9 | 5.1 | 5.1 | 5.1 |
| Laramie* | 58.3 | 5.3 | 6.2 | 6.0 | 4.8 | 5.2 | 5.0 | 5.4 | 5.1 | 4.9 | 5.1 | 5.1 |
| MRF 25 | 48.3 | 5.7 | 6.8 | 6.1 | 5.1 | 5.5 | 5.1 | 5.1 | 4.9 | 5.0 | 4.9 | 5.1 |
| Lexington (UT-RB3)* | 45.0 | 5.5 | 6.8 | 5.8 | 4.8 | 5.2 | 5.1 | 5.4 | 4.8 | 5.1 | 5.1 | 5.1 |
| Serengeti (GO-OD2)* | 43.3 | 5.9 | 6.3 | 5.9 | 4.9 | 5.1 | 5.0 | 5.5 | 5.0 | 5.0 | 4.9 | 5.1 |
| Blade Runner (Roberts SM4)* | 41.7 | 5.6 | 6.7 | 5.8 | 4.7 | 4.9 | 5.1 | 5.3 | 5.2 | 5.0 | 5.3 | 5.1 |
| PST-5BZ | 40.0 | 5.5 | 6.3 | 6.0 | 4.8 | 5.3 | 5.2 | 5.5 | 5.1 | 4.6 | 4.9 | 5.1 |
| SR 8600* | 38.3 | 5.6 | 6.2 | 6.2 | 4.8 | 5.3 | 5.2 | 5.3 | 4.8 | 4.9 | 5.3 | 5.1 |
| R-4 | 50.0 | 5.8 | 6.7 | 6.5 | 4.8 | 5.1 | 5.1 | 5.0 | 5.0 | 5.1 | 5.3 | 5.0 |
| Tar Heel* | 46.7 | 6.1 | 5.9 | 5.3 | 4.5 | 4.7 | 5.1 | 5.5 | 5.3 | 5.0 | 5.3 | 5.0 |
| CIS-TF-77 | 43.3 | 5.7 | 6.5 | 6.1 | 4.7 | 4.9 | 5.1 | 5.3 | 5.1 | 5.2 | 5.2 | 5.0 |
| Raptor (CIS-TF-33)* | 36.7 | 5.3 | 6.6 | 6.2 | 4.5 | 5.3 | 5.1 | 5.0 | 5.3 | 4.7 | 5.3 | 5.0 |
| Five Point MCN-RC* | 43.3 | 5.8 | 6.6 | 6.1 | 4.3 | 4.9 | 5.2 | 5.2 | 5.3 | 5.1 | 5.1 | 5.0 |
| Olympic Gold* | 55.0 | 5.8 | 6.1 | 5.9 | 5.0 | 5.0 | 5.1 | 5.2 | 5.1 | 4.9 | 5.1 | 5.0 |
| Pick ZMG | 40.0 | 5.8 | 6.3 | 5.7 | 4.3 | 5.1 | 5.1 | 5.3 | 5.1 | 5.1 | 5.2 | 5.0 |
| PST-5BAB | 36.7 | 5.6 | 6.3 | 6.2 | 4.7 | 4.9 | 5.1 | 5.1 | 5.3 | 5.0 | 5.1 | 5.0 |
| Focus* | 43.3 | 5.5 | 6.4 | 6.0 | 4.7 | 5.3 | 4.9 | 5.0 | 5.2 | 5.0 | 5.0 | 5.0 |
| Rendition* | 43.3 | 5.6 | 6.4 | 6.3 | 4.6 | 5.3 | 5.1 | 5.3 | 4.9 | 4.9 | 5.0 | 5.0 |
| Biltmore* | 45.0 | 5.4 | 6.6 | 6.3 | 4.8 | 5.2 | 5.4 | 5.2 | 4.9 | 4.7 | 5.1 | 5.0 |
| Matador GT (PST-5TUO)* | 45.0 | 5.6 | 6.5 | 5.8 | 4.5 | 5.2 | 5.2 | 5.5 | 5.1 | 4.7 | 4.9 | 5.0 |
| PST-5S12 | 50.0 | 5.8 | 6.0 | 5.7 | 4.6 | 5.3 | 5.0 | 5.1 | 5.1 | 5.0 | 5.2 | 5.0 |
| Falcon II* | 66.7 | 5.3 | 5.9 | 6.2 | 4.8 | 4.7 | 5.0 | 5.3 | 5.3 | 5.1 | 5.1 | 5.0 |
| Prospect* | 46.7 | 5.2 | 6.6 | 6.0 | 4.8 | 5.5 | 4.9 | 5.1 | 5.1 | 4.8 | 5.1 | 5.0 |
| PST-5KU | 43.3 | 5.3 | 6.7 | 5.9 | 4.3 | 5.4 | 5.1 | 5.3 | 4.7 | 5.1 | 5.2 | 5.0 |
| PST-5LO | 45.0 | 5.5 | 5.8 | 6.1 | 4.8 | 5.1 | 5.0 | 5.1 | 5.1 | 5.1 | 4.9 | 5.0 |
| Davinci (LTP-7801)* | 48.3 | 5.4 | 6.5 | 6.4 | 4.8 | 5.1 | 4.9 | 5.3 | 5.0 | 4.9 | 5.1 | 5.0 |
| Stonewall (JT-18)* | 38.3 | 5.4 | 6.9 | 6.0 | 4.8 | 5.3 | 5.3 | 5.1 | 4.9 | 4.5 | 5.1 | 5.0 |
| Tahoe (CAS-157)* | 40.0 | 5.5 | 6.3 | 5.8 | 4.4 | 5.1 | 5.2 | 5.3 | 4.5 | 5.1 | 5.2 | 5.0 |
| Forte (BE-2)* | 41.7 | 5.6 | 6.6 | 6.0 | 4.3 | 4.9 | 5.3 | 5.3 | 4.9 | 5.1 | 4.9 | 5.0 |

| Cultivar/ Experimental Number | % Cover 2001 | Avg. Green up | Avg. Genetic Color | Avg. Texture | Average Monthly Quality 2002–2006 Apr. | May | Jun. | Jul. | | Sep. | Oct. | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bravo* | 43.3 | 5.5 | 6.2 | 6.0 | 4.8 | 5.0 | 4.9 | 5.4 | 4.9 | 4.8 | 5.3 | 5.0 |
| MA 158 | 38.3 | 5.5 | 6.6 | 6.3 | 4.5 | 5.2 | 5.3 | 5.3 | 5.0 | 4.6 | 4.8 | 5.0 |
| Barrera* | 40.0 | 5.6 | 6.6 | 6.1 | 4.6 | 5.1 | 5.0 | 5.3 | 5.3 | 4.7 | 4.9 | 5.0 |
| Finesse II* | 36.7 | 5.6 | 6.9 | 6.0 | 4.3 | 5.2 | 5.1 | 5.1 | 5.0 | 5.2 | 4.8 | 5.0 |
| K01-E03 | 46.7 | 5.4 | 6.6 | 6.7 | 4.4 | 4.8 | 4.9 | 5.3 | 5.0 | 4.9 | 5.3 | 5.0 |
| Pick TF H-97 | 43.3 | 5.0 | 5.9 | 6.6 | 4.4 | 5.1 | 5.0 | 5.4 | 4.8 | 5.0 | 5.0 | 5.0 |
| BAR Fa 1003 | 53.3 | 5.5 | 6.6 | 5.7 | 4.5 | 5.3 | 4.9 | 5.4 | 5.0 | 4.9 | 4.8 | 5.0 |
| MA 138 | 41.7 | 5.3 | 6.4 | 5.8 | 4.5 | 5.0 | 5.2 | 5.3 | 4.8 | 4.8 | 5.1 | 5.0 |
| Pure Gold* | 41.7 | 5.4 | 6.1 | 6.2 | 4.5 | 5.1 | 5.3 | 5.3 | 4.9 | 4.7 | 4.9 | 5.0 |
| Magellan (OD-4)* | 45.0 | 5.6 | 6.5 | 6.1 | 4.9 | 5.2 | 4.6 | 4.7 | 5.2 | 4.9 | 5.2 | 4.9 |
| Inferno (JT-99)* | 45.0 | 5.6 | 6.1 | 6.8 | 4.8 | 5.5 | 4.9 | 5.1 | 4.8 | 4.5 | 5.1 | 4.9 |
| Fidelity (PST-5T1)* | 40.0 | 5.7 | 6.1 | 6.0 | 4.6 | 5.1 | 5.1 | 5.0 | 5.1 | 4.7 | 5.1 | 4.9 |
| Plantation* | 46.7 | 5.8 | 6.4 | 6.0 | 4.6 | 5.1 | 5.0 | 5.3 | 4.8 | 4.9 | 5.1 | 4.9 |
| Signia* | 45.0 | 5.6 | 7.0 | 5.8 | 4.7 | 5.1 | 5.1 | 5.4 | 4.9 | 4.4 | 5.0 | 4.9 |
| DLF-J210 | 45.0 | 5.4 | 6.8 | 5.8 | 4.7 | 5.0 | 5.1 | 5.1 | 5.1 | 4.7 | 5.0 | 4.9 |
| Jaguar 3* | 45.0 | 5.4 | 5.9 | 5.8 | 4.8 | 4.7 | 4.9 | 5.1 | 4.9 | 5.1 | 5.0 | 4.9 |
| PST-5FZD | 38.3 | 5.3 | 6.2 | 6.4 | 4.7 | 5.1 | 4.8 | 4.9 | 5.0 | 4.9 | 5.1 | 4.9 |
| Rebel Sentry* | 48.3 | 5.4 | 6.6 | 6.0 | 4.8 | 5.2 | 5.1 | 5.1 | 4.7 | 4.8 | 4.8 | 4.9 |
| Legitimate* | 38.3 | 5.4 | 6.4 | 5.6 | 4.3 | 4.7 | 4.8 | 5.5 | 4.9 | 4.9 | 5.3 | 4.9 |
| Dynamic (PST-57E)* | 43.3 | 5.3 | 5.7 | 6.3 | 4.3 | 5.2 | 5.1 | 5.3 | 4.9 | 4.7 | 4.9 | 4.9 |
| CIS-TF-64 | 38.3 | 5.8 | 6.6 | 6.5 | 4.6 | 5.3 | 5.0 | 5.4 | 5.0 | 4.2 | 4.8 | 4.9 |
| JT-15 | 36.7 | 5.3 | 6.6 | 6.7 | 4.6 | 4.9 | 5.1 | 5.2 | 4.8 | 4.7 | 5.0 | 4.9 |
| JT-12 | 41.7 | 5.3 | 6.6 | 6.8 | 4.3 | 5.2 | 4.8 | 5.2 | 5.1 | 4.7 | 5.0 | 4.9 |
| MRF 28 | 45.0 | 5.6 | 8.2 | 5.9 | 4.8 | 5.1 | 5.1 | 5.1 | 4.7 | 4.7 | 4.8 | 4.9 |
| Quest* | 43.3 | 5.2 | 6.4 | 6.4 | 4.3 | 5.0 | 5.1 | 5.3 | 4.9 | 4.9 | 4.8 | 4.9 |
| Silverstar (PST-5ASR)* | 36.7 | 5.6 | 6.1 | 5.8 | 4.5 | 4.7 | 4.7 | 4.9 | 5.0 | 5.3 | 5.1 | 4.9 |
| ATF 799 | 40.0 | 5.3 | 6.7 | 6.3 | 4.4 | 5.3 | 4.9 | 5.1 | 4.9 | 4.6 | 5.0 | 4.9 |
| TF66* | 50.0 | 5.6 | 6.4 | 6.3 | 4.5 | 4.8 | 4.8 | 4.9 | 5.1 | 5.1 | 5.0 | 4.9 |
| Barlexas II* | 50.0 | 5.4 | 6.4 | 6.4 | 4.6 | 5.1 | 4.7 | 5.2 | 4.5 | 5.0 | 5.1 | 4.9 |
| Guardian-21 (Roberts DOL)* | 35.0 | 5.8 | 6.3 | 6.0 | 4.6 | 4.8 | 5.1 | 5.3 | 4.8 | 4.5 | 5.0 | 4.9 |
| Bingo* | 35.0 | 5.6 | 7.4 | 6.1 | 4.3 | 4.7 | 5.1 | 5.3 | 5.2 | 4.5 | 4.8 | 4.9 |
| CIS-TF-60 | 40.0 | 5.8 | 7.7 | 6.4 | 4.3 | 5.1 | 5.0 | 5.1 | 4.8 | 4.6 | 5.2 | 4.9 |
| PST-DDL | 40.0 | 5.7 | 6.3 | 6.2 | 4.4 | 5.3 | 5.1 | 5.2 | 4.5 | 4.6 | 4.8 | 4.9 |
| Trooper (T1-TFOR3)* | 45.0 | 5.8 | 6.3 | 5.8 | 4.9 | 5.2 | 4.7 | 5.0 | 4.7 | 4.6 | 5.1 | 4.9 |
| JT-6 | 33.3 | 5.3 | 7.2 | 6.2 | 4.2 | 4.8 | 5.2 | 5.0 | 5.0 | 4.9 | 4.8 | 4.8 |
| K01-E09 | 41.7 | 5.7 | 6.6 | 6.7 | 4.6 | 4.8 | 5.1 | 5.1 | 4.9 | 4.5 | 4.9 | 4.8 |
| Mustang 3* | 36.7 | 5.8 | 6.3 | 6.0 | 4.3 | 4.7 | 4.9 | 4.9 | 4.9 | 5.0 | 4.9 | 4.8 |

| Cultivar/ Experimental Number | % Cover 2001 | Avg. Green up | Avg. Genetic Color | Avg. Texture | Average Monthly Quality 2002–2006 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Apr. | May | Jun. | Jul. | | Sep. | Oct. | Avg. |
| Ninja 2 (ATF-800)* | 48.3 | 5.2 | 6.3 | 6.5 | 4.4 | 5.1 | 4.6 | 5.2 | 4.5 | 4.9 | 5.3 | 4.8 |
| Expedetion (ATF-803)* | 50.0 | 5.5 | 6.6 | 6.7 | 4.5 | 4.8 | 4.9 | 5.1 | 4.7 | 4.7 | 5.3 | 4.8 |
| Firebird (CIS-TF-65)* | 38.3 | 5.3 | 7.4 | 6.2 | 4.2 | 5.0 | 4.9 | 4.7 | 4.9 | 5.1 | 4.9 | 4.8 |
| B-7001 | 40.0 | 5.5 | 6.5 | 5.8 | 4.8 | 5.3 | 4.6 | 5.0 | 4.8 | 4.5 | 4.9 | 4.8 |
| Kalahari* | 40.0 | 5.5 | 6.3 | 6.3 | 4.7 | 4.9 | 5.0 | 5.1 | 4.7 | 4.5 | 4.9 | 4.8 |
| Titan Ltd.* | 50.0 | 5.3 | 5.4 | 6.2 | 4.6 | 4.8 | 4.7 | 5.1 | 4.7 | 4.8 | 5.3 | 4.8 |
| Daytona (MRF 23)* | 45.0 | 5.1 | 7.5 | 5.6 | 4.3 | 4.8 | 4.7 | 5.3 | 5.0 | 4.9 | 4.8 | 4.8 |
| Southern Choice II* | 43.3 | 5.4 | 6.9 | 5.8 | 4.4 | 4.9 | 5.1 | 4.9 | 4.7 | 4.7 | 5.1 | 4.8 |
| PST-53T | 40.0 | 5.3 | 6.8 | 6.1 | 4.5 | 5.1 | 4.8 | 5.2 | 4.7 | 4.4 | 5.0 | 4.8 |
| DP 50-9226 | 43.3 | 5.3 | 6.2 | 6.0 | 4.2 | 4.7 | 5.0 | 5.4 | 4.7 | 4.7 | 4.9 | 4.8 |
| UT-155 | 41.7 | 5.4 | 6.4 | 5.7 | 4.3 | 4.8 | 4.8 | 4.9 | 4.7 | 5.0 | 4.8 | 4.8 |
| JTTFF-2000 | 41.7 | 5.8 | 6.2 | 5.8 | 5.0 | 5.0 | 4.7 | 4.8 | 4.5 | 4.6 | 4.8 | 4.8 |
| Barrington* | 38.3 | 5.2 | 6.5 | 6.7 | 4.5 | 4.9 | 4.9 | 4.9 | 4.8 | 4.4 | 5.0 | 4.8 |
| K01-8015 | 38.3 | 5.0 | 6.0 | 6.6 | 4.1 | 5.3 | 4.7 | 4.8 | 4.9 | 4.7 | 4.7 | 4.8 |
| Dominion* | 50.0 | 5.5 | 5.7 | 5.4 | 4.4 | 4.7 | 4.8 | 5.1 | 4.7 | 4.7 | 4.9 | 4.8 |
| Tempest* | 48.3 | 5.3 | 7.0 | 5.9 | 4.5 | 4.7 | 4.7 | 5.0 | 4.9 | 4.7 | 4.8 | 4.8 |
| Endeavor* | 45.0 | 5.3 | 5.9 | 6.1 | 4.3 | 4.7 | 4.6 | 4.9 | 4.9 | 4.9 | 4.9 | 4.8 |
| Tar Heel II (PST-5TR1)* | 45.0 | 5.8 | 5.4 | 5.5 | 4.1 | 4.7 | 4.5 | 5.0 | 4.9 | 4.9 | 5.2 | 4.7 |
| Regiment II (SRX 805)* | 33.3 | 5.4 | 7.9 | 6.1 | 4.3 | 4.9 | 4.7 | 5.0 | 4.7 | 4.7 | 4.9 | 4.7 |
| BAR Fa 1005 | 41.7 | 5.6 | 6.4 | 5.9 | 4.3 | 4.9 | 4.5 | 4.7 | 5.0 | 4.9 | 4.9 | 4.7 |
| SR 8250* | 38.3 | 5.4 | 6.4 | 5.8 | 4.3 | 4.7 | 4.6 | 4.9 | 4.9 | 4.8 | 4.8 | 4.7 |
| Matador* | 41.7 | 5.7 | 6.5 | 6.3 | 4.5 | 5.1 | 4.7 | 4.9 | 4.5 | 4.5 | 4.8 | 4.7 |
| ATF 704 | 50.0 | 5.0 | 6.4 | 5.9 | 4.3 | 4.9 | 4.9 | 4.9 | 4.9 | 4.5 | 4.8 | 4.7 |
| DP 50-9082 | 43.3 | 5.2 | 5.3 | 6.3 | 4.1 | 4.5 | 4.9 | 4.9 | 4.8 | 4.9 | 5.0 | 4.7 |
| ATF 806 | 40.0 | 5.4 | 6.3 | 6.9 | 4.3 | 5.1 | 5.1 | 4.8 | 4.5 | 4.4 | 4.6 | 4.7 |
| MRF 211 | 31.7 | 5.5 | 7.8 | 6.0 | 4.2 | 4.9 | 4.9 | 4.8 | 4.8 | 4.5 | 4.9 | 4.7 |
| South Paw (MRF 24)* | 48.3 | 5.4 | 6.5 | 5.4 | 4.6 | 4.9 | 4.7 | 4.9 | 4.6 | 4.4 | 5.0 | 4.7 |
| K01-8007 | 35.0 | 5.5 | 6.3 | 6.8 | 4.0 | 5.1 | 5.1 | 4.9 | 4.5 | 4.3 | 4.7 | 4.7 |
| K01-WAF | 46.7 | 5.3 | 5.9 | 5.9 | 4.4 | 4.9 | 4.5 | 4.7 | 4.6 | 4.7 | 5.0 | 4.7 |
| ATF 707 | 46.7 | 5.1 | 6.4 | 6.4 | 4.4 | 4.8 | 4.8 | 5.1 | 4.5 | 4.5 | 4.7 | 4.7 |
| Rebel Exeda* | 40.0 | 5.6 | 6.1 | 6.2 | 4.5 | 4.8 | 4.7 | 4.7 | 4.7 | 4.5 | 5.0 | 4.7 |
| GO-RD4 | 60.0 | 5.3 | 6.0 | 5.8 | 4.6 | 4.9 | 4.5 | 4.9 | 4.7 | 4.6 | 4.7 | 4.7 |
| MRF 29 | 43.3 | 5.5 | 7.4 | 5.8 | 4.5 | 4.9 | 5.0 | 4.9 | 4.5 | 4.1 | 4.8 | 4.7 |
| Barlexas* | 51.7 | 5.3 | 6.3 | 6.3 | 4.2 | 4.8 | 4.7 | 4.9 | 4.6 | 4.7 | 4.7 | 4.7 |
| Stetson* | 55.0 | 5.4 | 5.4 | 6.0 | 4.3 | 4.5 | 4.5 | 4.7 | 4.6 | 4.9 | 5.3 | 4.6 |
| ATF 586 | 36.7 | 5.3 | 5.9 | 6.1 | 4.2 | 4.5 | 5.0 | 4.9 | 4.7 | 4.3 | 4.9 | 4.6 |
| Pick-00-AFA | 46.7 | 5.1 | 5.9 | 6.3 | 4.4 | 4.9 | 4.7 | 4.6 | 4.7 | 4.2 | 4.5 | 4.6 |
| Tulsa II (ATF 706)* | 43.3 | 5.4 | 6.0 | 5.9 | 4.3 | 4.5 | 4.7 | 4.7 | 4.5 | 4.3 | 4.7 | 4.5 |

| Cultivar/ Experimental Number | % Cover 2001 | Avg. Green up | Avg. Genetic Color | Avg. Texture | Average Monthly Quality 2002–2006 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Apr. | May | Jun. | Jul. | | Sep. | Oct. | Avg. |
| Elisa* | 61.7 | 5.5 | 4.7 | 5.9 | 4.3 | 4.3 | 4.4 | 5.0 | 4.4 | 4.4 | 4.9 | 4.5 |
| Covenant (ATF 802)* | 40.0 | 5.3 | 6.6 | 6.0 | 4.0 | 4.7 | 4.5 | 4.7 | 4.3 | 4.5 | 4.7 | 4.5 |
| Kitty Hawk 2000* | 43.3 | 5.2 | 6.3 | 5.9 | 4.3 | 4.5 | 4.4 | 4.7 | 4.3 | 4.5 | 4.8 | 4.5 |
| Tracer* | 35.0 | 5.3 | 6.9 | 6.2 | 4.3 | 4.7 | 4.2 | 4.4 | 4.5 | 4.5 | 4.8 | 4.5 |
| Wyatt* | 46.7 | 5.1 | 6.0 | 6.0 | 4.2 | 4.4 | 4.5 | 4.7 | 4.5 | 4.2 | 4.9 | 4.5 |
| Tomahawk GT* | 43.3 | 5.1 | 6.4 | 5.8 | 3.8 | 4.6 | 4.4 | 4.8 | 4.3 | 4.3 | 4.8 | 4.4 |
| T991 | 31.7 | 4.8 | 7.0 | 5.7 | 3.8 | 4.6 | 4.5 | 4.3 | 4.5 | 4.1 | 4.8 | 4.4 |
| Lancer* | 50.0 | 5.5 | 6.1 | 6.3 | 4.1 | 4.7 | 4.7 | 4.5 | 4.0 | 4.2 | 4.4 | 4.4 |
| Bonsai* | 41.7 | 5.2 | 6.2 | 6.1 | 3.8 | 4.7 | 4.6 | 4.7 | 4.1 | 3.9 | 4.5 | 4.3 |
| Floridian (GO-FL3)* | 58.3 | 5.4 | 4.8 | 5.5 | 4.0 | 4.5 | 4.3 | 4.5 | 4.3 | 4.3 | 4.3 | 4.3 |
| PST-5KI | 38.3 | 5.5 | 6.1 | 6.0 | 3.9 | 4.5 | 4.0 | 4.1 | 4.3 | 4.4 | 4.7 | 4.3 |
| NA-TDD | 33.3 | 5.4 | 7.9 | 6.0 | 4.2 | 4.3 | 4.3 | 4.6 | 4.3 | 3.8 | 4.4 | 4.3 |
| GO-SIU2 | 46.7 | 5.5 | 5.3 | 5.6 | 4.0 | 4.3 | 4.0 | 4.6 | 4.0 | 4.2 | 4.4 | 4.2 |
| Ky-31 E+* | 61.7 | 5.4 | 3.8 | 3.9 | 3.5 | 3.5 | 3.4 | 3.5 | 3.5 | 3.3 | 3.6 | 3.4 |
| *LSD*[3] | *16.0* | *0.6* | *0.5* | *0.5* | *0.9* | *0.6* | *1.0* | *1.1* | *1.0* | *1.0* | *1.1* | *0.6* |

[1] Ratings based on a scale of 1–9 with 9=best measure.

[2] Cultivars marked with “*” became commercially available in 2005.

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

**TITLE:** Creeping Bentgrass Fairway NTEP Evaluation

**OBJECTIVES:** Evaluate performance of creeping bentgrass cultivars under golf course fairway management conditions

**PERSONNEL:** Jack Fry

**SPONSOR:** National Turfgrass Evaluation Program

**INTRODUCTION:**

Creeping bentgrass is used for putting greens in Kansas, but several courses are using it on fairways. In the eastern half of the United States, creeping bentgrass fairways are commonplace. Information is needed to find which creeping bentgrass cultivars are best suited to use under golf course fairway conditions.

**METHODS:**

Creeping bentgrass was seeded on September 24, 2004, in plots measuring 6 x 6 feet. In 2006, the study area received 3 lbs. N/1,000 $ft^2$. Turf was mowed at 0.5 inches; no aerification or topdressing was employed. Irrigation was applied to prevent drought stress. An insecticide was applied in July for white grub control; no other pesticides were applied.

Data were collected on turfgrass quality each month from April to August. Ratings were done visually on a 0 to 9 scale; 9=best. A quality rating of 7 was considered acceptable for a golf course fairway. In mid-June, plots were rated for percentage weed cover on a 0 to 100 percent scale.

**RESULTS:**

Those interested can see results from this location, and others throughout the United States at www.ntep.org. In general, creeping bentgrasses performed better than colonial bentgrasses. Quality of all grasses was generally better in June and July than in other months. Top performing cultivars included ‘Alpha’, ‘Penneagle II’, ‘Pennlinks II’, ‘L-93’, ‘SR-119’, ‘T-1’, ‘Independence’, ‘Kingpin’, ‘LS-44’, ‘Penncross’, and ‘Princeville’.

‘Seaside’ had the highest level of weed encroachment in mid-June. No other creeping bentgrass cultivars had significant levels of weeds, but several colonial bentgrasses had levels higher than 10 percent.

**Table 1**. Visual ratings of creeping and colonial bentgrass cultivars maintained under fairway conditions at Manhattan, KS, in 2006.

| | | Quality | | | | | |
|---|---|---|---|---|---|---|---|
| Name | Weeds (%) | April | May | June | July | August | Mean |
| Alpha | 0.7 | 4.3 | 5.3 | 6.7 | 7.3 | 6.3 | 6.0 |
| Penneagle II | 0.7 | 4.0 | 5.0 | 7.3 | 7.0 | 6.3 | 5.9 |
| Pennlinks II | 3.7 | 4.7 | 6.7 | 7.0 | 6.0 | 5.0 | 5.9 |
| PST-OEB | 1.7 | 4.7 | 6.0 | 6.3 | 6.3 | 5.7 | 5.8 |
| 13-M | 0.3 | 3.7 | 4.7 | 6.3 | 7.0 | 7.0 | 5.7 |
| IS-AP 14** | 0.3 | 3.0 | 4.7 | 7.0 | 6.7 | 7.0 | 5.7 |
| L-93 | 1.0 | 3.7 | 6.0 | 6.3 | 6.7 | 6.0 | 5.7 |
| SR 1119 | 1.3 | 4.0 | 5.3 | 6.7 | 6.7 | 6.0 | 5.7 |
| T-1 | 1.7 | 3.3 | 4.7 | 7.3 | 7.0 | 6.3 | 5.7 |
| SR 1150 (SRX 1PDH) | 0.3 | 3.0 | 4.7 | 7.0 | 7.3 | 6.0 | 5.6 |
| Independence | 1.0 | 4.0 | 5.3 | 6.0 | 6.0 | 6.0 | 5.5 |
| Kingpin (9200) | 0.7 | 2.7 | 4.3 | 6.3 | 6.7 | 7.3 | 5.5 |
| LS-44 | 1.3 | 3.7 | 5.0 | 6.7 | 6.3 | 6.0 | 5.5 |
| Penncross | 6.7 | 4.7 | 6.3 | 6.3 | 5.3 | 4.3 | 5.5 |
| Princeville | 6.0 | 4.7 | 5.3 | 6.0 | 5.3 | 5.0 | 5.3 |
| Bengal | 3.7 | 3.3 | 5.0 | 6.3 | 5.3 | 5.3 | 5.1 |
| Mackenzie (SRX 1GPD) | 1.3 | 3.3 | 4.3 | 5.7 | 6.0 | 6.0 | 5.1 |
| Authority (235050) | 0.7 | 2.7 | 4.0 | 6.0 | 6.3 | 6.0 | 5.0 |
| Declaration | 1.0 | 2.7 | 4.0 | 6.7 | 6.0 | 5.3 | 4.9 |
| Shark (23R) | 0.7 | 2.7 | 4.0 | 5.3 | 6.3 | 6.3 | 4.9 |
| Tiger II** | 9.0 | 5.0 | 5.7 | 5.3 | 4.3 | 3.7 | 4.9 |
| PST-9NBC** | 5.3 | 4.7 | 5.7 | 5.0 | 4.7 | 4.0 | 4.8 |
| EWTR** | 4.3 | 43. | 5.7 | 5.0 | 5.0 | 3.7 | 4.7 |
| SR 7150** | 11.7 | 5.0 | 5.3 | 5.0 | 4.3 | 4.0 | 4.7 |
| Bardot | 15.0 | 4.7 | 5.3 | 5.0 | 4.3 | 3.7 | 4.6 |
| IS-AT 7** | 11.0 | 4.7 | 5.0 | 4.7 | 4.7 | 4.0 | 4.6 |
| PST-9VN** | 10.3 | 4.7 | 5.0 | 4.7 | 4.7 | 4.0 | 4.6 |
| Seaside | 26.7 | 5.0 | 5.3 | 4.0 | 3.7 | 3.0 | 4.2 |
| LSD* | 10.9 | 1.3 | 1.0 | 1.0 | 1.6 | 1.1 | 0.8 |

*Least Statistical Difference. To determine statistical differences among entries, subtract the mean of one entry from that of another. A statistical difference occurs when the value is larger than the corresponding LSD value.

**TITLE:** NTEP Buffalograss Cultivar Trial

**OBJECTIVE:** Evaluate buffalograss cultivars for use in Kansas

**PERSONNEL**: Steve Keeley

**INTRODUCTION:**

Buffalograss (*Buchloe dactyloides*) is a warm-season grass that is native to the Great Plains. It is considered to be the lowest-maintenance turfgrass for use in Kansas. After establishment, it can be grown without supplemental irrigation. Fertilizer requirements are also minimal – 1 lb. N/1,000 $ft^2$ per year is adequate. However, better turf quality can be obtained with occasional irrigation during very dry periods. An additional pound of nitrogen per 1,000 $ft^2$ will darken color and improve density.

**MATERIALS AND METHODS:**

Ten buffalograss cultivars were planted in July 2002 at the Rocky Ford Turfgrass Research Field in Manhattan. The trial was mowed at 2.5 inches and fertilized with 2 lb. N/1,000 $ft^2$ per year. The turf was irrigated to prevent dormancy. No fungicides or insecticides were applied.

Turf quality was rated monthly from April to September on a visual scale of 1 to 9, where 1=dead turf and 9=optimum color, density, and uniformity. The cultivars were also rated for genetic color, spring green-up, leaf texture, and fall color retention.

**RESULTS:**

The 2006 growing season was the fourth – and final – year for this trial. The summarized data for all four years of this trial can be viewed at www.ntep.org.
Data for 2006 are shown in Tables 1 and 2.

**Table 1.** Monthly turfgrass quality of buffalograss cultivars grown in Manhattan, KS, in 2006.

| | Turfgrass quality[1] | | | | | | |
|---|---|---|---|---|---|---|---|
| Cultivar | April | May | June | July | August | September | Mean |
| Legacy | 4.0 | 7.0 | 5.3 | 7.0 | 7.3 | 6.7 | 6.2 |
| 609 | 4.0 | 6.0 | 6.0 | 6.3 | 7.0 | 6.7 | 6.0 |
| SWI-2000 | 4.0 | 6.0 | 6.0 | 7.3 | 6.0 | 6.3 | 5.9 |
| Density | 3.3 | 6.0 | 7.0 | 5.7 | 6.3 | 7.3 | 5.9 |
| Texoka | 3.7 | 6.3 | 6.0 | 7.0 | 6.3 | 6.0 | 5.9 |
| Bowie | 3.7 | 6.0 | 5.3 | 6.7 | 7.0 | 5.3 | 5.7 |
| Bison | 3.7 | 5.3 | 5.7 | 6.0 | 5.7 | 6.0 | 5.4 |
| 378 | 3.3 | 6.0 | 5.0 | 5.7 | 6.7 | 5.3 | 5.3 |
| Frontier Turfallo | 2.5 | 6.0 | 6.5 | 6.0 | 4.3 | 6.0 | 5.2 |
| NE 95-55 | 4.3 | 6.0 | 4.7 | 5.0 | 5.7 | 5.7 | 5.2 |
| MSD[2] | 1.1 | 2.2 | 1.1 | 1.9 | 0.9 | 1.7 | 1.1 |
| C.V. (%) | 16.3 | 13.2 | 9.9 | 13.8 | 7.8 | 12.6 | 8.2 |

[1/]1-9 scale; 9=Ideal turf.

[2/]Minimum significant difference based on the Waller-Duncan K-ratio t-Test. If the difference between any two means is less than this value, the means are not significantly different from one another.

**Table 2.** Spring green up, genetic color, leaf texture, and fall color retention of buffalograss cultivars grown in Manhattan, KS, in 2006.

| | Spring Green up[1] | Genetic Color[2] | Leaf Texture[3] | Fall Color Retention[4] |
|---|---|---|---|---|
| Legacy | 5.0 | 7.0 | 8.0 | 4.3 |
| SWI-2000 | 5.0 | 6.7 | 8.0 | 5.0 |
| Bowie | 4.3 | 7.0 | 8.0 | 4.7 |
| NE 95-55 | 5.3 | 7.0 | 7.0 | 4.3 |
| Texoka | 5.0 | 6.7 | 8.0 | 4.3 |
| 378 | 4.0 | 7.0 | 8.0 | 4.0 |
| Density | 3.7 | 5.0 | 8.0 | 6.3 |
| Bison | 4.3 | 7.0 | 7.0 | 5.0 |
| 609 | 4.7 | 6.7 | 7.7 | 5.7 |
| Frontier Turfallo | 3.0 | 6.0 | 7.0 | 4.5 |
| | | | | |
| MSD[5] | 1.7 | 0.5 | 0.3 | 2.1 |
| C.V. (%) | 16.7 | 4.9 | 2.4 | 18.6 |

[1/]1-9 scale; 9=Completely green.

[2/]1-9; 9= Darkest green.

[3/]1-9; 9=Very fine.

[4/]1-9; 9=Complete color retention (rated in early October).

[5/]Minimum significant difference based on the Waller-Duncan K-ratio t-Test. If the difference between any two means is less than this value, the means are not significantly different from one another.

[6/]Not significant.

**TITLE:** 2002 National Bermudagrass Test

**OBJECTIVE:** To evaluate bermudagrass cultivars under Kansas conditions and submit data collected to the National Turfgrass Evaluation Program

**PERSONNEL:** Linda R. Parsons and Rodney St. John

**SPONSOR:** USDA National Turfgrass Evaluation Program

**INTRODUCTION:**

Bermudagrass is a popular warm-season turfgrass that is heat- and drought-tolerant as well as wear resistant. It has a wide range of uses and is especially suited to athletic-field turf. Kansas represents the northernmost region in the central United States where bermudagrass can be successfully grown as a perennial turfgrass. Historically, few cultivars that have both acceptable quality and adequate cold-tolerance have been available to local growers. New introductions of interest are continually being selected for improved hardiness and quality; seeded varieties, in particular, show the potential for improved winter survival. Both seeded and vegetative types need regular evaluation to determine long-range suitability for use in Kansas.

**MATERIALS AND METHODS:**

In June 2002, three replications each of 42 bermudagrass cultivars and experimental numbers were planted in a randomized complete block design at the John C. Pair Horticultural Center in Wichita, KS. Twenty-nine entries were seeded; 13 vegetative entries were plugged with 12-inch spacings. Starter fertilizer was incorporated into the study plots at planting time at a rate of 1.0 lb. N/1,000 $ft^2$. Plot fertility was maintained at 0.5 to 0.75 lb. N/1,000 $ft^2$ per growing month. Plots were mowed once a week during the growing season at 0.75 to 1.0 inch, and irrigated as necessary to prevent dormancy. Weeds, insects, and diseases were controlled only to prevent severe stand loss.

During the course of the study, we information is collected on spring green-up, genetic color, leaf texture, seed head density, quality, and other measures when appropriate. Rating is done on a scale of 1=poorest, 6=acceptable, and 9=optimum measure.

**RESULTS:**

The 2006 growing season was begun with looking at greenup. By May 11, the vegetative varieties ‘Ashmore’, ‘Midlawn’, ‘OKC 70-18’, and ‘Patriot’, and the seeded variety ‘Yukon’ were the greenest (Table 1). Turf quality was rated monthly from May through September. Quality ratings were influenced by degree of coverage and weed infestation as well as turf color, texture, density, and the presence of seed heads. The best overall vegetative performers were ‘Patriot’, ‘Midlawn’, ‘OKC 70-18’, and ‘Premier (OR 2002)’; and the best seeded, ‘Yukon’ and ‘Riviera’. As clean-looking turf with no seed heads is preferred, seed head density was rated in spring, summer, and fall. At the end of May, most of the turfgrass plots had few, if any, seed heads (Table 2). In July, vegetative varieties ‘Patriot’, ‘MS-Choice’, and ‘Premier (OR 2002)’ and seeded varieties ‘CIS-CD6’ and ‘SWI-1044’ had the fewest seed heads; in September, the vegetative varieties ‘Ashmore’, ‘MS-Choice’, and ‘Midlawn’ and seeded variety ‘SWI-1046’ had the fewest. Mid-season, turfgrass stands were rated for overall density, with the densest found to be vegetative varieties ‘OKC 70-18’, ‘Midlawn’, and ‘Patriot’ and seeded varieties ‘SWI-1044’, ‘Riviera’, and ‘SWI-1012’. Turf color and texture were reviewed near the end of the growing season, with vegetative entries ‘Patriot’, ‘Tifway’, and ‘Celebration’, and seeded entry ‘Yukon’ the darkest green. Vegetative entries ‘Ashmore’, ‘Midlawn’, ‘Premier (OR 2002)’, and ‘Tifway’, and seeded entries ‘SWI-1044’ and ‘SWI-1046’ had the finest texture.

More information on the National Turfgrass Evaluation Program and nationwide 2002 National Bermudagrass Test results can be found at www.ntep.org.

**Table 1.** Performance of bermudagrass cultivars in 2006 at Wichita, KS.[1]

| Cultivar/ | | Spring | Quality | | | | | |
|---|---|---|---|---|---|---|---|---|
| Experimental Number | S or V[2] | Green up | May | Jun. | Jul. | Aug. | Sep. | Avg. |
| Patriot*[3] | V | 5.0 | 5.3 | 5.3 | 6.7 | 6.7 | 4.3 | 5.7 |
| Midlawn* | V | 5.3 | 6.0 | 5.3 | 6.3 | 6.3 | 3.7 | 5.5 |
| Yukon* | S | 5.0 | 5.3 | 5.0 | 5.0 | 7.3 | 4.0 | 5.3 |
| OKC 70-18 | V | 5.0 | 5.0 | 5.3 | 5.7 | 6.7 | 3.7 | 5.3 |
| Premier (OR 2002)* | V | 4.7 | 5.0 | 6.0 | 5.0 | 6.0 | 4.3 | 5.3 |
| Riviera* | S | 4.0 | 4.0 | 5.3 | 5.3 | 7.0 | 4.7 | 5.3 |
| Tifway* | V | 3.7 | 4.3 | 5.3 | 5.3 | 5.7 | 4.0 | 4.9 |
| Tifsport* | V | 3.3 | 4.3 | 5.0 | 5.0 | 6.0 | 3.7 | 4.8 |
| Tift No. 4 | V | 3.0 | 4.0 | 4.7 | 4.3 | 6.3 | 4.7 | 4.8 |
| SWI-1044 | S | 2.3 | 3.3 | 4.7 | 5.0 | 6.0 | 4.3 | 4.7 |
| Contessa (SWI-1045)* | S | 2.7 | 3.3 | 4.0 | 5.0 | 5.7 | 5.0 | 4.6 |
| SWI-1046 | S | 3.0 | 3.0 | 4.0 | 5.0 | 6.0 | 5.0 | 4.6 |
| SWI-1014 | S | 4.0 | 4.3 | 4.0 | 4.7 | 5.7 | 4.0 | 4.5 |
| CIS-CD6 | S | 3.7 | 4.0 | 4.3 | 4.7 | 5.3 | 4.0 | 4.5 |
| SWI-1012 | S | 3.0 | 3.3 | 4.0 | 4.3 | 5.7 | 5.0 | 4.5 |
| Aussie Green* | V | 3.3 | 4.3 | 5.0 | 4.7 | 4.7 | 3.3 | 4.4 |
| Celebration* | V | 2.0 | 2.7 | 4.3 | 4.3 | 6.3 | 4.3 | 4.4 |
| MS-Choice* | V | 2.0 | 2.0 | 4.0 | 5.0 | 5.3 | 3.7 | 4.0 |
| Sunbird (PST-R68A)* | S | 2.3 | 3.0 | 3.7 | 4.7 | 5.0 | 3.3 | 3.9 |
| LaPaloma (SRX 9500)* | S | 3.0 | 3.0 | 3.7 | 4.3 | 4.7 | 3.7 | 3.9 |
| CIS-CD7 | S | 3.0 | 3.0 | 4.0 | 4.0 | 5.0 | 3.3 | 3.9 |
| Tift No. 3 | V | 2.0 | 2.0 | 4.0 | 4.0 | 5.3 | 4.0 | 3.9 |
| Ashmore* | V | 6.0 | 6.0 | 4.7 | 2.3 | 3.0 | 2.7 | 3.7 |
| Panama* | S | 2.3 | 2.3 | 3.3 | 4.0 | 5.0 | 4.0 | 3.7 |
| CIS-CD5 | S | 2.3 | 2.3 | 3.0 | 4.0 | 5.3 | 3.7 | 3.7 |
| Princess 77* | S | 2.0 | 1.7 | 3.0 | 3.7 | 6.0 | 4.0 | 3.7 |
| FMC-6* | S | 2.3 | 2.7 | 3.3 | 3.7 | 4.7 | 3.7 | 3.6 |
| SR 9554* | S | 2.7 | 2.7 | 3.3 | 4.0 | 4.7 | 3.3 | 3.6 |
| Sundevil II* | S | 3.0 | 3.0 | 3.0 | 4.0 | 4.3 | 3.3 | 3.5 |
| Transcontinental* | S | 2.3 | 3.0 | 3.3 | 3.7 | 4.7 | 3.0 | 3.5 |
| Sunstar* | S | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 | 3.5 | 3.5 |
| SWI-1001 | S | 2.0 | 2.3 | 3.3 | 3.7 | 4.7 | 3.3 | 3.5 |
| B-14 | S | 3.0 | 2.0 | 3.0 | 4.0 | 4.7 | 3.3 | 3.4 |
| GN-1* | V | 2.7 | 2.7 | 3.7 | 3.3 | 4.0 | 3.3 | 3.4 |
| SWI-1041 (Veracruz)* | S | 2.0 | 1.3 | 3.0 | 3.7 | 5.0 | 4.0 | 3.4 |
| Mohawk* | S | 2.3 | 2.3 | 3.0 | 3.7 | 4.3 | 3.0 | 3.3 |
| SWI-1003 | S | 2.3 | 2.0 | 2.7 | 3.0 | 4.3 | 4.3 | 3.3 |
| Southern Star* | S | 2.3 | 2.3 | 3.0 | 3.7 | 4.0 | 3.0 | 3.2 |
| NuMex Sahara* | S | 2.7 | 2.3 | 3.0 | 3.3 | 4.0 | 3.0 | 3.1 |
| Arizona Common* | S | 2.7 | 2.3 | 2.7 | 3.3 | 3.7 | 3.3 | 3.1 |
| Tift No. 1 | S | 2.3 | 1.3 | 2.3 | 3.0 | 4.7 | 3.7 | 3.0 |
| Tift No. 2 | S | 2.5 | 1.7 | 1.3 | 1.7 | 2.3 | 2.0 | 1.8 |
| *LSD*[4] | | *0.8* | *0.7* | *0.9* | *0.9* | *1.3* | *1.2* | *0.6* |

[1] Ratings based on a scale of 1–9; 9=best measure.

[2] Seeded or vegetative varieties.

[3] Cultivars marked with "*" became commercially available in 2007

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

**Table 2**. Performance of bermudagrass cultivars in 2006 at Wichita, KS, continued[1].

| Cultivar/ Experimental Number | S or V[2] | Genetic Color | Texture | Summer Density | Seed Heads May | Seed Heads July | Seed Heads Sept. |
|---|---|---|---|---|---|---|---|
| Patriot* | V | 8.0 | 5.0 | 7.0 | 9.0 | 9.0 | 8.7 |
| Midlawn* | V | 7.0 | 8.7 | 7.0 | 9.0 | 7.7 | 9.0 |
| Yukon* | S | 7.7 | 6.0 | 5.7 | 9.0 | 6.7 | 5.7 |
| OKC 70-18 | V | 4.3 | 7.3 | 7.3 | 9.0 | 8.3 | 6.0 |
| Premier (OR 2002)* | V | 6.3 | 8.0 | 5.3 | 9.0 | 8.7 | 7.7 |
| Riviera* | S | 6.3 | 5.7 | 6.3 | 9.0 | 7.0 | 5.7 |
| Tifway* | V | 8.0 | 8.0 | 6.7 | 9.0 | 8.0 | 8.7 |
| Tifsport* | V | 7.3 | 7.3 | 6.7 | 9.0 | 8.0 | 8.0 |
| Tift No. 4 | V | 6.3 | 6.7 | 5.3 | 9.0 | 6.0 | 5.3 |
| SWI-1044 | S | 5.0 | 6.3 | 6.7 | 9.0 | 7.7 | 5.7 |
| Contessa (SWI-1045)* | S | 6.3 | 5.7 | 5.0 | 9.0 | 6.0 | 5.0 |
| SWI-1046 | S | 7.0 | 6.3 | 5.7 | 9.0 | 7.0 | 6.7 |
| SWI-1014 | S | 6.7 | 4.7 | 5.0 | 9.0 | 7.0 | 5.3 |
| CIS-CD6 | S | 5.0 | 5.7 | 6.0 | 8.3 | 7.7 | 4.7 |
| SWI-1012 | S | 7.0 | 6.0 | 6.3 | 9.0 | 6.7 | 5.7 |
| Aussie Green* | V | 6.0 | 5.0 | 5.3 | 9.0 | 8.3 | 7.3 |
| Celebration* | V | 7.7 | 6.3 | 5.7 | 9.0 | 6.7 | 8.0 |
| MS-Choice* | V | 5.3 | 5.0 | 5.3 | 9.0 | 8.7 | 9.0 |
| Sunbird (PST-R68A)* | S | 4.7 | 5.3 | 5.3 | 9.0 | 6.3 | 5.0 |
| LaPaloma (SRX 9500)* | S | 5.3 | 5.3 | 5.0 | 9.0 | 7.0 | 4.0 |
| CIS-CD7 | S | 6.0 | 4.7 | 4.3 | 9.0 | 6.0 | 4.0 |
| Tift No. 3 | V | 5.3 | 5.3 | 4.3 | 9.0 | 8.0 | 8.0 |
| Ashmore* | V | 5.0 | 9.0 | 5.3 | 9.0 | 8.0 | 9.0 |
| Panama* | S | 4.7 | 5.3 | 5.0 | 9.0 | 6.7 | 5.0 |
| CIS-CD5 | S | 5.7 | 5.0 | 4.7 | 9.0 | 5.7 | 4.3 |
| Princess 77* | S | 5.7 | 5.3 | 4.7 | 9.0 | 6.7 | 5.0 |
| FMC-6* | S | 4.7 | 5.3 | 4.7 | 9.0 | 7.0 | 4.3 |
| SR 9554* | S | 5.0 | 5.0 | 4.0 | 9.0 | 6.3 | 4.0 |
| Sundevil II* | S | 4.3 | 5.0 | 4.7 | 9.0 | 5.3 | 4.0 |
| Transcontinental* | S | 5.0 | 4.3 | 4.7 | 9.0 | 6.0 | 4.7 |
| Sunstar* | S | 5.0 | 5.0 | 5.0 | 9.0 | 7.0 | 4.0 |
| SWI-1001 | S | 4.7 | 5.0 | 4.7 | 8.7 | 7.0 | 4.7 |
| B-14 | S | 5.0 | 5.0 | 3.7 | 9.0 | 6.0 | 4.7 |
| GN-1* | V | 7.0 | 4.7 | 4.0 | 9.0 | 8.0 | 7.3 |
| SWI-1041 (Veracruz)* | S | 5.0 | 5.3 | 5.0 | 9.0 | 5.7 | 4.7 |
| Mohawk* | S | 4.0 | 5.0 | 4.0 | 9.0 | 7.0 | 5.0 |
| SWI-1003 | S | 4.7 | 5.7 | 4.3 | 8.7 | 5.7 | 4.7 |
| Southern Star* | S | 5.3 | 5.0 | 4.7 | 9.0 | 6.0 | 4.0 |
| NuMex Sahara* | S | 5.0 | 5.0 | 4.0 | 9.0 | 6.7 | 5.7 |
| Arizona Common* | S | 5.0 | 5.0 | 3.7 | 9.0 | 7.0 | 4.3 |
| Tift No. 1 | S | 6.3 | 5.3 | 4.0 | 9.0 | 5.7 | 5.0 |
| Tift No. 2 | S | 6.0 | 6.0 | 2.5 | 9.0 | 7.5 | 4.5 |
| *LSD*[3] | | *1.2* | *1.1* | *1.1* | *0.4* | *1.1* | *1.3* |

[1] Ratings based on a scale of 1–9; 9=best measure.

[2] Seeded or vegetative varieties.

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

**TITLE:** Preventative Fungicide Applications for Management of Dollar Spot on Greens-height Creeping Bentgrass

**PERSONNEL:** Megan Kennelly, Jack Fry, Alan Zuk

**SPONSORS:** Bayer, Syngenta, BASF

## INTRODUCTION:

Dollar spot is caused by the fungus *Sclerotinia homoeocarpa*. It is a common disease, appearing on 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 low-cut (putting green) turf, the disease appears as sunken patches of tan/brown turf up to 2 inches in diameter. In severe cases, the infection spots coalesce to form larger blighted areas. Many fungicides are labeled for dollar spot suppression in golf courses. This test was done to evaluate several standard and newer materials.

## MATERIALS AND METHODS:

Fungicides were evaluated on an established stand of 'Penncross' creeping bentgrass on a sand-based putting green at the Rocky Ford Turf Research Center, Manhattan, KS. The turf was mowed to a height of 0.156 inch, irrigated daily for 15 minutes, and fertilized during the season with 5.52 lb. total N/1,000 $ft^2$. Applications were made at 2-, 3-, or 4-week intervals beginning May 31, with the final application on Sep. 20. Fungicides were applied with a $CO_2$-powered boom sprayer with XR Tee Jet 8003VS nozzles at 30 psi in water equivalent to 2.0 gal/1,000 $ft^2$. Plots were 5 X 7 feet and arranged in a randomized complete block design with four replications. Plots were rated every 1 to 3 weeks from July 19 through September 21 by counting the number of dollar spot infection centers per plot.

## RESULTS:

Dollar spot developed at low levels in late July and increased through August and September. All materials provided significant disease reductions compared to the unsprayed control (Table 1). Chipco 26GT, Emerald, Headway, and Spectro 90 WDG provided excellent control (less than 2 infection centers per plot) on all rating dates. Daconil Ultrex provided significant control compared to the untreated plots but the 1.8-oz. rate allowed a modest amount of disease under high pressure late in the season. Similarly, Bayleton 50 WSP (0.5 oz. on 28-day interval) provided significant control but did allow some breakthrough under high disease pressure. No phytotoxic effects were observed.

**Table 1.** Preventative fungicide applications for management of dollar spot on creeping bentgrass.

| Treatment and rate/1,000 ft$^{2}$* | Spray interval (days) | Dollar spot infection centers per plot** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 19 Jul | 11 Aug | 25 Aug | 29 Aug | 5 Sep | 13 Sep | 21 Sep |
| Unsprayed control | -- | 0.0a | 12.5a | 22.8a | 79.3a | 98.3a | 173.0a | 131.3a |
| Chipco 26 GT 4 oz | 14 | 0.3a | 0.0b | 0.0c | 0.0c | 0.0c | 0.0c | 0.0c |
| Emerald 0.13 oz | 14 | 0.0a | 0.0b | 0.0c | 0.0c | 0.0c | 0.0c | 0.3bc |
| Emerald 0.18 oz | 21 | 0.0a | 0.0b | 0.3bc | 1.0bc | 0.0c | 0.0c | 0.0c |
| Emerald 0.18 oz | 28 | 0.0a | 0.0b | 0.0c | 0.0c | 0.0c | 0.0c | 0.0c |
| Headway 3 oz | 28 | 0.3a | 0.0b | 0.0c | 0.0c | 0.0c | 0.0c | 0.0c |
| Headway 1.5 oz | 14 | 0.5a | 0.5b | 0.0c | 0.0c | 0.0c | 0.0c | 0.0c |
| Bayleton 50 WSP 0.5 oz | 28 | 0.3a | 0.0b | 0.0c | 0.0c | 0.3c | 4.8bc | 3.8bc |
| Bayleton 50 WSP 0.25 oz | 14 | 0.3a | 0.3b | 0.0c | 0.3 | 1.3c | 0.5c | 0.8bc |
| Daconil Ultrex 82.5 WDG 1.8 oz | 14 | 0.0a | 0.0b | 2.5b | 6.3b | 13.0b | 7.8b | 5.8b |
| Daconil Ultrex 82.5 WDG 3.2 oz | 14 | 1.8a | 0.5b | 0.0c | 0.5bc | 1.3c | 1.3c | 0.8bc |
| Spectro 90 WDG 4 oz | 14 | 0.3a | 0.0b | 0.0c | 0.0c | 0.0c | 0.0c | 0.0c |

*Fungicide applications were initiated on 31 May. 14-day interval application calendar dates were 31 May, 14 and 28 Jun, 12 and 26 Jul, 9 and 23 Aug, and 6 and 20 Sep. 21-day interval application calendar dates were 31 May, 21 Jun, 12 Jul, 2 and 23 Aug, and 13 Sep. 28-day interval calendar dates were 31 May, 28 Jun, 26 Jul, 23 Aug, and 20 Sep.

** Values are means of four replicates. Values were log (x +1) transformed prior to analysis to stabilize variance and back-transformed for presentation. Means within columns followed by the same letter are not significantly different according to Tukey's pairwise comparisons (family error rate p = 0.05).

**TITLE:** Large Patch as Affected by Cultivation Practices and Timing of Nitrogen Application

**OBJECTIVE:** Evaluate cultivation practices, including core aerification, verticutting, and sand topdressing in conjunction with time of N application for effects on large patch

**PERSONNEL:** Jack Fry and Megan Kennelly

**SPONSORS:** Kansas Turfgrass Foundation

**INTRODUCTION:**
Cultural practices are a critical component in turfgrass disease management. Prior work by Ned Tisserat and David Green at Kansas State University has determined that large patch in zoysia is favored by lower mowing heights, but is not influenced by pre-emergence herbicides. In the same study, there were no differences in large patch due to source (organic vs. synthetic) or rate (high or low) of N. However, in these experiments, N was applied in June and August, not in spring or fall when large patch is most active. Early spring fertilization of zoysiagrass is commonly practiced to speed green up, which leads to the presence of susceptible turf during the peak large patch infection period. Some superintendents apply nitrogen in late summer and autumn to delay dormancy, which could increase fall susceptibility to disease. The hypothesis that spring and fall nitrogen applications increase large patch remains to be tested

The disease that causes large patch infects plants at the sheath level. This led us to hypothesize that promoting a drier soil surface/thatch layer with aerification, verticutting, and topdressing helps keep a drier environment around leaf sheaths where the disease initially occurs.

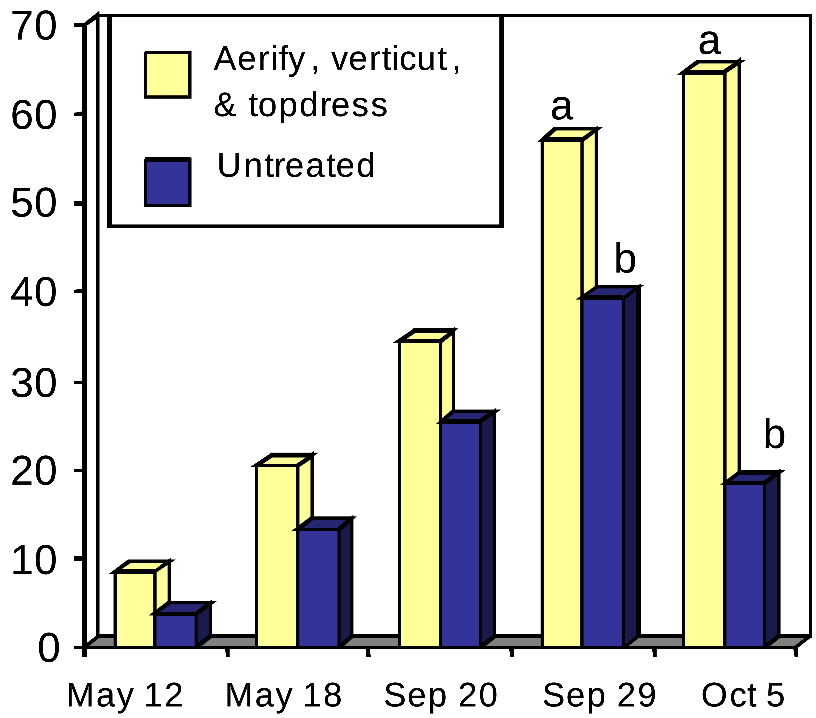
**MATERIALS AND METHODS:**
Plots in a split-plot design were established at the Rocky Ford Turfgrass Research Center Manhattan, KS. Whole plots were the cultivation treatment and sub-plots were fertilizer timing. Cultivation in 2006 was done on June 5 and included aerification, verticutting, and topdressing. Aerification was done with a John Deere hydraulic aerifier that created holes 0.5 inch in diameter and about 1.5 inches deep. There were 64 holes punched per square foot. Cores were allowed to dry and then broken up by running a verticutter across the surface. Topdressing was applied to provide dry sand at a rate of about 1,400 lbs. per 1,000 $ft^2$. A second topdressing of sand was applied in early July at about 320 lbs. of sand per 1,000 $ft^2$.

The two fertilizer timing regimes in 2006 included: i) summer fertilization, and ii) early spring and late summer fertilization. Traditional summer fertilization was accomplished by applying 2 lbs. of N 1,000 $ft^2$ on June 12. For early spring and late summer fertilization, 0.5 lbs. of N per from urea was applied on April 14, May 16, August 22, and September 25.

**RESULTS:**

A significant outbreak of large patch began in the study area in autumn 2006. Nitrogen fertilizer timing had no effect on large patch. However, zoysiagrass that was cultivated (aerified, verticut, topdressed) had significantly more large patch than untreated turf on September 29 and October 5 (Figure 1). This result contradicted expectations, and the explanation is yet to be determined. It is possible that the pathogen is spread with the cultivation process, or that cultivation somehow creates a more desirable environment in the turf canopy for the disease to proliferate. This work continues in 2007, and we hope to expand the scope of the study.

**Fig. 1.** Influence of zoysiagrass cultivation in June on resulting large patch levels in autumn 2006.



**TITLE**: Effects of Drought on the Performance of Two Hybrid Bluegrasses, Kentucky Bluegrass and Tall Fescue

**OBJECTIVE:** Evaluate the effects of drought on the visual quality and photosynthesis in two hybrid bluegrasses ('Thermal Blue' and 'Reveille'), one Kentucky bluegrass ('Apollo'), and one tall fescue ('Dynasty')

**AUTHOR**: Kemin Su, Dale Bremer, Steve Keeley, Jack Fry

**SPONSORS**: The Scotts Co., GCSAA, Kansas Turfgrass Foundation

**INTRODUCTION:**

Drought stress is a major problem in cool-season turfgrasses during summer months in the U.S. transition zone. Kentucky bluegrass is a fine-textured, high quality cool-season turfgrass commonly used in athletic fields and golf courses fairways and roughs. The performance of Kentucky bluegrass is marginal in the transition zone because of its sensitivity to drought. Tall fescue, also a cool-season grass, is sometimes used in golf course roughs and is popular in lawns because of its good drought resistance, but some golf course superintendents do not like its coarser texture. Hybrid bluegrasses, which are genetic crosses between native Texas bluegrass and Kentucky bluegrass, may have similar visual quality as Kentucky bluegrass but greater drought- and heat-resistance than other cool-season grasses. To further complicate the issue, increasing competition for water among industry, agriculture, and the public has resulted in restrictions on turfgrass irrigation.

New cultivars of hybrid bluegrasses are being investigated as potential alternatives that may perform better under drought than current cool-season turfgrasses. Despite the potential for using hybrid bluegrasses in lawns and golf course fairways and roughs, little scientific data are available about the field performances of hybrid bluegrasses in the transition zone, including under well-watered and drought conditions.

**METHODS:**

This study was conducted from 3 August to 8 October, 2004, and from 27 June to 15 September, 2005, under an automated rainout shelter (180 $m^2$) at the Rocky Ford Turfgrass Research Center near Manhattan, KS (Fig. 1). Thirty two plots (1.36 x 1.76 m) of a Kentucky bluegrass ('Apollo'), a tall fescue ('Dynasty'), and two hybrid bluegrasses ('Reveille' and 'Thermal Blue') were arranged in a randomized complete block design with four replications; plots were bordered by metal edging (10 cm depth) to prevent lateral soil-water movement between adjacent plots. One water deficit treatment, which included the replacement of 60% of the water lost from plant and soil surfaces via evapotranspiration (ET), was applied to 16 plots, or 4 plots (reps) of each species/cultivar. The remaining 16 plots were well watered (100% ET replacement) and served as a control. To determine irrigation requirements, evapotranspiration (ET) was calculated by using the Penman-Monteith equation (FAO, 1998) and climatological data obtained at a weather station located at Rocky Ford Turfgrass Research Center. Water was applied twice weekly through a fan spray nozzle attached to a hose; a meter was attached to ensure proper application rate. Plots were mowed at 7.62 cm twice a week with a walk-behind rotary mower.

Turf visual quality was rated on a scale of 1 to 9 (1=poorest quality, 6=minimally acceptable, and 9=highest quality) according to color, texture, density, and uniformity. Quality ratings were recorded weekly by the same individual during the 2-year study. Photosynthesis was measured biweekly on clear days between 1000 and 1400 CST with an LI-6400 portable gas exchange system using a custom surface chamber. Permanent polyvinyl chloride collars (10-cm diam.) were placed randomly at one location in each plot and were driven approximately 5 cm into the soil. Gross photosynthesis (Pg) was estimated as the sum of photosynthesis measured by sunlit chamber and respiration measured by shaded chamber. In all plots, the volumetric soil water content ($\theta_v$) in the 0- to 50-cm profile was measured weekly using time domain reflectometry and in drought plots at 5 cm using dual-probe heat-pulse sensors.

**RESULTS:**

In well-watered plots, visual quality was highest in tall fescue and lowest in Thermal Blue among species and cultivars. Visual quality was generally higher in Reveille than Thermal Blue during the second month of the study (Fig. 2A).

In the drought treatment, tall fescue also had the highest visual quality among species and cultivars. The visual quality of Reveille was greater than Thermal Blue and Kentucky bluegrass as the plots dried, but then became similar to Thermal Blue and Kentucky bluegrass during the most severe part of drought (Fig. 2B). After termination of the drought treatment and upon re-watering (on 70 DOT), Thermal Blue and Reveille recovered faster than Kentucky bluegrass, and both hybrid bluegrasses had higher visual quality than Kentucky bluegrass late in the study (Fig. 1B).

In well-watered conditions, Pg was generally greatest in TF among species and cultivars (Fig. 3A). In the drought treatment, Pg was greater in TF than in Thermal Blue and KBG during the first two weeks, but Pg thereafter became similar among cultivars and species. There was generally no difference in Pg between TF and Reveille (Fig. 3B).

**CONCLUSIONS:**

In well-watered and drought treatments, tall fescue had highest the visual quality and greatest Pg among species and cultivars. In the drought treatment, Reveille performed better than Thermal Blue, and both hybrids (i.e., Thermal Blue and Reveille) recovered from drought more quickly than Kentucky bluegrass. In general, the performances ranked: tall fescue > Reveille >= Thermal Blue=Kentucky bluegrass.

**Figure 1**. Rainout shelter (180 m2) at Rocky Ford Turfgrass Research Center near Manhattan, KS. The rainout shelter automatically moved over plots (on tracks) when rainfall began, then retracted one hour after rainfall ended.

**Figure 2.** Visual quality of Thermal Blue (HBG1), Reveille (HBG2), Kentucky bluegrass (KBG), and tall fescue (TF) rated on a scale of 1 to 9 (1=poorest and 9=highest) under well-watered (A) and drought (B) conditions in 2005. Means followed with the same letter on a given day after treatment initiation (days of treatment) are not significantly different (P<0.05).

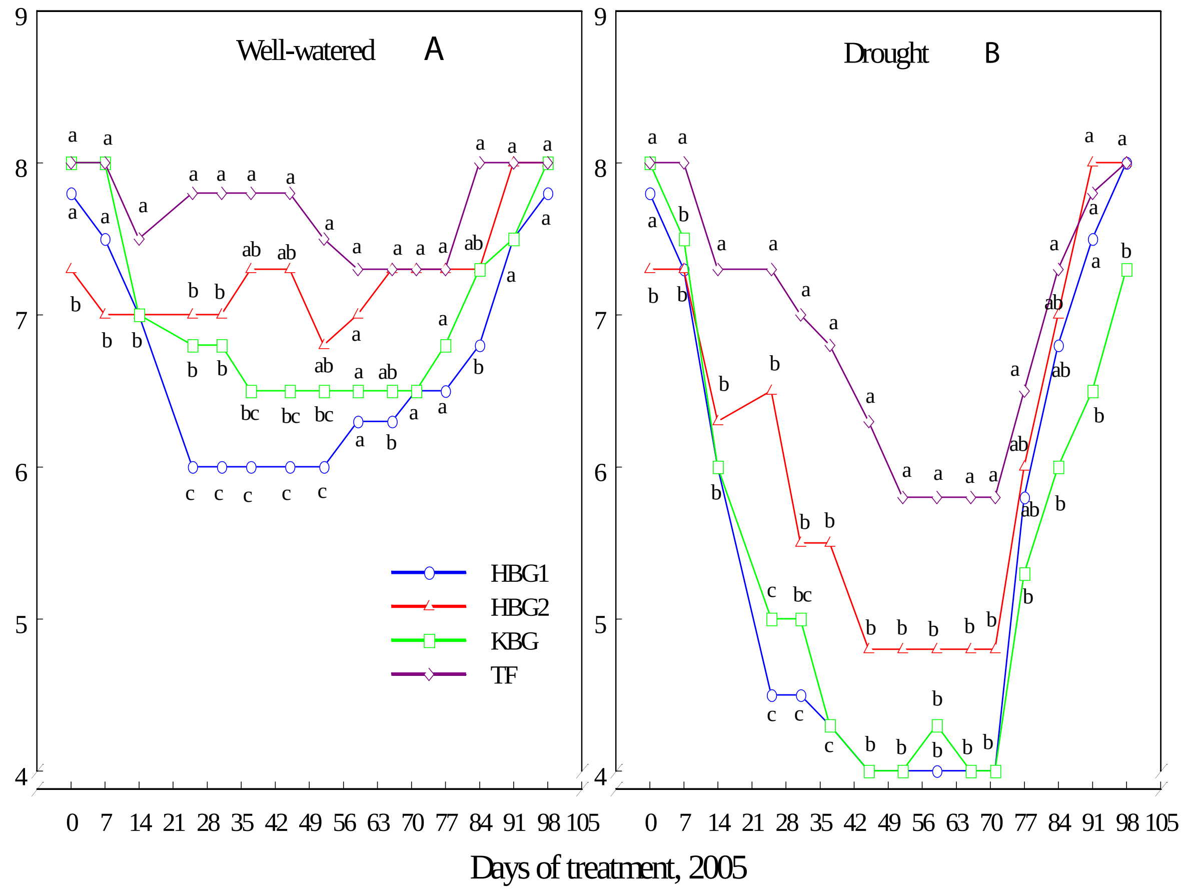
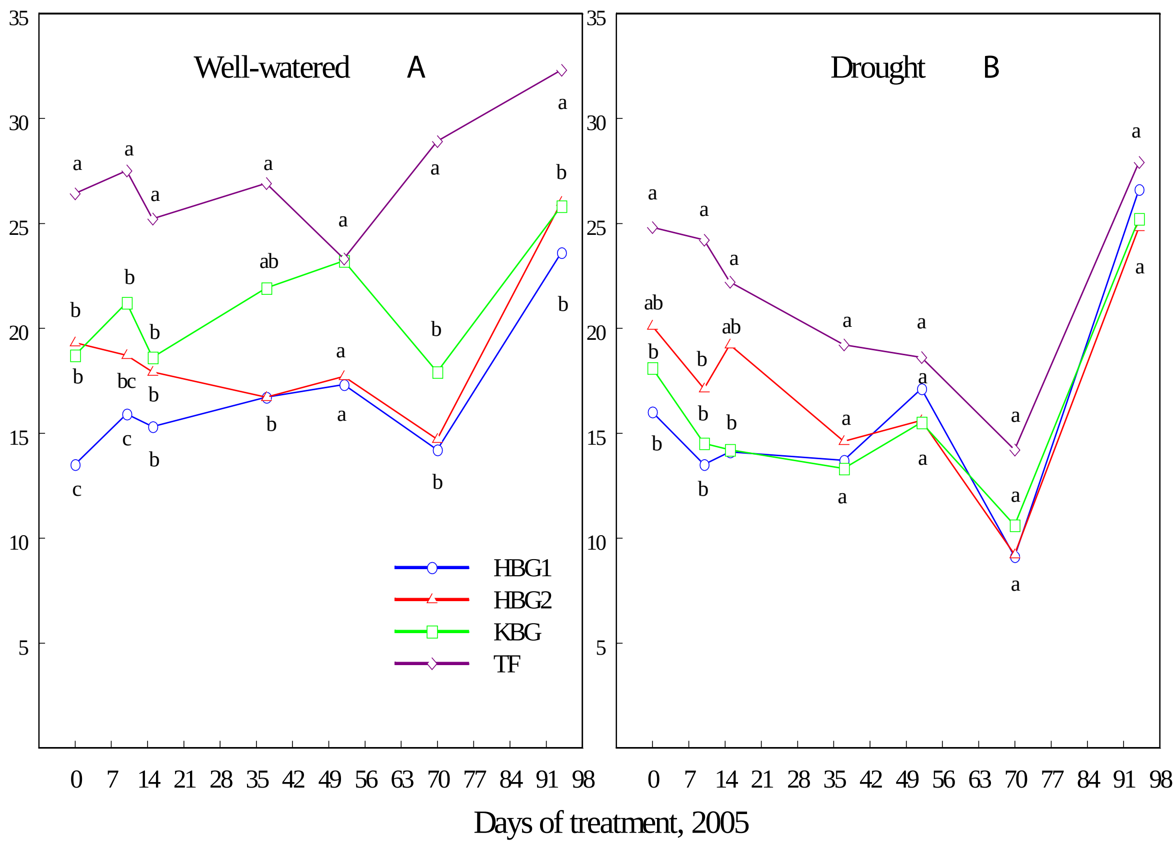


**Figure 3**. Gross photosynthesis (Pg; sum of photosynthesis and respiration) in Thermal Blue (HBG1), Reveille (HBG2), Kentucky bluegrass (KBG), and tall fescue (TF) in well-watered (A) and drought (B) plots in 2005. Means followed with the same letter on a given day after treatment initiation (days of treatment) were not significantly different (P<0.05).



**TITLE**: Comparative Irrigation Requirements of 30 Cultivars of Kentucky Bluegrasses under a Large Rainout Facility in the Transition Zone

**OBJECTIVES:** 1. Develop and implement a novel method for concurrently comparing irrigation requirements among 30 cultivars of turfgrasses using a large rainout facility at Kansas State University; 2. produce a database of relative irrigation requirements for 30 cultivars of Kentucky bluegrass; 3. partition cultivars of Kentucky bluegrasses into irrigation-requirement categories of "high, medium, and low"; and 4. conduct dry-down and genetic rooting potential experiments in a greenhouse to evaluate responses to drought and physiological characteristics among the same cultivars as those tested in the field.

**AUTHORS**: Dale Bremer, Steve Keeley, Jack Fry, and Jason Lewis

**SPONSORS**: U.S. Golf Association and Turfgrass Producers International

**INTRODUCTION:**

One of the most important challenges facing the turfgrass industry today is the increasingly limited supply of water for irrigation. Water conservation and improvement of turfgrass resistance to drought stresses have become topics of major importance as turf managers face drought across the county. In 2004, the Environmental Institute for Golf concluded in a task group meeting that future water availability is a *serious* issue in the western United States and that data on water use is lacking in many states. They also noted that state and local drought restrictions may be imposed on turf managers with no regard for damage to turfgrasses.

Clients and the public (for example, golfers, participants at outdoor sporting events, and lawn owners) express their displeasure when turfgrass does not meet quality standards they expect – even when irrigation is restricted. Adding to the issue's importance, land acreage covered with turfgrasses is rapidly expanding. A 2005 NASA study indicated that turfgrass covers an area three times greater than any other irrigated crop in the United States. Identifying cultivars that use less water and tolerate drought better could result in significant water savings.

Kentucky bluegrass is one species commonly used on golf course roughs and fairways, in sports fields, and in home and commercial lawns. Information is needed on Kentucky bluegrass cultivars that conserve water while maintaining acceptable quality.

**MATERIALS AND METHODS:**

The project is being conducted in a fully automated, mobile rainout shelter (12 x 12 m) and in a greenhouse facility located at Kansas State University, Manhattan, during the summers of 2007 and 2008.

*Cultivars and turfgrass management*

Turfgrasses in the study include 28 cultivars of Kentucky bluegrass and two Texas bluegrass hybrids (Table 1). Cultivars were selected to include representatives from major groups, based on similar phenotypic characteristics, of Kentucky bluegrasses. Most cultivars were best-performers in NTEP trials. Four standard entries were included in the mix: 'Midnight', 'Baron', 'Eagleton', and 'Kenblue'.

On September 19, 2006, Kentucky bluegrasses were seeded at approximately 10 g $m^{-2}$ pure live seed in a randomized block design (Fig. 1). Cultivars were replicated three times each for a total of 90 plots (plot dimensions: 1.13 x 1.22 m each). Plots were covered with a seed germination blanket (Futerra F4 Netless, Profile Products LLC, Buffalo Grove, IL) to prevent movement of seed across plots from water or wind. Plots were then irrigated several times daily to maintain a wet seedbed during germination. Three weeks after seeding during the fall of 2006, germination and establishment were good (Fig. 2). Turfgrasses were mowed once in the fall of 2006 at approximately 5 cm, and are being maintained during 2007 and 2008 following typical rough management programs in the Midwest regions.

*Irrigation management and data collection*

Plots were initially well-watered until June 2007. Thereafter, turfgrasses are being allowed to dry down without irrigation or precipitation until the first sign of wilt. Individual cultivars will be evaluated a minimum of three times per week, and plots will be irrigated with approximately one inch of water at the beginning of wilt. Plots will be evaluated daily as drydown commences and during extremely high temperatures (e.g., above 30$^{o}$C). Each plot will be irrigated manually, and irrigation quantity and date for each plot will be recorded. This experiment will continue through the end of September, including both hot and cool months to determine possible interactions among cultivars with changes in atmospheric evaporative demands. Total irrigation requirements of each cultivar for the entire study period will be summarized. This project will be repeated in 2008 to incorporate further climatic variability. General turf performance will be evaluated biweekly by visually rating turf quality. To account for plots in different stages of drydown (e.g., cultivars irrigated on the previous day vs. those that have not been irrigated for several days), quality of individual plots will be rated on the day after receiving irrigation.

*Greenhouse component*

The same cultivars used in the field study will be evaluated for rooting depth in the greenhouse using slanted root tubes. This involves transplanting plugs of turfgrasses into clear polyethylene root tubes filled with fritted clay. Polyethylene tubes are then inserted into opaque PVC pipe (sleeves). Root growth can then be monitored periodically along the side of the clear root tubes. When roots in the first tube reach the bottom of its container, a dry down will be started to evaluate relative drought resistance among cultivars. Plants will be rewetted to evaluate recovery. Finally, roots will be harvested, dried in forced-convection ovens, and weighed to compare root biomass among cultivars. This research will be conducted during 2007, and initial results will be included in next year's K-State Turfgrass Research Reports.

**Table 1.** List of 28 Kentucky bluegrass cultivars and two Texas bluegrass hybrids selected for the 2-year study under the rainout shelter at Kansas State University. Groups indicate cultivars with similar phenotypic characteristics.

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

**Figure 1.** Plot layout of 28 cultivars of Kentucky bluegrasses and two Texas bluegrass hybrids under the rainout shelter at Kansas State University. Plot dimensions are 1.13 x 1.22 m each; plots are arranged in a randomized block design.

Block

NORTH

WEST | EAST

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

SOUTH

**Figure 2.** View of plots approximately six weeks after seeding.

**TITLE**: Effects of High Temperature and Drought on a Hybrid Bluegrass Compared with Kentucky Bluegrass and Tall Fescue

**OBJECTIVE:** Evaluate effects of high temperature and drought on physiology and growth of ‘Apollo’ Kentucky bluegrass (*Poa pratensis* L.), ‘Dynasty’ tall fescue (*Festuca arundincea* Schreb.), and ‘Thermal Blue’, a hybrid between KBG and Texas bluegrass (*Poa arachnifera* Torr.)

**AUTHOR**: Kemin Su, Dale Bremer, Steve Keeley, Jack Fry

**SPONSORS**: The Scotts Co., GCSAA, Kansas Turfgrass Foundation (KTF)

**INTRODUCTION:**

High temperature and drought stresses are significant problems in cool-season turfgrasses during summer months in the U.S. transition zone. High temperature and drought stresses often occur simultaneously during summer months and may limit growth and cause a severe decline in the visual quality of cool-season turfgrasses. Recent increases in competition for water have resulted in restrictions in water use for irrigation of turfgrasses, which further exacerbates the problem of drought stress in cool-season turfgrasses. Predictions of higher temperatures from global warming also suggest that heat stress in cool-season turfgrasses may become more common in some regions, including the transition zone.

Texas bluegrass hybrids, which are genetic crosses between native Texas bluegrass and Kentucky bluegrasses, may have greater heat and drought resistance than other cool-season grasses. Hybrid bluegrasses have similar visual qualities to Kentucky bluegrass, which is a fine-textured, cool-season turfgrass commonly used in lawns and golf courses in the United States. Consequently, new cultivars of hybrid bluegrasses are being investigated as potential water-saving, heat-resistant alternatives to current cool-season turfgrasses. However, little information is available about the effects of both high temperature and drought on hybrid bluegrasses.

**MATERIALS AND METHODS:**

Turfgrasses were exposed for 48 days to supra-optimal (high temperature; 35/25$^{o}$C, 14-h day/10-h night) and optimal (control; 22/15$^{o}$C, 14-h day/10-h night) temperatures under well-watered (100% evapotranspiration [ET] replacement) and deficit (60% ET replacement) irrigation

Turf visual quality was rated on a scale of 1 to 9 (1=poorest quality, 6=minimally acceptable, and 9=highest quality) according to color, texture, density, and uniformity. Quality ratings were recorded every 6 d by the same individual during the entire study. Photosynthesis was measured every 6 d at about 8 h into the daily light cycle, with a LI-6400 portable gas exchange system. Leaf electrolyte leakage (EL) was measured at 0, 3, 15, 27, 39, and 45 days of heat and drought treatments.

Turfgrasses were mowed every 3 d, and all clippings were collected. Clippings were dried in a forced-air oven for 48 h at 70$^{o}$C and then weighed. Cumulative dry matter production for each treatment was determined by summing the dry weights of all clippings during the 48 d study. Daily dry matter production was calculated as the clipping weight at each mowing divided by the number of days since the previous mowing.

Soil surface temperature was measured with soil-encapsulated thermocouples. To evaluate potential cumulative heat effects among treatments during the most stressful periods, heat units (degree-hours) were calculated as the sum of soil surface temperatures during the final 8 h of each daily light cycle. Our data indicated that this was the period of maximum soil surface temperatures, which may have had important physiological impacts on the turfgrasses (e.g., on meristematic activity in the crowns).

At the end of each 48 d replication, aboveground biomass was harvested from each lysimeter and separated into living and dead components. Green leaves were separated from green shoots and the area of the leaves was measured with an area meter (LI-3100, LI-COR, Lincoln, NE). All green and dead tissue was then dried in a forced-air oven for 48 h at 70$^{o}$C and weighed separately. Green LAI was calculated as the ratio of the green leaf area to ground surface, and total aboveground biomass for each treatment was calculated as the sum of the dry weights of all living and dead tissue.

After aboveground biomass was harvested, lysimeters were laid horizontally and cut into three sections (0 to 15, 15 to 35, and 35 to 57.5 cm). The soil was washed from the roots in each section and roots were dried in a forced-air oven for 48 h at 70$^{o}$C and then weighed. Root mass density of each section was calculated as dry root mass divided by the volume of soil inside each respective section of lysimeter.

**RESULTS:**

Heat resistance was greater in the hybrid bluegrass, which was illustrated by its greater visual quality than Kentucky bluegrass and tall fescue under high temperature (Fig. 1). The hybrid bluegrass also exhibited greater photosynthesis, ET, and dry matter production (Table 1), and lower electrolyte leakage and soil-surface temperatures than Kentucky bluegrass and tall fescue under high temperature (data not shown). Cumulative photosynthesis during the study was 16% and 24% greater in the hybrid than in Kentucky bluegrass and tall fescue, respectively, in the high temperature treatment. Green leaf area index (LAI) in the hybrid bluegrass was not affected by high temperature, but LAI was reduced by 29 % in Kentucky bluegrass and 38% in tall fescue. Differences in drought resistance were negligible among species. The combination of high temperature and drought caused rapid declines in visual quality and dry matter production (Table 1), but the hybrid bluegrass generally performed better; cumulative photosynthesis decreased by 50% to 60% among all species compared with the control, but photosynthesis was higher in the hybrid than in tall fescue. Results indicated greater heat resistance, but not drought resistance, in the hybrid bluegrass than in Kentucky bluegrass or in tall fescue.

**Note**: More information on this study is available in Crop Science (in press).

**Figure 1.** Effects on visual quality rated on a scale of 1 to 9 (1=poorest and 9=highest) of: high temperature (A), drought (B), high temperature and drought (C), and control (D) in Kentucky bluegrass (KBG), hybrid bluegrass (HBG), and tall fescue (TF). Symbols along the abscissa of each graph indicate significant differences (P<0.05) between: HBG and KBG (*); HBG and TF (+); and KBG and TF (+); on a given day after treatment initiation (Days of treatment).

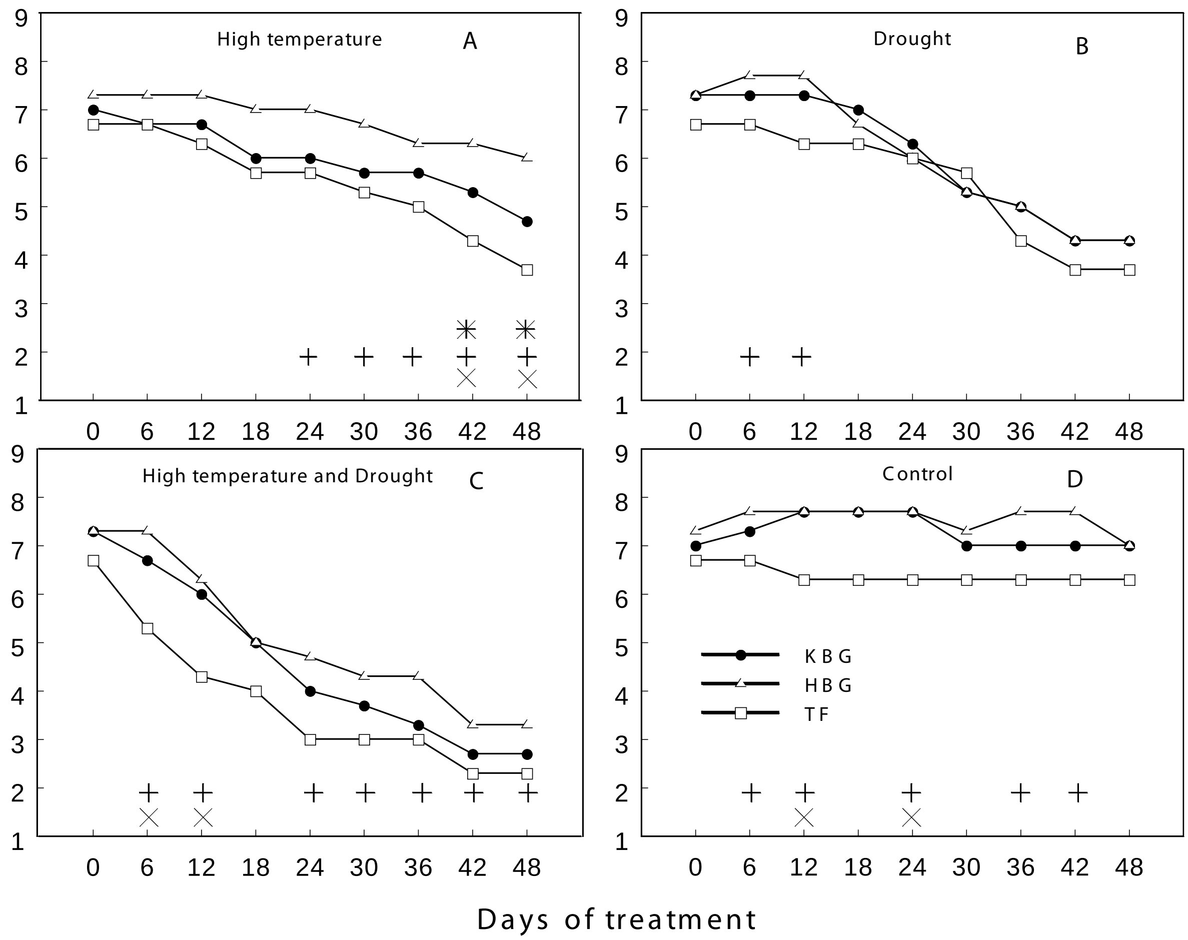


**Table 1.** Effects on dry aboveground biomass of high temperature, drought, high temperature and drought, and control in Kentucky bluegrass (KBG), hybrid bluegrass (HBG), and tall fescue (TF).

| *Treatments* | *Species* | *Aboveground biomass(g m$^{-2}$)* | | | *Percentage of living biomass in total (%)* |
|---|---|---|---|---|---|
| | | Total | Dead | Living | |
| High temperature | KBG | 1411.8 ef[†] | 776.4 de | 635.4 bcdef | 45 abcd |
| | HBG | 1430.6 def | 606.5 de | 824.2 abc | 58 a |
| | TF | 1706.7 bcd | 1092.6 abc | 614.1 cdef | 36 cde |
| Drought | KBG | 1596.4 cde | 869.5 bcde | 726.9 abcd | 46 abcd |
| | HBG | 1338.7 ef | 687.2 de | 651.5 bcde | 49 abc |
| | TF | 1932.6 ab | 1153.6 ab | 779.0 abc | 40 bcde |
| High temperature and drought | KBG | 1266.4 f | 903.1 abcd | 363.3 f | 29 de |
| | HBG | 1179.7 f | 718.0 de | 461.7 def | 39 bcde |
| | TF | 1581.3 cde | 1205.0 a | 376.3 ef | 24 e |
| Control | KBG | 1717.6 bc | 802.2 cde | 915.5 ab | 53 ab |
| | HBG | 1444.8 cdef | 571.4 e | 873.4 abc | 60 a |
| | TF | 2151.1 a | 1207.4 a | 943.6 a | 44 abcd |

[†] Means followed by the same letter within a column were not significantly different ($P<0.05$).

**TITLE**: Mowing Height and Drought Effects on a Texas Bluegrass Hybrid Compared with Kentucky bluegrass

**OBJECTIVE:** Evaluate the effects of mowing height and drought on the visual quality, photosynthesis, canopy spectral reflectance, and soil moisture of a Kentucky bluegrass (‘Apollo’) and a hybrid bluegrass (‘Thermal Blue’). Recovery from drought after re-watering was also investigated.

**AUTHOR**: Kemin Su, Dale Bremer, Steve Keeley, Jack Fry

**SPONSORS**: The Scotts Co., GCSAA, Kansas Turfgrass Foundation (KTF)

**INTRODUCTION:**
A growing challenge facing the turfgrass industry is limited availability of water for irrigation. Local water-use restrictions may be imposed during drought that limit growth and cause severe declines in the visual quality of many cool-season turfgrasses. In golf courses, lower mowing heights in fairways may result in additional stress to turfgrass during drought because lower mowing typically reduces root growth and development. Texas bluegrass hybrids, which are genetic crosses between native Texas bluegrass and Kentucky bluegrasses, may have greater heat and drought resistance than other cool-season grasses. Hybrid bluegrasses have similar visual qualities to Kentucky bluegrass, which is a fine-textured, cool-season turfgrass commonly used in lawns and golf courses in the United States. Consequently, new cultivars of hybrid bluegrasses are being investigated as potential water-saving, heat-resistant alternatives to current cool-season turfgrasses. Research is needed to identify species or cultivars of cool-season turfgrasses that may perform better under drought stress, including maintenance at lower mowing heights.

**MATERIALS AND METHODS:**
This study was conducted from 3 August to 8 October, 2004, and from 27 June to 15 September, 2005, under an automated rainout shelter (180 $m^2$) at the Rocky Ford Turfgrass Research Center near Manhattan, KS. Thirty two plots (1.36 m x 1.76 m) of a Kentucky bluegrass and a hybrid bluegrass were arranged in a randomized complete block design with four replications; plots were bordered by metal edging (10 cm depth) to prevent lateral soil water movement between adjacent plots. Three treatments were applied to the plots: 1) a low mowing height (3.81 cm); 2) reduced irrigation (replacement of 60% of the water lost from plant and soil surfaces via evapotranspiration [ET]) at higher mowing height (7.62 cm); and 3) combination of low mowing height (3.81 cm) and reduced irrigation (60% ET replacement). A control was also included that was well watered (100% ET replacement) and mowed at the greater height (7.62 cm). Plots were mowed twice a week with a walk-behind rotary mower. Water was applied twice weekly through a fan spray nozzle attached to a hose; a meter was attached to ensure proper application rate. To determine irrigation requirements, evapotranspiration (ET) was calculated by using the Penman-Monteith equation (FAO, 1998) and climatological data obtained at a weather station located at Rocky Ford Turfgrass Research Center.

Turf visual quality was rated on a scale of 1 to 9 (1=poorest quality, 6=minimally acceptable, and 9=highest quality) according to color, texture, density, and uniformity. Quality ratings were recorded weekly by the same individual during the 2-year study. Photosynthesis was measured biweekly on clear days between 1000 and 1400 CST with a LI-6400 portable gas exchange system using a custom surface chamber. Permanent polyvinyl chloride collars (10-cm diam.) were placed randomly at one location in each plot and were driven approximately 5 cm into the soil. Canopy spectral reflectance was measured weekly on clear days at approximately 1200 CST with a Cropscan multispectral radiometer (MSR) (model MSR16, Cropscan Inc., Rochester, MN). Canopy reflectance was measured in eight wavelengths including 507, 559, 613, 661, 706, 760, 813, and 935 nm. The normalized difference vegetation index (NDVI) was computed as ([R935-R661] / [R935 +R661]), where Rx indicates reflectance at wavelength x. The ratio of near infrared to red (NIR / R) was computed as R935 / R661. In all plots, the volumetric soil water content ($\theta_v$) in the 0 to 50 cm profile was measured weekly using time domain reflectometry and in drought plots at 5 cm using dual-probe heat-pulse sensors.

**RESULTS:**

*Low mowing height*

In general, our data indicated that this hybrid bluegrass (Thermal Blue) generally performed poorer than this Kentucky bluegrass (Apollo) in well-watered plots at the low mowing height. Visual quality, which may be the most important parameter to the turfgrass manager, was not affected in Kentucky bluegrass by low mowing but was reduced in the hybrid bluegrass (Figs. 1A and 1B). The deleterious effects of low mowing on photosynthesis and canopy reflectance, which indicate reductions in the vigor or size of the turfgrass canopy, were generally greater in the hybrid than in Kentucky bluegrass (data not shown).

*Drought*

Drought significantly reduced the visual quality of both species in 2005, but the effects of drought on visual quality were less severe in 2004 (Figs. 1C and 1D). In 2005, drought reduced mean visual quality by 28% in Kentucky bluegrass and by 25% in hybrid bluegrass compared with the control. In 2004, visual quality decreased in drought plots as the study progressed although significantly only in the hybrid bluegrass. The greater decline in visual quality with drought in 2005 than in 2004 was likely caused by corresponding higher temperatures during the study. High air temperature may compound drought stresses by adding heat stress; low soil moisture in drought plots reduces ET and evaporative cooling in canopies of drought, compared with well-watered plots. Visual quality between species was similar, although visual quality in the hybrid bluegrass tended to be lower than in Kentucky bluegrass in drought plots in 2004.

Soil moisture was consistently lower in the hybrid bluegrass (Fig. 2A), which indicates the hybrid bluegrass may have been more efficient at extracting soil moisture during drought, including at near the surface (5 cm; data not shown) (i.e., where root density is greater). In general, however, values of photosynthesis and canopy reflectance were lower in the hybrid than in Kentucky bluegrass (data not shown), which indicates that any advantage in soil moisture extraction capability by this hybrid during drought are not reflected in greater performance compared with Kentucky bluegrass.

*Effects of low mowing height and drought combined*

Visual quality was strongly reduced in Kentucky bluegrass and in the hybrid bluegrass by the combination of low mowing and drought, and the effects during both years were similar to or more pronounced than in separate treatments of low mowing or drought (Figs. 1A to 1F). In 2005, visual quality was significantly lower in the hybrid bluegrass than in Kentucky bluegrass for about the first half of the study period (Fig. 1F). Visual quality in 2005 averaged 14% lower in the hybrid bluegrass than in the Kentucky bluegrass.

The combination of low mowing and drought significantly reduced photosynthesis in both species compared with the control (data not shown). Between species, however, photosynthesis was consistently lower in the hybrid bluegrass than in Kentucky bluegrass in low mowed and drought plots in 2005. Soil moisture in the 0-50 cm profile steadily decreased in combination low mowing and drought plots in 2005, but soil moisture decreased faster in Kentucky bluegrass than in the hybrid (Fig. 2B). Soil moisture was significantly lower in Kentucky bluegrass than in the hybrid during most of the study, which was similar to the trend in soil moisture at 5 cm (not shown). Consistently lower soil moisture in Kentucky bluegrass indicates that Kentucky bluegrass extracted more water from the soil than the hybrid bluegrass, which in combination with generally higher visual quality suggests (Figs. 1E and 1F) that this Kentucky bluegrass (Apollo) is better suited for conditions of low mowing height and drought than this hybrid bluegrass (Thermal Blue).

*Recovery after drought and summer stress*

The hybrid bluegrass recovered more quickly in drought plots after termination of the drought treatment and re-watering on 70 DOT (Fig. 1D). Visual quality, which was measured weekly for four weeks after re-watering, increased more rapidly in the hybrid bluegrass than in Kentucky bluegrass and was significantly higher in the hybrid than in Kentucky bluegrass during the last two weeks of the recovery period. The recoveries of the hybrid bluegrass and Kentucky bluegrass were similar, however, in the combination low mowing and drought treatment (Fig. 1F).

**CONCLUSIONS:**

In summary, these data indicate that this Kentucky bluegrass (Apollo) generally performed better than this hybrid bluegrass (Thermal Blue) at the lower mowing height, during drought, and in the combination of lower mowing height and drought. Therefore, no advantage in drought resistance was observed in this hybrid compared with Kentucky bluegrass in this study, with the exception of faster recovery time after drought.

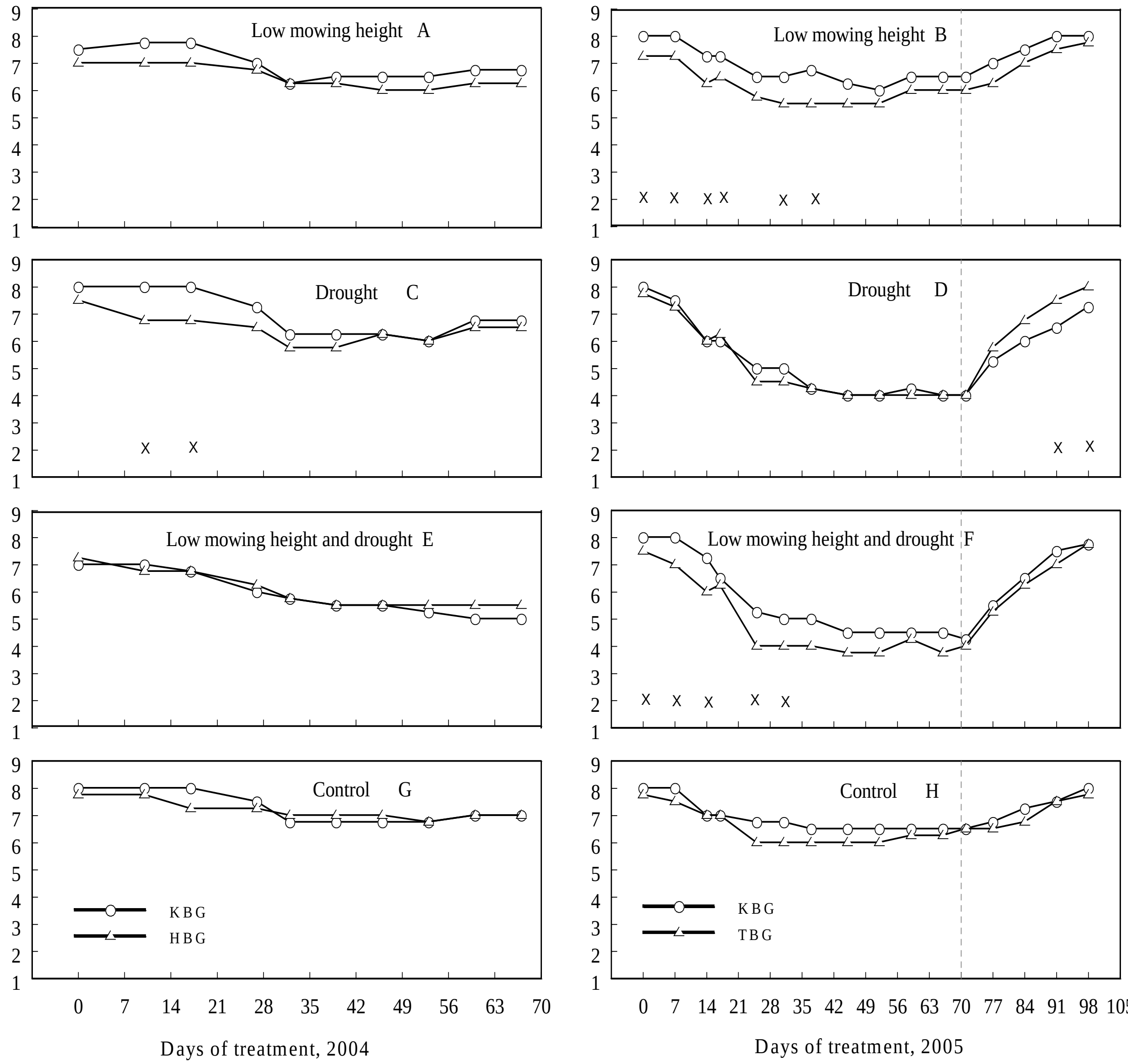



**Figure 1**. Visual quality of a Kentucky bluegrass (KBG) and a Texas bluegrass hybrid (TBG) rated on a scale of 1 to 9 (1=poorest and 9=highest) in treatments: Low mowing height (A, B), drought (C, D), combination low mowing height and drought (E, F), and control (G, H) in 2004 and 2005. Symbols (+) along the abscissa of each graph indicate significant difference between HBG and KBG (P<0.05) on a given day after treatment initiation (Days of treatment).

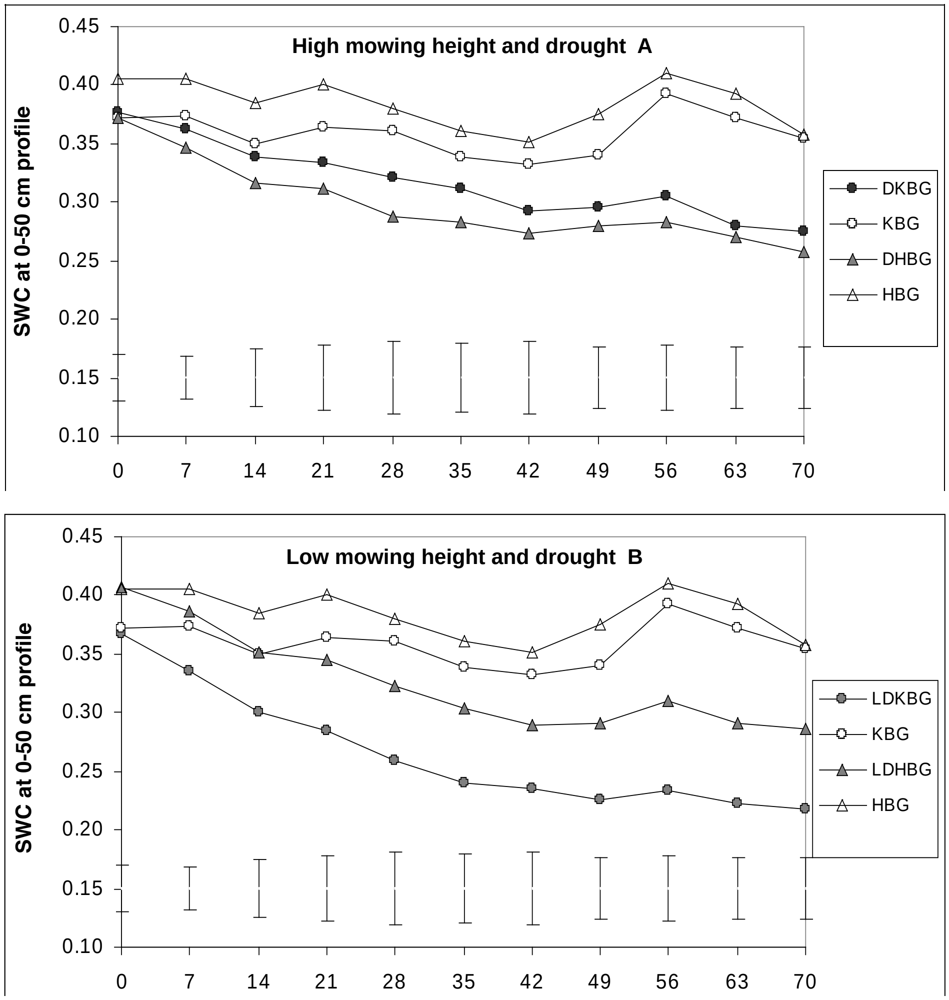



**Figure 2**. The effects drought (A) and the combination of low mowing and drought (B) on volumetric soil water content (SWC) at 0-50 cm in Kentucky bluegrass (KBG) and in a hybrid bluegrass (HBG). Closed symbols represent SWC in each respective treatment (D=drought; LD=low mowing and drought combination) and open symbols represent the control (higher mowing height, well watered). Vertical bars indicate LSD values (P<0.05) among treatments on a given day after treatment initiation (Days of treatment).

**TITLE:** Freezing Tolerance of New Zoysiagrass Progeny

**OBJECTIVE:** Evaluate field performance of 381 zoysiagrass progeny and identify the potential cultivars that can be used in the transition zone with similar cold tolerance as 'Meyer'.

**PERSONNEL:** Qi Zhang, Jack Fry, Milt Engelke, Dennis Genovesi, and Dale Bremer

**SPONSORS:** Heart of America Golf Course Superintendents Association, the Kansas Golf Course Superintendents Association, and the Kansas Turfgrass Foundation

**INTRODUCTION:**
'Meyer' zoysiagrass (*Zoysia japonica* Steud.) has been the predominant cultivar used in the transition zone since its release in 1952 because of its excellent freezing tolerance and good turf quality. However, it is relatively slow to establish and coarser in texture than cultivars of *Z. matrella.* Researchers at Texas A & M released several zoysiagrass cultivars including 'Crowne', 'Cavalier', 'Diamond', and 'Palisades' that exhibited higher turf quality than 'Meyer' in southern evaluations, but lacked freezing tolerance necessary in the transition zone. New progeny have been generated from crosses between freezing-tolerant cultivars and high quality lines that may have desirable characteristics lacking in 'Meyer', but with a comparable level of freezing tolerance. Eventually, this may lead to the selection of one or more high quality cultivars that are well adapted to the transition zone environment.

**MATERIALS AND METHODS:**
Three hundred seventy-eight genetically different zoysiagrass progeny resulting from crosses at Texas A & M were space-planted (3-ft centers) as 4- x 4-inch plugs at Manhattan, KS, on 16 August, 2004, for field evaluation (Table 1). In most cases, 18 offspring from a cross represented a "family" and were arranged in groups of six in a randomized complete block design with three replicates. Meyer was replicated three times for comparison. The plugs were watered twice and mowed at 4 inches weekly during the growing season in 2005 and 2006. Urea was applied at 1 lbs/1,000 ft$^2$ on 20 July, 2005, and 28 July, 2006.

Zoysiagrass progeny were evaluated visually for fall color, leaf texture, winter kill, and rate of growth. Leaf color was used as an indicator for the rate at which each selection enters autumn dormancy and was evaluated in October and November, from 2004 to 2006 using a 0 to 9 scale, where 0=straw-brown and 9=dark green. On 15 May, 2005, winter kill (damage in 3- x 3-ft area) was evaluated visually using a 0 to 9 scale, where 0=dead and 9=no winter injury. Seventy-eight progeny with no severe winter damage and high quality were further evaluated in 2005 and 2006 (Tables 2 and 3). Winter kill was recorded again on 10 May, 2006, and center damage (damage to the initial 4- x 4-inch plug) was also evaluated with a 0 to 9 scale, where 0=90–100% damage in the initial plug and 9=less than 10% damage. Lateral spread was determined by measuring the diameter of each selection on 18 May, 2005. Percentage surface coverage in a 30- x 30-inch square of each selected progeny was measured using a First Growth digital camera monthly from June to October 2005. Leaf texture of each selection was evaluated monthly on a 0 to 9 scale, where 0=coarsest texture and 9=finest texture. Data were analyzed with PROC GLIMMIX procedure. In some cases, means in tables represent an average of several progeny derived from a particular cross. As such, we are also looking more closely at performance of individual progeny within some of these crosses. Air and soil surface temperatures were collected using a weather station located within 30 feet of the study area and dual probe sensors placed in contact with randomly selected crowns and connected to a CR-10 data collection unit.

**RESULTS:**

*Soil temperature.* Soil temperature was recorded from 3 December, 2004, to 30 April, 2005 (Figure 1); 18 October, 2005, to 22 May, 2006 (Figure 2); and 25 September, 2006, to 23 January, 2007. The lowest temperatures at the soil surface in each year were 7º F on day 359 (24 December) 2004; 25º F on day 341 (7 December), 2005; 28º F on day 17, 2007. Lower soil temperature in the winter, 2004, compared to the winter, 2005 and 2006, resulted from the colder weather in 2004 and less soil surface coverage by turf. As the grasses spread out, the difference between soil surface temperature and temperature at a 1 inch depth was gradually reduced.

*Field performance.* In fall 2004, Meyer, Meyer x BMZ230 (TAES #5322), Meyer x Anderson #2 (TAES #5323), and Companion x Diamond (TAES # 5332) had lower color ratings in November, indicating an earlier entry into dormancy (Table 2). Leaf texture ratings were variable, but some selections clearly had a finer texture than Meyer. Texture is also being evaluated in the greenhouse where duplicate samples of all progeny are being kept. A lower mowing height, which will be employed when a smaller group of progeny is selected, will better help separate the progeny based upon leaf texture.

Progeny within 5 crosses, Cavalier x Anderson #1 (TAES #5311), Cavalier x Anderson #2 (TAES #5312), Meyer x BMZ230 (TAES #5322), Meyer x Anderson #2 (TAES #5323), and Emerald x Zenith (TAES #5334) had winter damage ratings similar to Meyer on May 15, 2005.

Meyer exhibited a growth rate (diameter) that was as good as any of the averages of the families evaluated on 15 May, 2005. By October, only 2 progeny from TAES #5330 (Crowne x Companion) had greater coverage than Meyer.

Seventy-eight progeny exhibiting good freezing tolerance and quality characteristics were identified for further evaluation in the field on 15 May, 2005 (Table 2). Half of the selected progeny were from crosses of Cavalier x Anderson #1 (TAES #5311) and Meyer x Anderson #2 (TAES #5323) (Table 2). No progeny from crosses of Meyer x Cavalier (TAES #5282), Meyer x BMZ230 (TAES #5322), Meyer x Diamond (TAES #5327), or 8501x Zenith (TAES #5343) were selected due to severe winter damage or coarse leaf texture. Lower color rating in November 2005 compared to 2004 was due to the faster air temperature drop in fall 2005.

On 10 May, 2006, Meyer x Anderson #2 (TAES #5323), Meyer x 8501 (TAES #5325), and Companion x Diamond (TAES #5332) had the same level of winter kill and center damage as Meyer, although none of the crosses had superior color and texture compared to Meyer. On 30 August, 2006, all selected progeny had 100% coverage, and Cavalier x Meyer (TAES #5283) and 8501 x Meyer (TAES #5324) had the highest rating in texture. Crowne x Companion (TAES #5330) and 8501 x Meyer (TAES #5324) had the best color on 13 October, 2006. All progeny were dormant by 21 November, 2006.

During 2006, we selected 34 zoysiagrass progeny from the study described above, and also from an additional 241 progeny that were planted in 2005 (the data from these 241 are not included above). The 34 progeny, along with 'Meyer' and DALZ 0102, another zoysia of interest, are listed in Table 4. These progeny were propagated in the greenhouse in 2006 and were planted in the field in Manhattan and Olathe in June 2007. Plots will be 5 x 5 ft., with three replicates of each. Grasses will be maintained under golf course fairway/tee conditions.

**Table 1.** Zoysiagrass progeny generated from crosses between cold-tolerant and high quality parental lines.

| TAES (#) | Pedigree |
|---|---|
| 5282 | Meyer x Cavalier |
| 5283 | Cavalier x Meyer |
| 5311 | Cavalier x Anderson #1 |
| 5312 | Cavalier x Anderson #2 |
| 5313 | Zorro x Meyer |
| 5320 | Palisades x Meyer |
| 5321 | Emerald x Meyer |
| 5322 | Meyer x BMZ230 |
| 5323 | Meyer x Anderson #2 |
| 5324 | 8501 x Meyer |
| 5325 | Meyer x 8508 |
| 5327 | Meyer x Diamond |
| 5330 | Crowne x Companion |
| 5331 | Palisades x Companion |
| 5332 | Companion x Diamond |
| 5334 | Emerald x Zenith |
| 5343 | 8501 x Zenith |

**Table 2.** Field performance of zoysiagrass progeny from autumn 2004 to 2005 at the Rocky Ford Turfgrass Research Center, Manhattan, KS.

| TAES # | # of progeny to start | 2004 16 Oct. Color‡ | 2004 16 Oct. Texture‡ | 2004 11 Nov. Color‡ | 2005 15 May Winter kill‡ | # of progeny after selection† | 2005† 18 May Color‡ | 2005† 18 May Diameter (inch) | 2005† 19 Oct. Color‡ | 2005† 19 Oct. Coverage (%) | 2005† 12 Nov. Color |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5282 | 8 | 5.50 g* | 7.63 abcd | 5.15 bcd | 2.56 ef | 0 | ------------ | -------------- | --------- | -------------- | ------------ |
| 5283 | 10 | 5.10 gh | 7.30 de | 4.88 cd | 2.26 ef | 2 | 6.92 abc | 7.56 bc | 7.07 a | 39.0 ab | 1.84 abc |
| 5311 | 36 | 6.33 de | 7.19 e | 5.28 bcd | 7.39 ab | 22 | 7.57 a | 9.13 bc | 6.23 a | 28.3 bc | 2.92 a |
| 5312 | 36 | 6.28 e | 7.44 cd | 5.22 ab | 6.31 b | 10 | 7.59 a | 8.23 bc | 6.23 a | 34.2 b | 2.76 a |
| 5313 | 36 | 6.64 abc | 7.92 a | 5.81 ab | 1.89 f | 2 | 7.04 abc | 7.83 bc | 7.00 a | 31.0 bc | 3.58 a |
| 5320 | 18 | 6.41 bcde | 6.77 ef | 5.64 abc | 2.28 ef | 1 | 7.12 abc | 8.11 bc | 5.86 a | 25.0 bc | 1.03 bc |
| 5321 | 18 | 6.61 abcd | 7.72 abc | 5.44 abc | 4.11 cde | 4 | 7.25 ab | 6.65 c | 5.82 a | 27.0 bc | 3.10 a |
| 5322 | 18 | 6.18 ef | 6.82 ef | 3.83 ef | 4.89 bc | 0 | ------------ | -------------- | --------- | -------------- | ------------ |
| 5323 | 36 | 6.00 f | 6.58 fg | 3.11 f | 8.06 a | 19 | 7.03 abc | 11.30 ab | 6.23 a | 27.0 bc | 1.20 bc |
| 5324 | 36 | 6.72 ab | 7.92 a | 5.86 ab | 3.33 de | 6 | 7.13 abc | 5.87 c | 6.50 a | 22.8 c | 3.42 a |
| 5325 | 18 | 6.67 abc | 7.50 bcd | 6.17 a | 1.61 f | 1 | 7.12 abc | 9.29 abc | 6.86 a | 17.0 c | 4.04 a |

Table 2. (cont.)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5327 | 18 | 6.88 a | 7.75 ab | 5.54 abc | 1.06 f | 0 | ------------ | -------------- | --------- | -------------- | ------------ |
| 5330 | 18 | 6.33 cde | 6.39 g | 5.67 abc | 3.67 cde | 2 | 6.96 abc | 16.18 a | 7.14 a | 49.0 a | 3.63 a |
| 5331 | 18 | 6.39 cde | 6.06 h | 5.72 abc | 6.56 b | 4 | 6.68 bc | 9.29 bc | 7.03 a | 33.8 bc | 2.91 a |
| 5332 | 18 | 6.47 bcde | 6.77 ef | 4.54 de | 3.72 cde | 1 | 7.92 a | 14.06 ab | 6.00 a | 42.0 ab | 3.84 a |
| 5334 | 18 | 6.22 ef | 7.50 bcd | 5.28 bcd | 4.72 bcd | 4 | 6.49 c | 11.26 ab | 6.53 a | 28.0 bc | 2.28 ab |
| 5343 | 18 | 6.39cde | 7.72 ab | 5.67 abc | 0.50 f | 0 | ------------ | -------------- | --------- | -------------- | ------------ |
| Meyer | 3 | 4.67 h | 6.67 efg | 4.00 def | 7.67 ab | 3 | 7.33 ab | 12.28 ab | 6.33 a | 32.7 bc | 1.00 c |

*Means of each hybrid line before and after selection. Numbers in a column followed by the same letter are not significantly different according to Tukey's LSD ($P \leq 0.05$).

†Zoysiagrasses with promising quality characteristics and freezing tolerance were selected on 15 May, 2005. Selection was based upon performance of the group and individuals. Data were collected and analyzed only from selected individuals within each hybrid line after 15 May, 2005.

‡Color, texture, and winter kill were rated with a 0 to 9 scale, where 0 = straw-brown color, coarsest texture, or winter-killed turf and 9 = dark green color, finest texture, and no winter damage. Color and texture were rated monthly and winter kill was rated on 15 May, 2005.

**Table 3.** Field performance of zoysiagrass progeny in 2006 at the Rocky Ford Turfgrass Research Center, Manhattan, KS.

| TAES # | # of progeny after selection[†] | 10 May | | | | 30 August | | 13 October | |
|---|---|---|---|---|---|---|---|---|---|
| | | Color | Texture | Winter Kill | Center damage | Color | Texture | Color | Texture |
| 5282 | 0 | --------------- | --------------- | --------------- | ---------------- | --------------- | -------------- | ------------ | ------------ |
| 5283 | 2 | 3.91 a[*] | 6.50 a | 4.57 d | 3.00 cd | 7.00 a | 7.50 a | 6.00 b | 7.00 ab |
| 5311 | 22 | 5.12 a | 5.55 bc | 7.34 b | 6.28 b | 6.73 a | 7.05 ab | 6.09 b | 7.09ab |
| 5312 | 10 | 4.84 a | 5.20 c | 6.48 bc | 5.59 bc | 6.90 a | 7.00 ab | 5.80 b | 6.90b |
| 5313 | 2 | 5.13 a | 6.50 a | 5.63 cd | 1.80 d | 7.00 a | 7.00 ab | 7.00 ab | 7.00 ab |
| 5320 | 1 | 5.18 a | 5.00 c | 2.87 d | 1.01 d | 7.00 a | 6.00 bc | 7.00 ab | 6.00 c |
| 5321 | 4 | 5.36 a | 6.50 a | 6.01 bc | 4.44 bcd | 7.00 a | 7.00 ab | 6.50 ab | 6.99 ab |
| 5322 | 0 | --------------- | --------------- | ---------------- | ---------------- | --------------- | -------------- | ------------ | ------------ |
| 5323 | 19 | 4.91 a | 5.05 c | 8.53 a | 8.34 a | 7.00 a | 6.68 b | 5.63 b | 6.32 c |
| 5324 | 6 | 5.37 a | 6.67 a | 7.04 bc | 5.54 bc | 7.00 a | 7.50 a | 7.17 a | 7.34 a |
| 5325 | 1 | 5.18 a | 6.00 abc | 7.87 ab | 8.01 ab | 7.00 a | 7.00 ab | 7.00 ab | 7.00 ab |
| 5327 | 0 | ---------------- | ---------------- | ---------------- | ---------------- | --------------- | -------------- | -------------- | -------------- |
| 5330 | 2 | 4.59 a | 5.00 c | 6.38 bc | 6.08 bc | 7.00 a | 6.00 c | 7.50 a | 5.99 c |
| 5331 | 4 | 4.57 a | 5.00 c | 5.66 cd | 5.45 bc | 6.50 a | 6.00 c | 6.75 ab | 6.00 c |
| 5332 | 1 | 3.73 a | 5.00 c | 7.75 ab | 7.41 ab | 6.00 a | 7.00 ab | 7.00 ab | 6.01 c |
| 5334 | 4 | 5.02 a | 6.25 ab | 6.35 bc | 5.40 bc | 7.00 a | 6.75 b | 7.00 ab | 7.00 ab |
| 5343 | 0 | ---------------- | ---------------- | ---------------- | ---------------- | --------------- | -------------- | -------------- | -------------- |
| Meyer | 3 | 5.67 a | 5.33 bc | 9.00 a | 9.00 a | 7.00 a | 7.00 ab | 6.00 b | 6.67 b |

[*]Means of each hybrid line before and after selection. Numbers in a column followed by the same letter are not significantly different according to Tukey's LSD ($P \leq 0.05$).

[†]Zoysiagrasses with promising quality characteristics and freezing tolerance were selected on 15 May, 2005. Selection was based upon performance of the group and individuals. Data were collected and analyzed only from selected individuals within each hybrid line after 15 May, 2005.

[‡]Color, texture, winter kill, and center damage were rated with a 0 to 9 scale, where 0 = straw-brown color, coarsest texture, or winter damaged turf and 9 = dark green color, finest texture, and no winter damage. Color and texture were rated monthly and winter kill and head kill was rated on 10 May, 2006.

**Table 4.** Thirty-four zoysia progeny and two “controls” that have exhibited good cold-tolerance and have been selected for further evaluation in Manhattan and Olathe. The first parent in the cross is the *Z. matrella* type, the second is the *Z. japonica* type.

| TAES# | Cross | Number |
|---|---|---|
| 5311 and 5312 | Cavalier x Anderson | 10 |
| 5313 | Zorro x Meyer | 2 |
| 5321 | Emerald x Meyer | 8 |
| 5324 | 8501 x Meyer | 8 |
| 5327 | Diamond x Meyer | 1 |
| 5334 | Emerald x Zenith | 4 |
| 5282 and 5283 | Cavalier x Meyer | 1 |
| | DALZ 0102 | 1 |
| | Meyer | 1 |

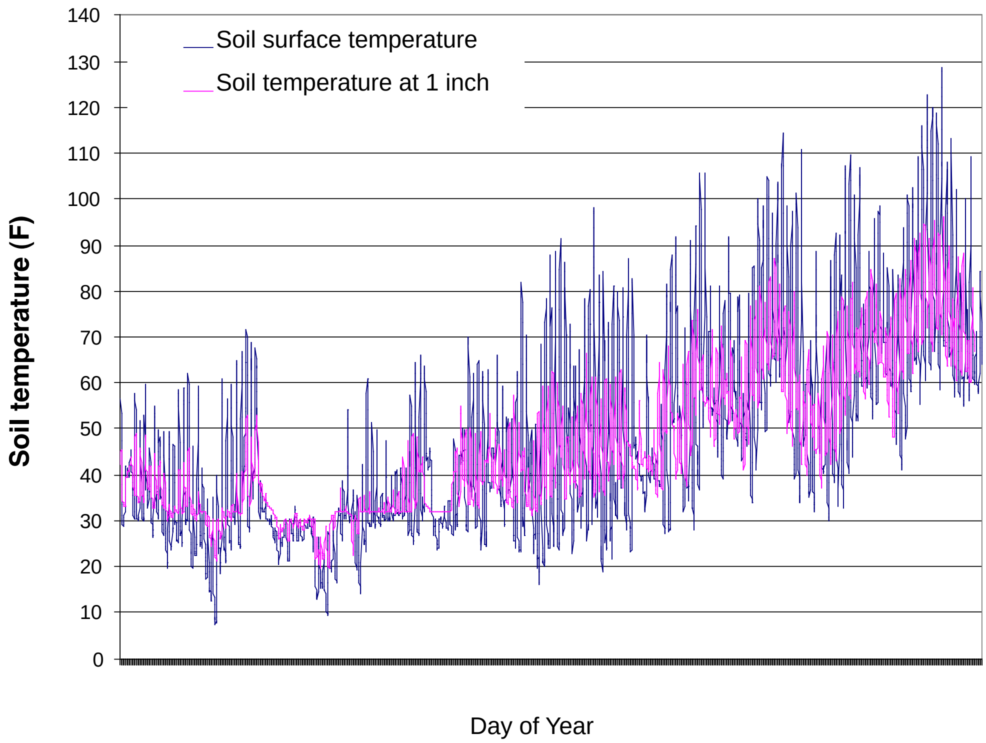



**Figure 1**. Soil temperature in winter 2004 and spring 2005.

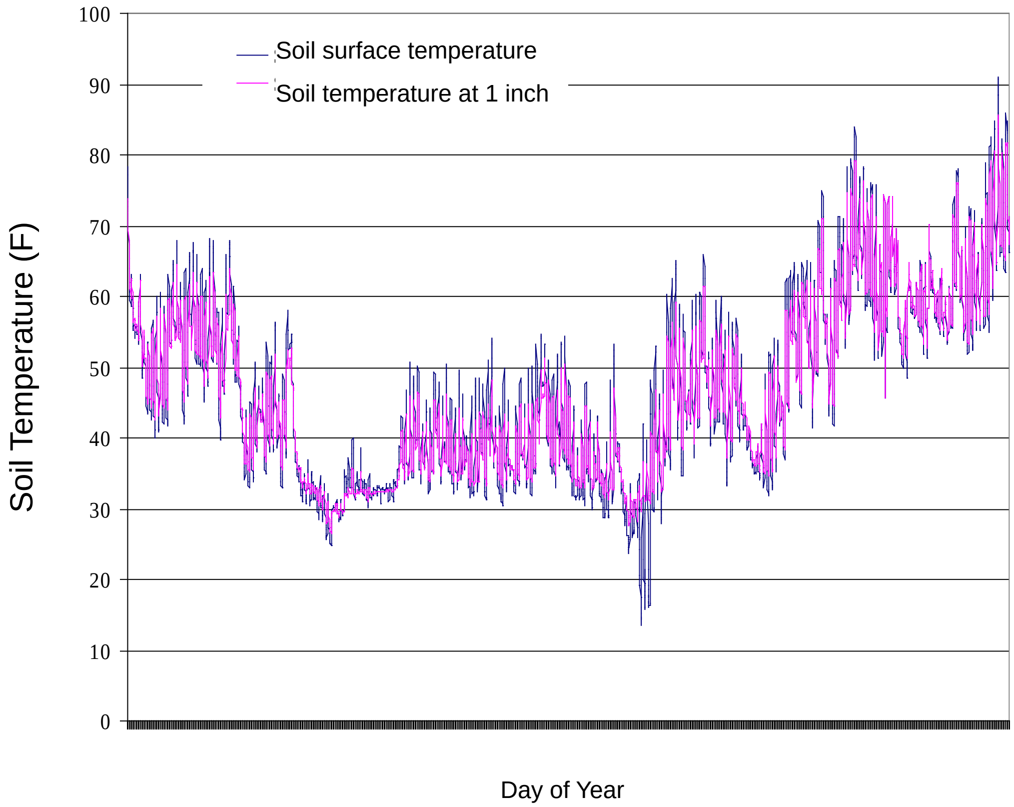



**Figure 2.** Soil temperature in winter 2005 and spring 2006.

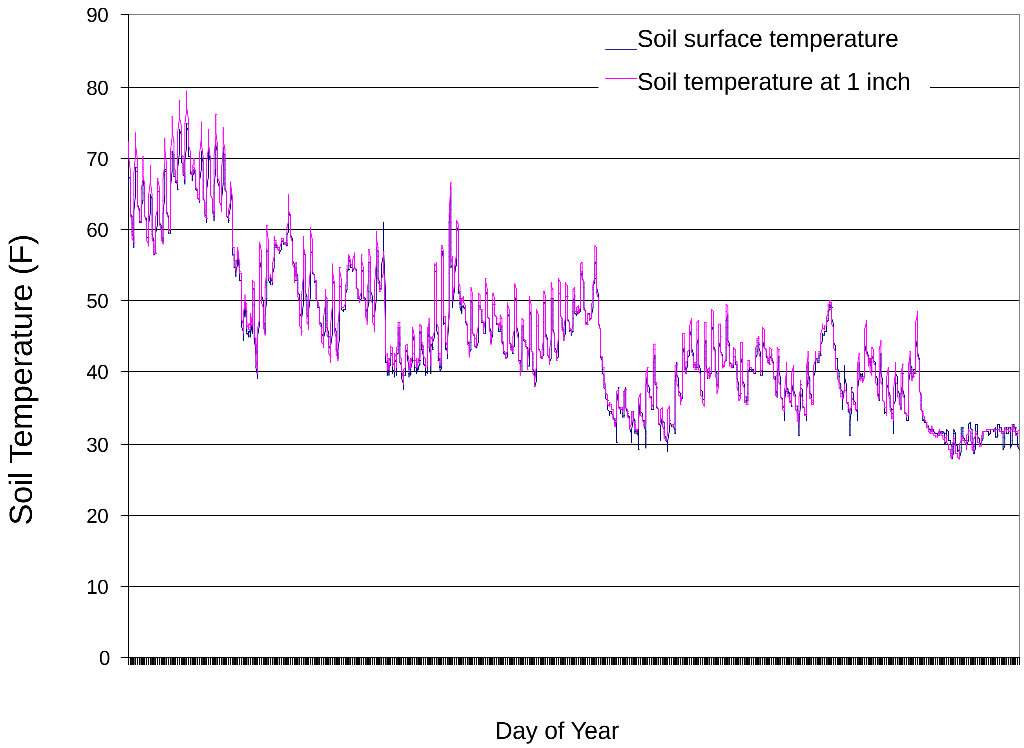



**Figure 3.** Soil temperature in winter 2006 and spring 2007.

**TITLE:** Preliminary Evaluation of Freezing Tolerance of Meyer and DALZ 0102 Zoysiagrass

**OBJECTIVE:** Compare freezing tolerance of 'Meyer' and DALZ 0102 zoysiagrass

**PERSONNEL:** Qi Zhang and Jack Fry

**SPONSORS:** Kansas Turfgrass Foundation

## INTRODUCTION:

Meyer has long been the standard zoysiagrass cultivar for use in Kansas and throughout the transition zone. DALZ 0102 (*Z. japonica*) is a new experimental zoysia that has demonstrated good hardiness and fast lateral spread. To minimize the unpredictable and uncontrollable environmental conditions in the field, this study was done in a controlled freezing chamber to determine relative freezing tolerance of DALZ 0102 compared to Meyer.

## MATERIALS AND METHODS:

One hundred and ninety-two rhizomes from Meyer and from DALZ 0102 were sampled from Rocky Ford Turfgrass Research Center on 24 February and 1 March, 2006. Sixteen rhizomes of each (four replications and four subsamples) were exposed to temperatures ranging from control (no freezing) to -23º C. Sixteen rhizomes of each (four replications and four subsamples) were exposed to temperatures ranging from control (no freezing) to -19º C. Rhizomes measured about 2~3 inches long and each had 4 nodes. Each group of 10 rhizomes was wrapped in a wet paper towel and then in aluminum foil. Rhizome bundles were put in a circulating ethylene glycol bath set at -3º C for 3 hours, and ice pieces were added to ensure ice formation. The temperature was decreased at 2º C/hour; one group of rhizomes was taken out at each interval. Rhizomes were slowly thawed in a growth chamber at 4º C overnight, planted in small pots containing a standard potting mixture, and placed in the greenhouse. The experiment was repeated on 7 December, 2006, and 15 February, 2007, with the number of subsamples increased to 10 and freezing temperatures tested from control to -19º C.

Data were collected on the percentage of living rhizomes and nodes, number of shoots, and leaf and root dry weights 8 weeks after exposure to the freezing temperatures. The minimum freezing temperature at which some recovery occurred was also recorded. Data were analyzed with PROC GLM procedure, and means were separated with Fisher's protected LSD test. The experiment was set up as a complete randomized design with four replications.

## RESULTS:

This study was complicated by a relatively low percentage of surviving rhizomes in controls that were not exposed to freezing temperatures. When a rhizome is washed in the field after sampling, it is unknown if it is alive or dead. As such, Meyer and DALZ 0102 had an average rhizome survival that was never above 60%.

The greatest decrease in rhizome survival occurred between -13º and -15º C in both Meyer and DALZ 0102 on the 24 February, 2006, sampling date (Table 1). Meyer exhibited greater rhizome survival at -7º and -9º C, and had more living nodes than DALZ 0102 on this date. Meyer exhibited some rhizome survival to -17º C, whereas no survival occurred beyond -13º C in DALZ 0102. Both cultivars seemed to have lost some hardiness when sampled one week later on 1 March, 2006 (Table 2). No regrowth occurred below -15º C in either cultivar. Meyer was superior to DALZ 0102 for all measured variables except root weight at -7º C; otherwise, cultivars responded similarly.

On 7 December, 2006, DALZ 0102 had more shoots and greater biomass following freezing at temperatures ≥-7º C, reflecting its fast growth and recovery potential (Table 3). Cultivars did not differ in freezing tolerance at lower evaluation temperatures.

On the 15 February, 2007, sampling date, Meyer had 47.5% living rhizomes at -19º C, while DALZ 0102 had 12.5%. The number of shoots in Meyer was nine times as much as in DALZ 0102 at -15º C; leaf and root dry weight were also higher in Meyer than in DALZ 0102. These data are somewhat suspect, for DALZ 0102 was inferior to Meyer even at warmer temperatures evaluated.

Preliminary results indicate that DALZ 0102 indicate that recovery from minor winter injury may be faster than in Meyer. However, Meyer has demonstrated that it is, at the least, slightly hardier than DALZ 0102. Should DALZ 0102 be released, these results, as well as field survival in the winter, need to be considered in recommending its northernmost boundary of use in the United States.

**Table 1.** Evaluation of Meyer and DALZ 0102 zoysiagrass regrowth 8 weeks after exposure to freezing temperatures on 24 February, 2006.

| Treatment | Living Rhizomes (%) | | Living Nodes (%) | | Shoots (no./pot) | | Leaf Weight (mg/pot) | | Root Weight (mg/pot) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Meyer | DALZ | Meyer | DALZ | Meyer | DALZ | Meyer | DALZ | Meyer | DALZ |
| Control | 62.5 a* | 43.8 a | 28.0 a | 26.3 a | 5.0 a | 6.8 a | 19.6 a | 34.1 a | 11.6 a | 19.8 a |
| -3 C | 68.8 a | 37.5 a | 26.5 a | 22.8 a | 5.0 a | 7.5 a | 25.0 a | 46.2 a | 10.0 a | 25.1 a |
| -5 C | 87.5 a | 37.5 a | 35.8 a | 16.5 a | 8.0 a | 6.3 a | 50.7 a | 35.7 a | 20.1 a | 16.3 a |
| -7 C | 81.3 a | 43.8 b | 33.5 a | 27.5 a | 8.5 a | 6.0 a | 59.9 a | 30.0 a | 25.6 a | 15.3 a |
| -9 C | 56.3 a | 18.8 b | 35.0 a | 14.3 b | 6.8 a | 2.8 a | 42.2 a | 17.8 a | 33.4 a | 22.5 a |
| -11 C | 31.3 a | 31.3 a | 11.8 a | 10.3 a | 3.0 a | 1.8 a | 16.2 a | 9.2 a | 9.1 a | 4.7 a |
| -13 C | 50.0 a | 31.3 a | 9.8 a | 10.8 a | 4.5 a | 3.0 a | 18.0 a | 16.2 a | 10.8 a | 5.1 a |
| -15 C | 6.3 a | 0.0 a | 1.8 a | 0.0 a | 0.3 a | 0.0 a | 0.5 a | 0.0 a | 0.2 a | 0.0 a |
| -17 C | 12.5 a | 0.0 a | 3.8 a | 0.0 a | 0.5 a | 0.0 a | 2.1 a | 0.0 a | 0.0 a | 0.0 a |
| -19 C | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a |
| -21 C | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a |
| -23 C | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a |

*Means followed by the same letter treated within the same temperature are not significantly different at $P \leq 0.05$.

**Table 2.** Evaluation of Meyer and DALZ 0102 zoysiagrass regrowth 8 weeks after exposure to freezing temperatures on 1 March, 2006.

| Treatment | Living Rhizomes (%) | | Living Nodes (%) | | Shoots (no./pot) | | Leaf Weight (mg/pot) | | Root Weight (mg/pot) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Meyer | DALZ | Meyer | DALZ | Meyer | DALZ | Meyer | DALZ | Meyer | DALZ |
| Control | 60.0 a* | 37.5 a | 41.5 a | 24.5 a | 8.5 a | 8.3 a | 49.0 a | 42.7 a | 25.2 a | 19.8 a |
| -3 C | 68.8 a | 81.3 a | 35.0 a | 47.3 a | 9.0 a | 8.8 a | 47.1 a | 40.2 a | 25.8 a | 19.5 a |
| -5 C | 68.8 a | 50.0 a | 45.3 a | 34.8 a | 8.8 a | 5.8 a | 29.4 a | 21.5 a | 19.1 a | 9.8 a |
| -7 C | 37.5 a | 12.5 b | 30.0 a | 5.0 b | 7.0 a | 0.8 b | 26.7 a | 3.0 b | 12.2 a | 1.1 a |
| -9 C | 81.3 a | 41.7 a | 38.5 a | 19.3 a | 8.0 a | 4.7 a | 40.5 a | 19.0 a | 20.4 a | 13.3 a |
| -11 C | 33.3 a | 8.3 a | 18.3 a | 2.7 a | 4.0 a | 0.3 a | 11.0 a | 0.7 a | 4.6 a | 0.4 a |
| -13 C | 50.0 a | 8.3 b | 23.3 a | 4.3 a | 4.7 a | 0.7 a | 15.8 a | 0.7 a | 4.9 a | 0.4 a |
| -15 C | 8.3 a | 6.7 a | 2.0 a | 1.7 a | 0.7 a | 0.3 a | 1.7 a | 0.7 a | 0.0 a | 0.3 a |
| -17 C | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.3 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a |
| -19 C | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a |
| -21 C | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a |
| -23 C | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 a |

*Means followed by the same letter treated within the same temperature are not significantly different at $P \leq 0.05$.

**Table 3.** Evaluation of Meyer and DALZ 0102 zoysiagrass regrowth 8 weeks after exposure to freezing temperatures on 7 December, 2006.

| Treatment | Living Rhizomes (%) | | Living Nodes (%) | | Shoots (no./pot) | | Leaf Weight (mg/pot) | | Root Weight (mg/pot) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Meyer | DALZ | Meyer | DALZ | Meyer | DALZ | Meyer | DALZ | Meyer | DALZ |
| Control | 45.0 a* | 50.0 a | 16.2 a | 22.5 a | 11.0 b | 22.8 a | 56.1 b | 192.2 a | 21.2 a | 97.6 a |
| -3 C | 32.5 a | 52.5 a | 12.9 a | 25.7 a | 8.0 b | 23.8 a | 48.2 b | 200.0 a | 23.8 b | 109.7 a |
| -5 C | 12.5 a | 40.0 a | 5.3 a | 16.6 a | 3.0 a | 14.3 a | 11.1 a | 98.8 a | 11.1 a | 61.0 a |
| -7 C | 20.0 a | 40.0 a | 6.1 a | 17.4 a | 2.5 b | 11.5 a | 5.3 a | 75.8 a | 1.3 b | 46.5 a |
| -9 C | 27.5 a | 37.5 a | 11.8 a | 18.0 a | 8.0 a | 18.5 a | 34.1 a | 124.5 a | 18.2 a | 78.5 a |
| -11 C | 35.0 a | 50.0 a | 14.7 a | 17.6 a | 9.0 a | 13.3 a | 46.1 a | 78.2 a | 18.6 a | 47.9 a |
| -13 C | 27.5 a | 23.3 a | 10.0 a | 9.7 a | 5.8 a | 5.0 a | 17.8 a | 24.5 a | 12.1 a | 14.9 a |
| -15 C | 20.0 a | 17.5 a | 7.7 a | 7.5 a | 10.5 a | 5.3 a | 34.4 a | 36.0 a | 18.5 a | 25.5 a |
| -17 C | 20.0 a | 2.5 a | 5.4 a | 0.7 a | 2.5 a | 0.3 a | 5.4 a | 0.9 a | 2.5 a | 0.1 a |
| -19 C | 15.0 a | 15.0 a | 5.2 a | 3.0 a | 3.0 a | 1.8 a | 12.0 a | 7.63 a | 6.1 a | 5.1 a |

*Means followed by the same letter treated within the same temperature are not significantly different at $P \leq 0.05$.

**Table 3.** Evaluation of Meyer and DALZ 0102 zoysiagrass regrowth 8 weeks after exposure to freezing temperatures on 15 February, 2006.

| Treatment | Living Rhizomes (%) | | Living Nodes (%) | | Shoots (no./pot) | | Leaf Weight (mg/pot) | | Root Weight (mg/pot) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Meyer | DALZ | Meyer | DALZ | Meyer | DALZ | Meyer | DALZ | Meyer | DALZ |
| Control | 35.0 a* | 17.5 a | 14.8 a | 12.5 a | 16.8 a | 13.3 a | 144.7 a | 91.8 a | 26.2 a | 27.1 a |
| -3 C | 62.5 a | 15.0 b | 28.5 a | 8.5 b | 28.3 a | 14.3 a | 194.8 a | 131.3 a | 53.2 a | 27.4 a |
| -5 C | 52.5 a | 20.0 b | 24.3 a | 7.5 b | 19.5 a | 10.8 a | 156.6 a | 85.2 a | 51.4 a | 30.1 a |
| -7 C | 62.5 a | 17.5 b | 32.0 a | 6.0 b | 26.5 a | 11.0 b | 240.7 a | 117.0 a | 72.7 a | 27.3 a |
| -9 C | 40.0 a | 20.0 a | 19.0 a | 9.0 a | 15.0 a | 11.3 a | 110.2 a | 118.5 a | 36.9 a | 33.1 a |
| -11 C | 40.0 a | 17.5 b | 18.0 a | 10.5 a | 15.5 a | 12.0 a | 116.0 a | 111.3 a | 40.0 a | 25.3 a |
| -13 C | 52.5 a | 12.5 b | 21.0 a | 7.5 a | 14.0 a | 6.8 a | 100.5 a | 49.5 a | 28.7 a | 16.3 a |
| -15 C | 57.5 a | 17.5 b | 26.0 a | 5.5 b | 24.3 a | 8.8 b | 150.6 a | 93.7 a | 38.7 a | 33.9 a |
| -17 C | 52.5 a | 7.5 b | 19.0 a | 2.8 b | 18.8 a | 2.0 b | 107.2 a | 8.0 b | 33.5 a | 3.6 b |
| -19 C | 47.5 a | 12.5 b | 18.3 a | 5.3 b | 19.0 a | 7.3 b | 147.6 a | 55.2 a | 40.0 a | 10.5 a |

*Means followed by the same letter treated within the same temperature are not significantly different at $P \leq 0.05$.

**TITLE:** Changes in Membrane Lipids and Abscisic Acid in Meyer and Cavalier Zoysiagrass during Cold Acclimation

**OBJECTIVE:** Identify the differences in lipids and ABA between Meyer and Cavalier during cold acclimation

**PERSONNEL:** Qi Zhang, Jack Fry, Channa Rajashekar, and Xiangqing Pan

**SPONSORS:** Kansas Turfgrass Foundation

**INTRODUCTION:**
We are interested in identifying new zoysiagrass (*Zoysia spp.*) cultivars with a level of freezing tolerance comparable to ‘Meyer’ (*Zoysia japonica* Steud.), but with better quality characteristics. New progeny have been generated from crosses between freezing-tolerant cultivars and high-quality lines. Our goal is to identify some of the physiological contributors to freezing tolerance in zoysiagrass. Membrane lipid species and abscisic acid have been reported to serve a role in signaling pathways that are important in the acclimation process. The type of lipid in living membranes influences how it responds to freezing temperatures. Membranes that contain more unsaturated fatty acids (analogous to cooking oil at home) are more flexible and tolerate freezing stress better. Membranes composed more of saturated fatted acids (analogous to butter) are less flexible and may sustain more freezing injury. Accumulation of abscisic acid helps enhance freezing-dehydration caused by ice crystals. Changes in lipid composition and abscisic acid content in Meyer (cold tolerant) and Cavalier (cold sensitive) (*Z. matrella*) were evaluated during cold acclimation.

**MATERIALS AND METHODS:**
Meyer (sampled from Rocky Ford Turfgrass Research Center) and Cavalier (provided by Dr. Milt Engelke from Texas A & M) were propagated in cone containers (2-inch diameter, 10 inches deep) in a greenhouse in June 2005 and 2006. Containers were moved into an 8-ft. diameter storage tank, with sand filled around the containers for natural cold acclimation. Containers were sampled monthly from October to January. One set of the containers was brought to a greenhouse set at 70º to 80º F during the day and 60º to 70º F at night (control). Another set of containers was exposed to cold temperatures in a freezing chamber. Cavalier was subjected to temperatures of -3º, -6º, -9º, and -12º C. Meyer was exposed to temperatures of -5º, -9º, -13º, and -17º C. The experiment was arranged as a randomized complete-block design with four replications. Plant survival was estimated visually as percentage of regrowth 6 weeks after the freezing treatment. The lethal temperature that killed 50% of the grasses ($LT_{50}$) was calculated by using regression. The minimum freezing temperature from which any shoot recovery occurred was also recorded ($T_{min}$). In winter 2006, one more sampling date was added for each cultivar, 18 November for Cavalier and 20 December for Meyer.

Rhizomes were sampled from another set of acclimated plants removed from the field at the same time other plants were subjected to freezing treatments. Rhizomes were sampled from ~1 inch below the soil surface, and roots and leaves were excised from rhizomes. Rhizomes were then immersed in liquid nitrogen and stored in a -80º C freezer. A profile of the polar complex lipids (membrane lipids) was generated by electrospray ionization tandem mass spectrometry (ESI-ES/MS) and recorded as the percentage in the total amount of the lipids. Each of the entries in Table 2 represents a group of fatty acids ranging in number from 5 to 64. Abscisic acid was analyzed with high-performance liquid chromatography electrospray-ionization tandem mass spectrometry (HPLC-ESI-MS/MS).

Data were analyzed with the PROC GLM procedure, and means were separated with Fisher's protected LSD test. $LT_{50}$ was calculated with a regression model.

**RESULTS:**

*Freezing tolerance.* Freezing tolerance increased from October to December in both cultivars (Table 1 & 2). The $LT_{50}$ and $T_{min}$ were lower in Meyer than in Cavalier in all months. Cavalier reached its maximum cold tolerance in late November ($LT_{50}$ -10.0 C), but recovery growth from Cavalier treated at -12º C was still observed in December and January. The lowest $LT_{50}$ in Meyer occurred in December, -15.9º C in 2005 and -15.2º C in 2006, respectively, one month later than that in Cavalier. Recovery growth from exposure to -17º C was also observed in December and January in Meyer.

*Changes in membrane fatty acid species.* Eleven lipid classes have been identified in zoysiagrass rhizomes, including phosphatidylcholine (PC) and phosphatidic acid (PA), which have been reported to be related to freezing stress in other plants. Lipids in the PC group were highest in Cavalier and Meyer when each reached their peak hardiness (November for Cavalier; December for Meyer) in winter 2005 (Figure 1). About 90% of the fatty acids in the PC group were unsaturated fatty acids, indicating that PC might serve to stabilize membranes. Total PA content increased to a much higher extent in Cavalier than in Meyer in December when Cavalier, but not Meyer, was severely damaged by freezing (Figure 2). However, a similar trend was not observed in winter 2006 (Table 3).

*Changes in abscisic acid content.* ABA content in rhizomes was negatively correlated to freezing tolerance in both cultivars, i.e. as ABA content increased, freezing tolerance improved (Table 3). ABA has been shown to reduce drought injury in turfgrasses and may also serve a role in freezing tolerance.

**ACKNOWLEDGEMENTS:**

We appreciate the assistance of Dr. Ruth Welti, Richard Jeannotte, and Mary Roth with the Kansas Lipidomics Research Center.

**Table 1.** Recovery growth (%), $LT_{50}$[†], and $T_{min}$[†] of Meyer and Cavalier zoysiagrass six weeks after exposure to freezing temperatures from October to December 2005.

| | 4 October | | 5 November | | 2 December | |
|---|---|---|---|---|---|---|
| | Cavalier | Meyer | Cavalier | Meyer | Cavalier | Meyer |
| Control | 100.0 a* | 100.0 a | 100.0 a | 100.0 a | 23.3 a | 95.0 ab |
| -3 C | 50.0 b | ------------- | 100.0 a | ------------- | 33.8 a | ------------- |
| -5 C | -------------[‡] | 100.0 a | ------------- | 100.0 a | ------------- | 97.5 a |
| -6 C | 0.0 c | ------------- | 100.0 a | ------------- | 35.0 a | ------------- |
| -9 C | 0.0 c | 0.0 b | 37.5 b | 100.0 a | 20.0 a | 87.5 ab |
| -12 C | 0.0 c | ------------- | 0.0 c | ------------- | 3.8 a | ------------- |
| -13 C | ------------- | 0.0 b | ------------- | 77.5 b | ------------- | 77.5 b |
| -17 C | ------------- | 0.0 b | ------------- | 0.0 c | ------------- | 35.0 c |
| $LT_{50}$ (C) | -3.0 | -7.7 | -8.3 | -13.4 | N/A[§] | -15.9 |
| $T_{min}$ (C) | -3.0 | -5.0 | -9.0 | -13.0 | -12.0 | -17.0 |

*Means with the same letter in each column are not significantly different at $P \leq 0.05$. Means represent the average of four replications.

[†]$LT_{50}$, lethal temperature that results in 50% or less recovery growth; $T_{min}$, the lowest freezing temperature at which any recovery growth was observed.

[‡]Dashed lines indicate that this freezing temperature not tested.

[§]N/A, no LT50 was calculated because recovery growth was out of range.

**Table 2.** Recovery growth (%), $LT_{50}$†, and $T_{min}$† of Meyer and Cavalier zoysiagrass six weeks after exposure to freezing temperatures from October 2006 to January 2007.

| Treatment | 2 October | | 7 November | | 18 November | | 1 December | | 20 December | | 9 January | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cavalier | Meyer | Cavalier | Meyer | Cavalier | Meyer | Cavalier | Meyer | Cavalier | Meyer | Cavalier | Meyer |
| Control | 100.0 a* | 100.0 a | 100.0 a | 100.0 b | 100.0 a | ------- | 46.3 ab | 100.0 a | ------- | 100.0 a | 53.75 a | 100.0 a |
| -3 C | 80.0 b | -------- | 100.0 a | -------- | 100.0 a | ------- | 57.5 ab | ------- | ------- | ------- | 36.3 ab | ------- |
| -5 C | --------§ | 85.0 a | -------- | 100.0 b | -------- | ------- | ------- | 100.0 a | ------- | 100.0 a | ------- | 95.0 ab |
| -6 C | 5.0 c | -------- | 87.5 ab | -------- | 100.0 a | ------- | 75.0 a | ------- | ------- | ------- | 36.3 ab | ------- |
| -9 C | 0.0 c | 0.0 b | 65.0 b | 100.0 b | 95.0 a | ------- | 30.0 bc | 87.5 a | ------- | 100.0 a | 7.5 b | 77.5 b |
| -12 C | 0.0 c | -------- | 0.0 c | -------- | 3.8 b | ------- | 0.0 c | ------- | ------- | ------- | 7.5 b | ------- |
| -13 C | -------- | 0.0 b | -------- | 42.5 b | -------- | ------- | ------- | 85.0 a | ------- | 90.0 b | ------- | 42.5 c |
| -17 C | -------- | 0.0 b | -------- | 0.0 c | -------- | ------- | ------- | 40.0 b | ------- | 17.5 c | ------- | 8.8 d |
| $LT_{50}$ (C) | -4.0 | -6.5 | -8.7 | -12.2 | -10.0 | ------- | -6.2 | -17.1 | ------- | -15.2 | N/A§ | -11.8 |
| $T_{min}$ (C) | -6.0 | -5.0 | -9.0 | -13.0 | -12.0 | ------- | -9.0 | -17.0 | ------- | -17.0 | -12.0 | -17.0 |

*Means with the same letter in each column are not significantly different at $P \leq 0.05$. Means represent the average of four replications.

†$LT_{50}$, lethal temperature that results in 50% or less recovery growth; $T_{min}$, the lowest freezing temperature at which any recovery growth was observed.

‡Dashed lines indicate that this freezing temperature or date not tested.

§N/A, no LT50 was calculated because recovery growth was out of range.

**Table 3.** Correlation between freezing tolerance ($LT_{50}$ and $T_{min}$[†]) in Cavalier and Meyer rhizomes and changes in phosphatidylcholine (PC), phosphatidic acid (PA), and abscisic acid content (ABA) in the winter of 2005 and 2006[§].

| | 2005[§] | | | | 2006[§] | | | |
|---|---|---|---|---|---|---|---|---|
| | Cavalier | | Meyer | | Cavalier | | Meyer | |
| | $LT_{50}$ | $T_{min}$ | $LT_{50}$ | $T_{min}$ | $LT_{50}$ | $T_{min}$ | $LT_{50}$ | $T_{min}$ |
| PC | r = 0.19 | r = 0.74 | r = 0.54 | r = 0.54 | r = -0.26 | r = -0.62 | r = -0.33 | r = -0.58 |
| | *P* = 0.55 | *P* < 0.01 | *P* = 0.07 | *P* = 0.07 | *P* = 0.28 | *P* < 0.01 | *P* = 0.16 | *P* < 0.01 |
| PA | r = -0.26 | r = -0.84 | r = -0.94 | r = -0.94 | r = 0.43 | r = 0.72 | r = -0.03 | r = 0.13 |
| | *P* = 0.41 | *P* < 0.01 | *P* < 0.01 | *P* < 0.01 | *P* = 0.06 | *P* <0.01 | *P* =0.90 | *P* = 0.61 |
| ABA | r = -0.74 | r = -0.21 | r = -0.55 | r = -0.55 | r = -0.94 | r = -0.32 | r = -0.58 | r = -0.33 |
| | *P* < 0 .01 | *P* = 0.54 | *P* = 0.08 | *P* = 0.08 | *P* < 0.01 | *P* = 0.17 | *P* < 0.01 | *P* = 0.17 |

[†]$LT_{50}$, lethal temperature that results in 50% or less recovery growth; $T_{min}$, the lowest freezing temperature at which any recovery growth was observed.

[§]Measurements were taken monthly from October to December 2005 and from October 2006 to January 2007.

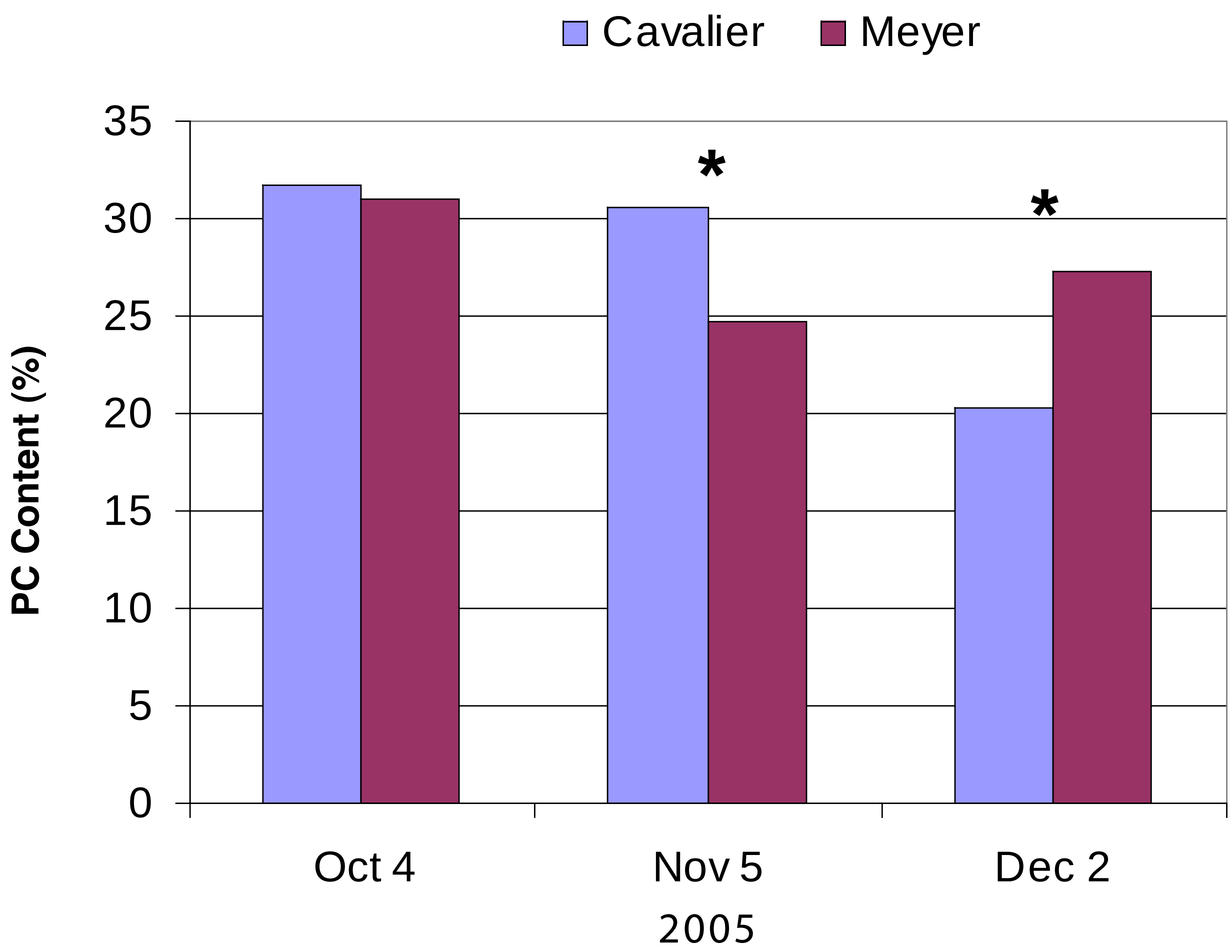



**Figure 1.** Changes in the total amount of phosphatidylcholine (PC) in winter 2005.

*Denotes significant differences between Cavalier and Meyer at $P \leq 0.05$.

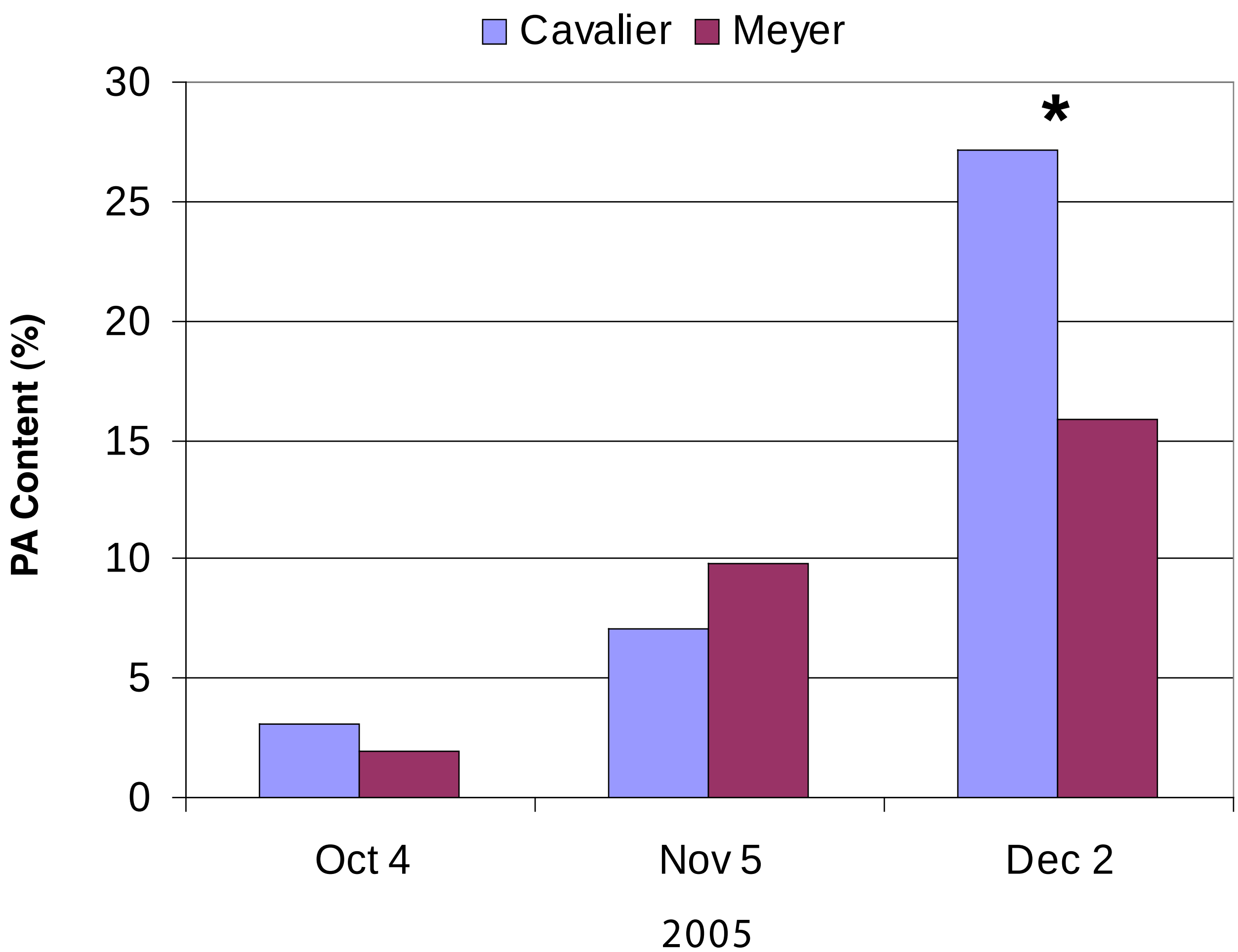



**Figure 2.** Changes in the total amount of phosphatidic acid (PA) in the winter, 2005.

*Denotes significant differences between Cavalier and Meyer at $P \leq 0.05$.

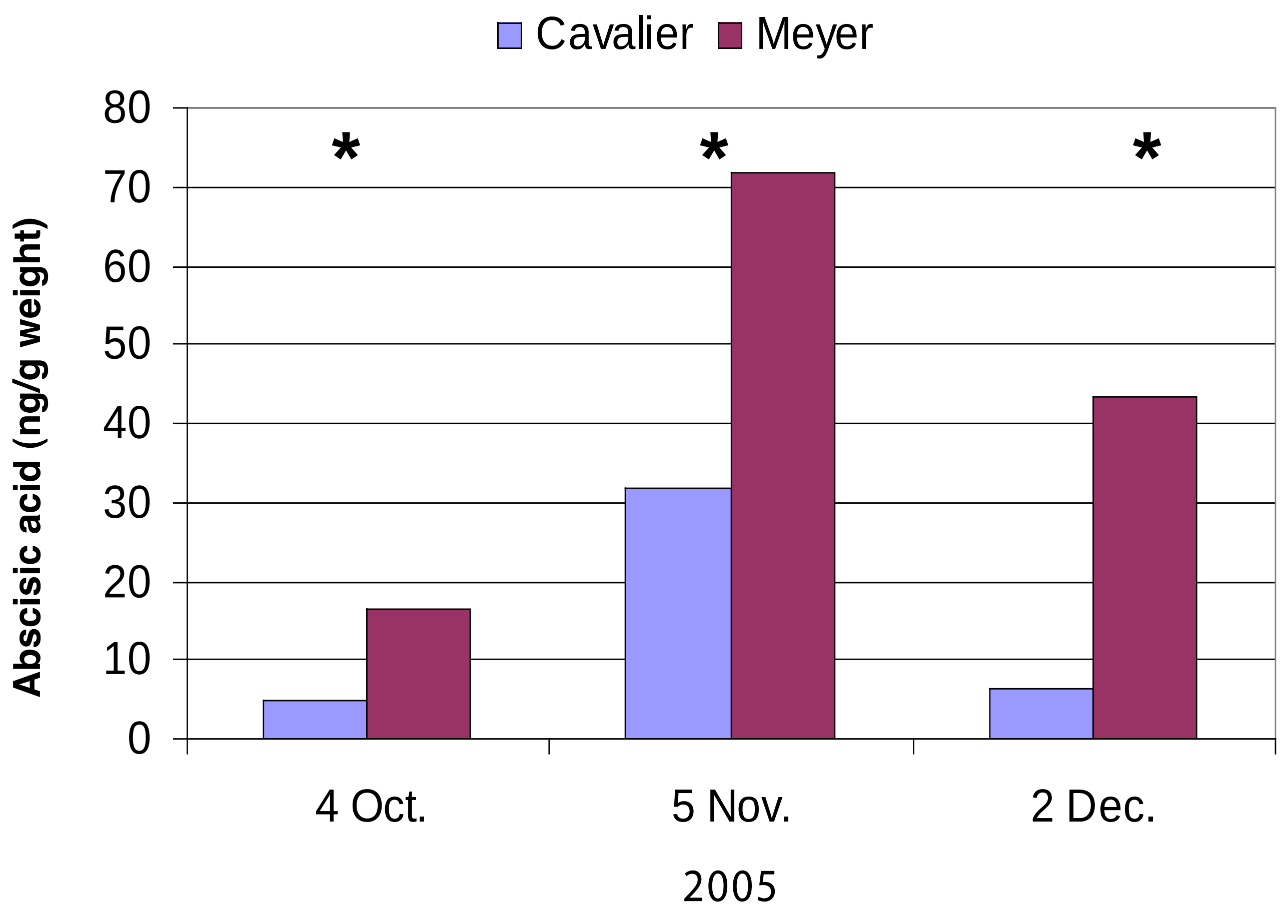



**Figure 3.** Changes in abscisic acid content in winter 2005.

*Denotes significant differences between Cavalier and Meyer at $P \leq 0.05$.

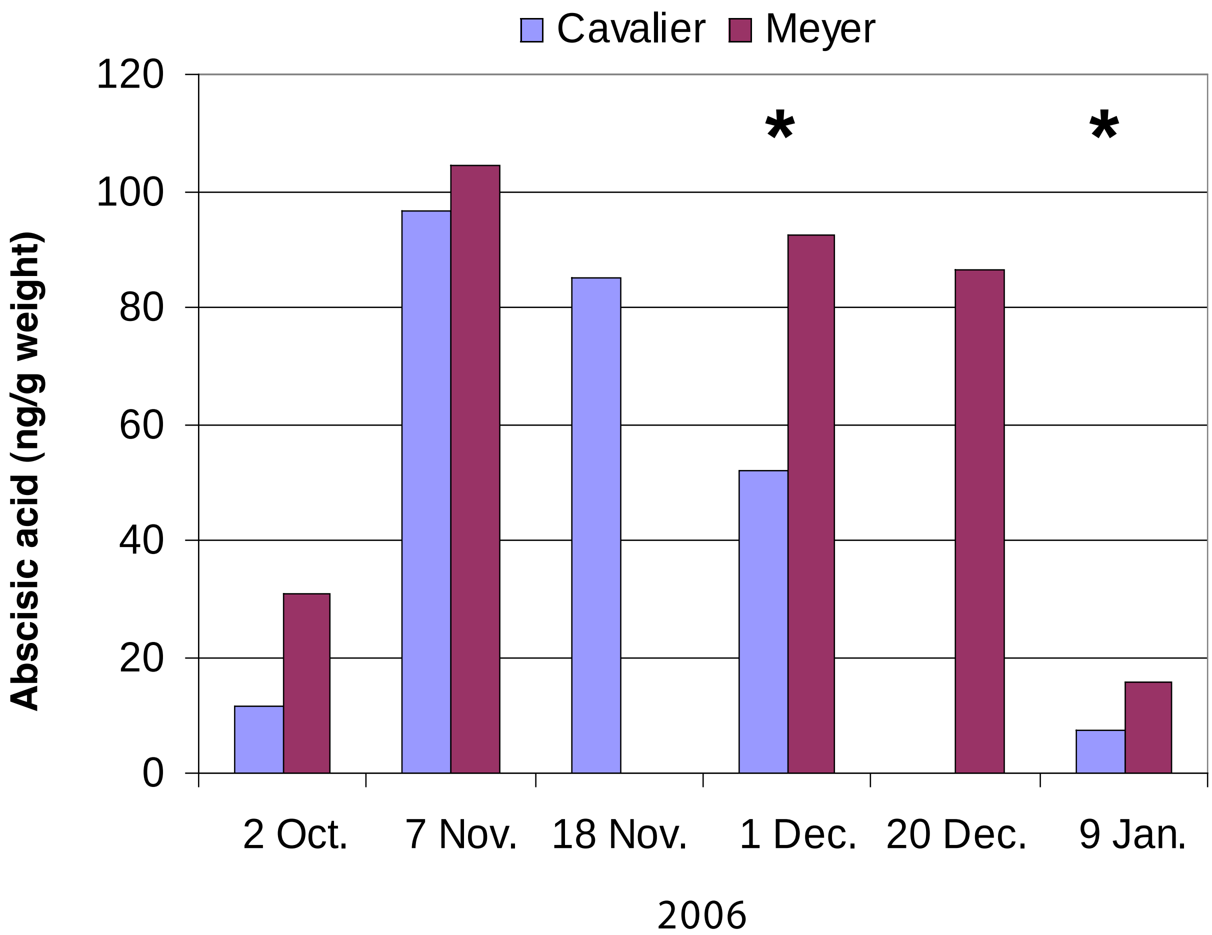



**Figure 4.** Changes in the abscisic acid content in winter 2006.

*Denotes significant differences between Cavalier and Meyer at $P \leq 0.05$.

**TITLE**: Emissions of Nitrous Oxide from Three Different Turfgrass Species and from Perennial Ryegrass under Different Irrigation Regimes

**OBJECTIVES:** Investigate: (1). the seasonal magnitude and patterns of nitrous oxide ($N_2O$) fluxes in one cool season and two warm season turfgrasses; and (2). effects of irrigation on $N_2O$ emissions from perennial ryegrass

**AUTHOR**: Jason Lewis and Dale Bremer

**SPONSORS**: Kansas Turfgrass Foundation (KTF)

**INTRODUCTION:**
Different species of turfgrasses (for example, warm- and cool-season turfgrasses) may be fertilized with nitrogen (N) at different rates and frequencies, and irrigated with different amounts of water, all of which may affect $N_2O$ emissions. The selection of different species of turfgrasses may be a useful management tool in mitigating $N_2O$ emissions from turfgrass ecosystems. Irrigation may also significantly impact $N_2O$ emissions from turfgrass. Therefore, this study investigated (1) $N_2O$ emissions from three species of turfgrasses during a 5-month period (i.e., June through October) of the 2006 growing season; and (2) the effects of irrigation on $N_2O$ emissions in turfgrass during a 2-month period in the summer of 2006.

**METHODS:**
*Study 1: Species effects.* Eighteen plots, or six plots per species, were arranged and established in a repeated Latin square design (Fig. 1). The species investigated included one cool-season (perennial ryegrass, *Lolium perenne* L.) and two warm-season turfgrasses (bermudagrass [*Cynodon dactylon*] and zoysiagrass [*Zoysia japonica*]). Urea N fertilizer was applied to turfgrasses according to the schedule presented in Table 1. Soil fluxes of $N_2O$ were measured weekly to biweekly from 6 June to 25 October, 2006, using static surface chambers and analyzing $N_2O$ by gas chromatography. Turfgrass irrigation requirements were determined with the Penman-Monteith equation (FAO-56), and all plots were irrigated one or two times weekly as needed, by hand to ensure uniformity. Plots were mowed at 7.62 cm twice a week with a walk-behind rotary mower.

*Study 2: Irrigation effects.* Eighteen plots were arranged in a previously established sward of perennial ryegrass. Three treatments were applied to the plots in a randomized block design. Irrigation amounts included (1) 100% evapotranspiration (ET) replacement; (2) 80% ET replacement; and (3) no irrigation. To determine irrigation requirements, evapotranspiration (ET) was calculated by using the Penman-Monteith equation (FAO, 1998) and climatological data obtained at a weather station located at Rocky Ford Turfgrass Research Center. Water was applied twice weekly as needed through a fan spray nozzle attached to a hose; a meter was attached to ensure proper application rate. Soil fluxes of $N_2O$ were measured weekly to biweekly using the same technique as described above from 22 June to 17 August, 2006. Plots were mowed at 7.62 cm twice a week with a walk-behind rotary mower.

**RESULTS:**
*Study 1: Species effects.* Daily fluxes of $N_2O$ ranged from 8 $\mu$g $N_2O$-N $m^{-2}$ $h^{-1}$ on 25 October to 1709 $\mu$g $N_2O$-N $m^{-2}$ $h^{-1}$ after N fertilization on 11 July (Fig. 2). Nitrogen fertilization increased $N_2O$ emissions by up to 45 times within one day, although the amount of increase differed after each fertilization. Cumulative emissions of $N_2O$-N during the study differed slightly among species (Fig. 3). Cumulative fluxes were 2.60 kg $ha^{-1}$ in bermudagrass, 2.31 kg $ha^{-1}$ in perennial ryegrass, and 2.63 kg $ha^{-1}$ in zoysiagrass. Thus, cumulative $N_2O$ emissions were very similar between the two warm season turfgrasses (i.e., bermudagrass and zoysiagrass), and cumulative $N_2O$ emissions averaged 13% higher in

the warm-season species than in the cool-season turfgrass species. However, because perennial ryegrass was actively growing earlier in the spring than warm-season grasses (e.g., during March, April, and May), before measurements were collected in this study, $N_2O$ emissions may have been greater from perennial ryegrass during that period. Therefore, data collected during this 5-month period likely do not represent cumulative fluxes from the entire season from March through November.

*Study 2: Irrigation effects.* Significant precipitation during much of the study period muted the effects of reduced and no irrigation on $N_2O$ emissions (Fig. 4). Cumulative $N_2O$ fluxes during the study period decreased by about 8% when irrigation was reduced to 80% ET and when irrigation was withheld, compared with well-watered plots (100% ET). No difference in $N_2O$ emissions was observed between 80% and no irrigation treatments.

*Note*: These data are preliminary and therefore, not conclusive because the study was still underway at the writing of this report. Results from the completed study will be presented in the 2008 K-State Turfgrass Research Report.

**Table 1.** Fertilization schedule for bermudagrass, perennial ryegrass, and zoysiagrass.

| | Bermudagrass | Perennial Ryegrass | Zoysiagrass |
|---|---|---|---|
| | ........................................ lbs N 1000 $ft^{-2}$ ........................................ | | |
| May | 1.0 | 1.0 | 1.0 |
| June | 1.0 | -- | -- |
| July | 1.0 | 0.5 | 1.0 |
| August | 1.0 | -- | -- |
| September | -- | 1.5 | -- |

**Figure 1.** Plots of perennial ryegrass, zoysiagrass, and bermuda grass were established in 2005 and arranged in a Latin square design. Photo was taken in mid-November 2005, when zoysia and bermuda were dormant.

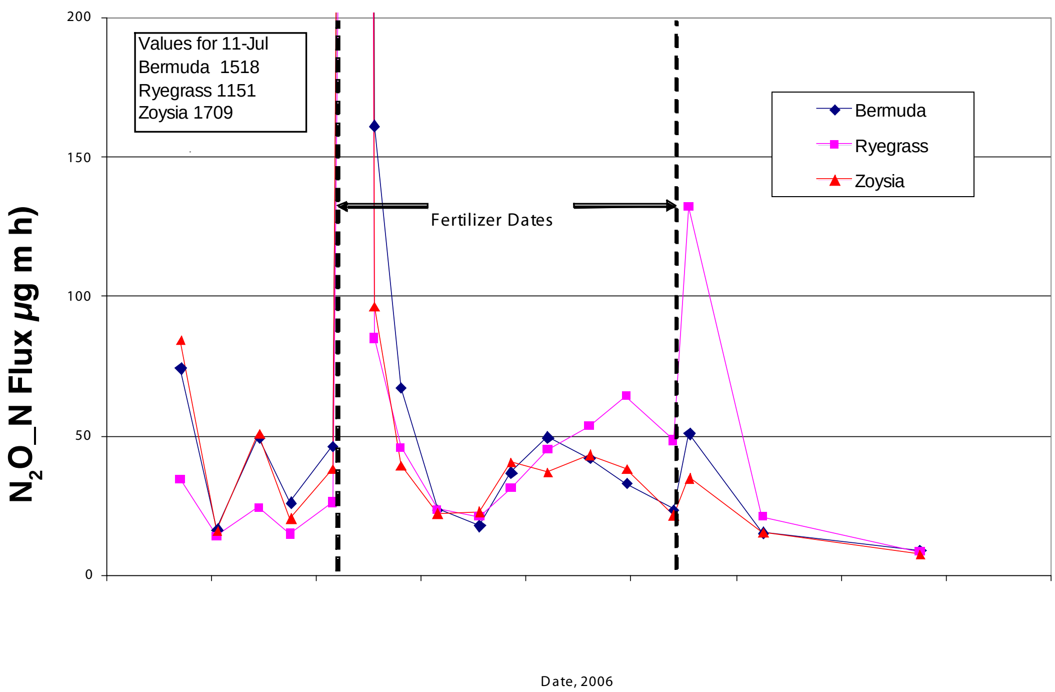



**Figure 2.** Patterns among turfgrass species of nitrous oxide nitrogen fluxes (µg $N_2O\_N$ $m^{-2}$ $h^{-1}$) from 6 June to 25 October, 2006. Vertical dashed lines represent N-fertilization dates.

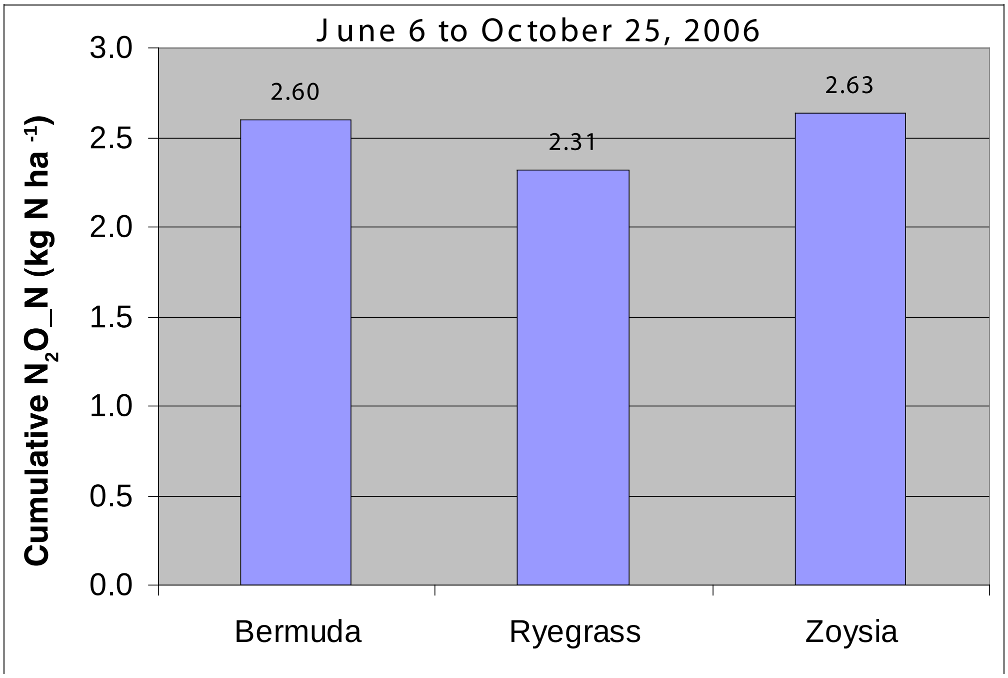



**Figure 3.** Cumulative emissions of of nitrogen ($N_2O$_N) from three species of turfgrasses during a 5-month period in the summer and fall of 2006.

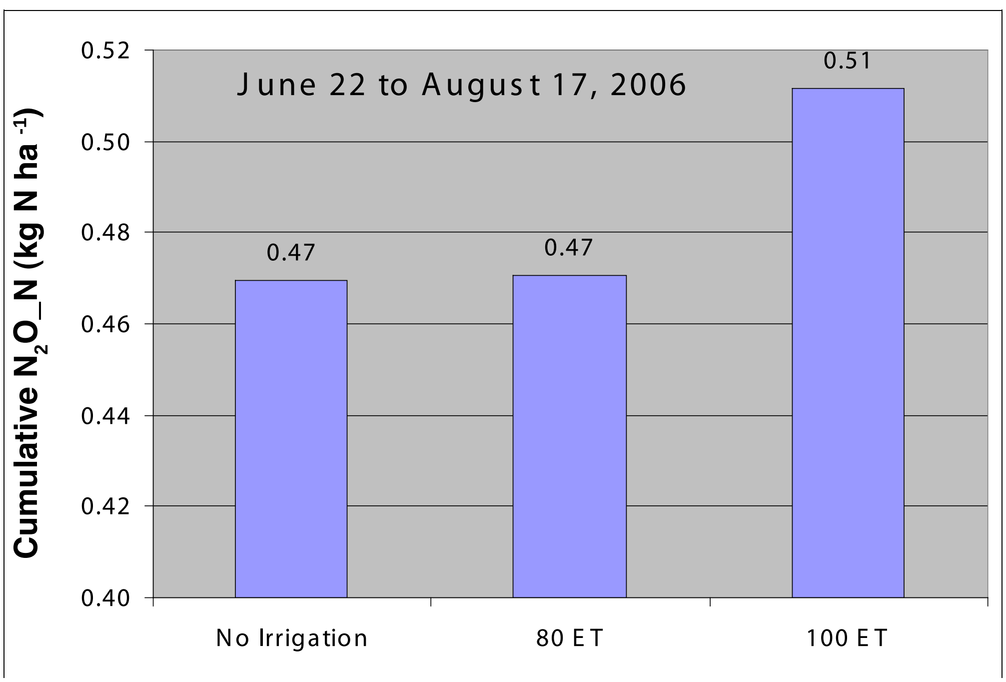



**Figure 4.** Cumulative emissions of of nitrogen ($N_2O$_N) from perennial ryegrass under three different irrigation regimes for a 2-month period in the summer of 2006.

**TITLE:** Nitrogen Source and Timing Effect on Carbohydrate Status of Bermudagrass and Tall Fescue

**OBJECTIVE:** Evaluate coated nitrogen sources at various timings, compared with urea at traditional timings, for their effect on carbohydrate status of bermudagrass and tall fescue

**PERSONNEL:** Tony Goldsby and Steve Keeley

**INTRODUCTION:**

Non-structural carbohydrates (NSC) are the energy source for turfgrass growth and recovery; therefore, NSC levels have often been used as an indicator of the physiological health and/or stress-tolerance of a turfgrass (Hull,1992). Research has shown that higher NSC levels in winter improved low-temperature survival of various turfgrass species (Shahba et al., 2003; Ball et al., 2002; Fry et al., 1993). Similarly, cool-season turfgrass quality during summer has been related to higher NSC content in shoots and roots (Xu and Huang, 2003; Liu and Huang, 2000). Spring regrowth after winter dormancy and turfgrass recovery from excessive traffic and other stresses is also dependent on an adequate supply of NSC (Fry and Huang, 2004).

Turfgrass cultural practices can have a significant effect on plant health by altering NSC levels. For example, lowering the mowing height reduces leaf area for photosynthesis, which ultimately results in a reduction in rooting (Liu and Huang, 2002; Juska and Hanson, 1961). Nitrogen fertilizer is essential for high quality turfgrass, but multiple studies have documented decreased NSC levels with higher N rates (Gonzalez et al., 1989; Westhafer et al., 1982; Watschke and Waddington, 1974; Brown and Blaser, 1965). This reduction in NSC likely occurs because nitrogen promotes vegetative growth, which has been shown to deplete NSC levels in turfgrass (Youngner and Nudge, 1976). Turfgrass stands receiving high N may be less able to tolerate and/or recover from various stresses.

Non-structural carbohydrates may also play a role in preventing winter injury in warm-season turfgrass. Late season N applications typically take place between the months of August and December. Late season N should increase turfgrass NSC levels, but studies investigating the effect of late season N on bermudagrass winter survival have been conflicting (Schmidt and Blaser, 1969; Beard, 1973). Early reports suggested there may be negative effects of late season N applications on bermudagrass cold tolerance. Goatley et at. (1994) found that late-season N improved fall and spring color and had little effect on NSC. Schmidt and Chalmers (1993) found positive effects associated with late-season N applications. Therefore, there is a need for better information regarding how fertilization affects NSC status in relation to cold injury.

Slow-release nitrogen fertilizers have the potential to provide a solution to these problems by moderating turfgrass vegetative growth. However, many slow-release N sources are dependent on microbial activity for N release, which makes the timing and rate of release somewhat difficult to predict. Polymer-coated nitrogen fertilizers have been developed that are not dependent on microbial activity for N release, providing a more predictable and precise rate of N release (Christians, 2004). Research is needed concerning the optimum rates and application timing when using these polymer-coated N sources on turfgrass, especially with regard to their effects on NSC levels.

Because turfgrass NSC levels are known to fluctuate seasonally (Narra et.al., 2004; Miller and Dickens, 1996; Youngner et al. 1978), it is important that NSC sampling be conducted throughout the year in order to provide a clear picture of treatments' effects on turfgrass NSC levels. The objective of our study was to evaluate the effect of spring vs. late summer applications of polymer-coated N sources, in comparison to traditional N sources, on 'Midlawn' bermudagrass (*Cynodon dactylon* [L.] Pers. × *C. transvaalensis* Burtt-Davy) and a blend of turf-type tall fescue (*Festuca arundinacea* Screb.) and the effect on NSC status throughout the year.

**MATERIALS AND METHODS:**

On August 1, 2005, we initiated N fertilizer treatments (Tables 1 and 2) in a completely randomized design with four replications. This research was conducted at Rocky Ford Research Center in Manhattan, KS. NSC were measured bi-monthly by extracting two 10-cm diameter plugs from each plot and measuring regrowth in darkness in a growth chamber at 24$^{o}$ C. The regrowth period lasted for 8 weeks. Plugs were completely defoliated before being placed in the growth chamber. Shoot growth was removed biweekly, and the clippings were dried at 70$^{o}$ C for 48 hours, and dry weights were recorded. The data were analyzed using SAS for Windows and MSTAT.

**RESULTS:**

Initial results have shown no difference in NSC status between polymer-coated N sources and traditional N sources for the eight completed sampling periods. In the bermudagrass study, late-summer applications have resulted in significantly higher NSC status during November, January and March, than with spring-only applications (Figures 1, 2 and 3). Late summer applications may have a positive effect on bermudagrass winter survival. NSC sampling continues through the 2007 growing season.

Controlled freeze testing of samples from various treatments is also under way. This research will allow a clearer determination of the effect of N source and timing on bermudagrass cold tolerance.

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**Table 1.** Bermudagrass treatment list.

1) Polyon 43-0-0 @ 4 lbs N/M in early April
2) Polyon 43-0-0 @ 4 lbs N/M in early August
3) Polyon 41-0-0 @ 4 lbs N/M in early April
4) Polyon 41-0-0 @ 4 lbs N/M in early August
5) SCU @ 4 lbs N/M in early April
6) SCU @ 4 lbs N/M in early August
7) SCU @ 2 lbs N/M in early April + 2 lbs N/M in early August
8) Methylene urea @ 4 lbs N/M in early April
9) Methylene urea @ 4 lbs N/M in early August
10) Check: Urea @ 1 lb N/M in May, June, July and August

**Table 2.** Tall fescue treatment list.

1) Polyon 43-0-0 @ 3 lbs N/M in early Sept.
2) Polyon 43-0-0 @ 1.5 lbs N/M in early Sept + 1.5 lbs N/M in late March
3) Polyon 41-0-0 @ 3 lbs N/M in early Sept.
4) Polyon 41-0-0 @ 1.5 lbs N/M in early Sept + 1.5 lbs N/M in late March
5) SCU @ 3 lbs N/M in early Sept.
6) SCU @ 1.5 lbs N/M in early Sept + 1.5 lbs N/M in late March
7) Methylene urea @ 3 lbs N/M in early Sept.
8) Methylene urea @ 1.5 lbs N/M in early Sept + 1.5 lbs N/M in late March
9) Check: Urea @ 1 lb N/M in early Sept., Nov. and May

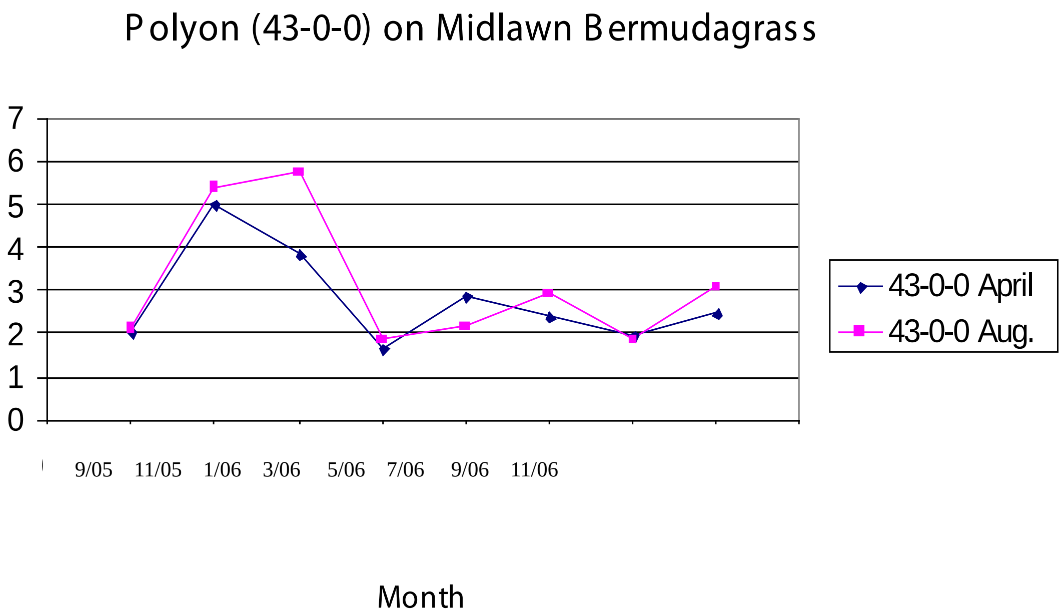


**Figure 1.** NSC status of 'Midlawn' bermudagrass receiving 4lb N/1000 ft$^2$ from Polyon (43-0-0) in April or August.

*Denotes significance at p=0.05

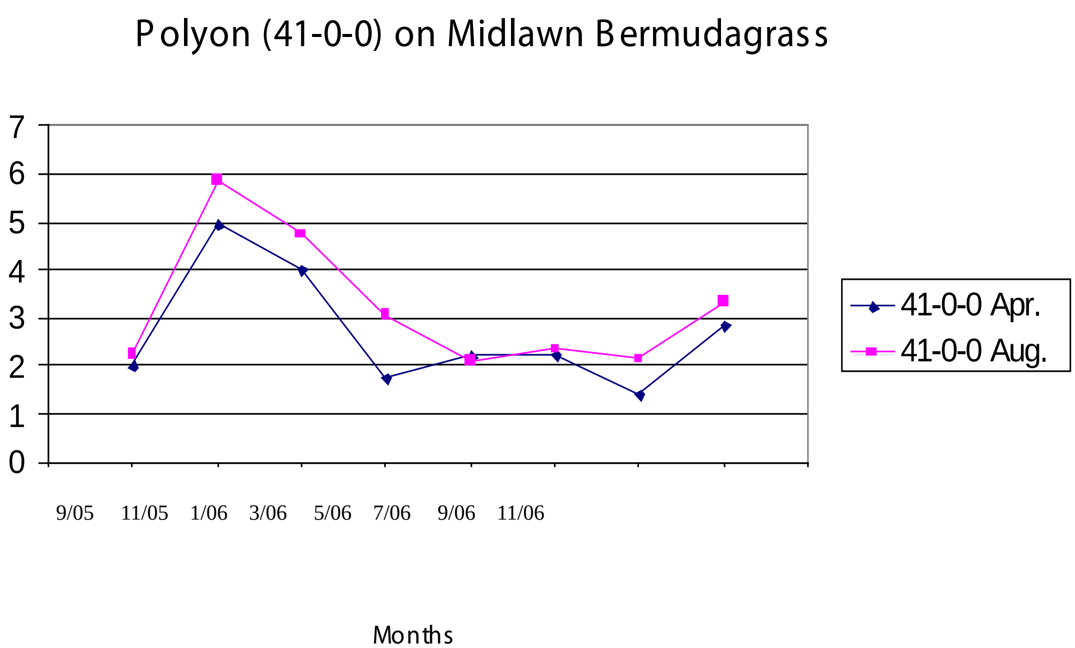


**Figure 2.** NSC status of 'Midlawn' bermudagrass receiving 4lb N/1000 ft$^2$ from Polyon (41-0-0) in April or August.

*Denotes significance at p=0.05

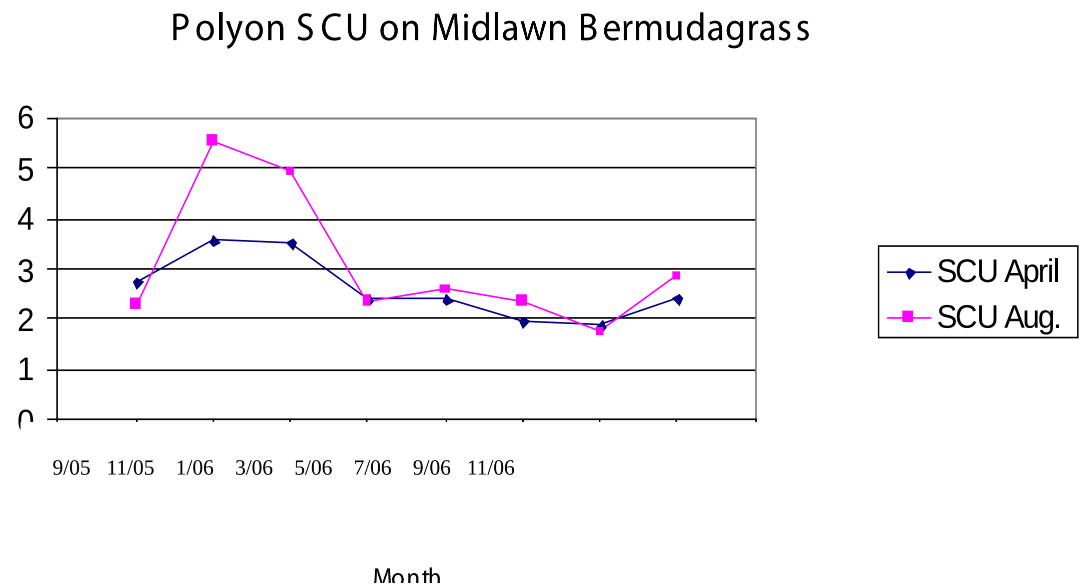


**Figure 3.** NSC status of ‘Midlawn’ bermudagrass receiving 4lb N/1000 $ft^2$ from sulfur-coated urea in April or August.

*Denotes significance at p=0.05

# Turfgrass Research 2007

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SRP 981 August 2007