San Antonio Water System (SAWS)

Texas A &M and Turf Producers of Texas

On Drought Tolerance & Drought Resistance

Summary

- Objective: to identify turf varieties that have demonstrated “summer dormancy” capabilities. i.e.: the ability to survive without water for a period of 60 consecutive days between the months of May and September
- 25 turf varieties planted in Sept 2005
- No Irrigation from July 23 through September 20, 2006 (the hottest 60 days on record in San Antonio)
- 60 day recovery period (September 21 through November 19, 2006)

Results

- Celebration was green and growing after 60 days without water
- Celebration was rated #1 after the recovery period with a recovery rate of 100%

For complete research results visit www.sodsolutions.com/research

Evaluation of Sixty-Day Drought Survival In San Antonio of Established Turfgrass Species and Cultivars: Year 1

A December 2006 Progress Report to the San Antonio Water System and the Turfgrass Producers of Texas

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Introduction

Texas Cooperative Extension faculty in Soil and Crop Sciences and Agricultural Engineering entered into Memorandum of Agreements with the San Antonio Water System (SAWS) Conservation Program and the Turfgrass Producers of Texas for a two-year research project. The project evaluates the sixty-day drought survival of turfgrass species and cultivars in San Antonio. Team members constructed the research site, sodded the plots with 25 different turfgrasses (September 2005) and constructed a 5,000 sq. ft. "drought simulator" (rain-out shelter) on the site. The drought simulator covered the plot area during times of rainfall in 2006 to maintain a 60-day summer drought period. Grasses were evaluated during the drought period (July 23 through September 20, 2006). There were differences in time to leaf firing. The 4-inch soil depth plots fired quickly, while those on native soil depth fired more gradually. There were differences on how grass cultivars fired in response to the drought. Immediately following the drought period the grasses were allowed to recover with irrigation for 60 days (September 21 through November 19, 2006). No grasses survived the drought on the 4-inch soil depth. For that reason the data presented in this report will concentrate on the response of grasses planted on the unrestricted native soil. All grasses survived the 60-day drought period. The survival after 60 days recovery, under irrigation, ranged from from 4 to 100 percent living ground cover. The Year 2 plot area was constructed on a separate site at the opposite end of the drought simulator and planted September 22, 2006. The same set of grasses will again be evaluated for 60-day drought survival in July 2007.

Objectives of the research

The objectives of this research are to evaluate grass performance in San Antonio as related to the provisions of the SAWS 2005 Conservation Ordinance that impact turfgrass performance and determine which turfgrasses might qualify for inclusion in the list mentioned in item 3 below. Specific to the ordinance are the summarized following provisions:

1. Turfgrass established or associated with new construction after January 1, 2006, shall have a minimum soil depth of 4-inches beneath the turfgrass.

2. Turfgrass established after January 1, 2007, shall have summer dormancy capabilities. "Summer dormancy" is defined as the ability of turfgrass to survive without water for a period of sixty consecutive days between the months of May through September.

3. Beginning January 1, 2007 SAWS will maintain a list of turfgrasses that have demonstrated summer dormancy capabilities.

A description of the research study

The research is located in San Antonio. Grasses were sodded in replicated 4 by 4 foot plots and include bermudagrass (Celebration; Common; GN-1; Grimes EXP; Premier; TexTurf; TifSport and Tifway (419); St. Augustinegrass (Amerishade, Common, Delmar, Floratam, Palmetto, Raleigh, and Sapphire); and

Zoysiagrass (Cavalier, El Toro, Emerald, Empire, Jamur, Palisades, Y-2, Zeon and Zorro). Although the SAWS list will accept all buffalograss cultivars without testing, one buffalograss was planted for comparison purposes. TPT members supplied the sod for the study. Texas A&M researchers constructed the test area and oversee test plot management, data collection/analysis and interpretation of results.

Grasses are planted on four inches of native soil over an impermeable plastic barrier to simulate the 4-inch topsoil requirement in the SAWS ordinance. This barrier slopes to drains to remove saturated water flow. Grasses are also planted on the native soil without restriction to rooting to represent drought survival on unrestricted soil depth. The 25 grasses were established from washed sod to minimize differences resulting from the soil on the sod. Grasses established well in a warmer than normal 2005-06 winter. The establishment period prior to beginning the imposed drought was 10.25 months.

The drought simulator ensures a 60-day drought for 25 grasses on two soil profiles. A 60-day irrigated drought recovery period followed the 60-day drought. The research plots were well established at the beginning of the study. Data was collected weekly for turfgrass quality, density, leaf firing due to moisture stress, color as percent green turf cover.

Data was taken that was in addition to that of the original research protocol. The 23-day delay in beginning the drought pushed the end of the recovery period to late November. Therefore the additional data will not be presented at this time. Additional data included:

1. Core plug samples (4.25 inch diameter) were removed from the plots 0, 20, 40, and 60 days into the drought and brought back to College Station to evaluate re-growth capabilities.

2. Digital images taken for each plot and analyzed using a SigmaScan Pro macro named "Turf Analysis". This relatively new technology is capable of batch analyzing turf images. These data were collected for both the drought and the recovery periods.

3. Air temperatures taken immediately above the individual grasses during drought.

Research Plot Management

Establishment Period: The research site was fertilized according to soil test results in Fall 2005. Additional nitrogen applications were made in the spring and early summer 2006. Fungicides were applied preventatively for Brown Patch and Take-All Root Rot in Fall 2005 and spring 2006. The plots were mowed at 2.25 inches weekly as needed. Irrigation was applied to prevent excess moisture stress and enhance establishment. The four-inch plots were therefore irrigated more frequently as indicated by more frequent periodic wilting than those plots on native soil without restriction to rooting. Irrigation during the recovery was applied so water was not a limiting factor in turfgrass recovery from the 60-day drought treatment.

Drought Period: Plots were mowed up until the fifth week of the drought when mowing was stopped, to prevent unnecessary stress, due to little or extremely slow growth. The drought simulator appeared to be operational when the infrequent rainfall occurred.

Recovery Period: The research site was irrigated so water availability was not to be a limiting factor in turfgrass recovery. The site was fertilized twice during recovery with a total of 1.5 LBS of actual nitrogen per 1000 sq. ft. Mowing was begun at the start of the study at a height of 2.75 inches. The mowing height was reduced to 2.25 inches two weeks into the recovery period. Lowering the mowing height caused scalping the bermudagrass cultivars and this is reflected in recovery ground cover ratings (Figure 10a).

Data Collection: Data was taken, for the most part, weekly by D. Chalmers and K. Steinke. Chalmers and Steinke collected data together all but three dates during the 120 days of the drought and recovery periods, where Chalmers went to the site alone two times and Steinke once. This is mentioned to verify that methods for data observations were according to turf protocol standards witnessed repeatedly and with consensus.

Weather Conditions - Drought and Recovery

Drought period: Potential evapotranspiration (PET) totaled 13.61 inches during the drought period. If the PET was characterized every 20 days the PET for days 1-20, 21-40 and 41-60 was 5.03, 5.14 and 3.34 inches, respectively. Average high daily temperatures for days 1-20, 21-40 and 41-60 were 95.5, 97.9 and 89.1 degrees F respectively. PET for the drought period is seen in Figure 1 while Figure 2 displays maximum and minimum temperatures during the drought. Figure 3 graphs PET during the recovery period while Figure 4 graphs maximum and minimum temperatures during the 60-day recovery.

Figure 1. PET during the 60-day drought.

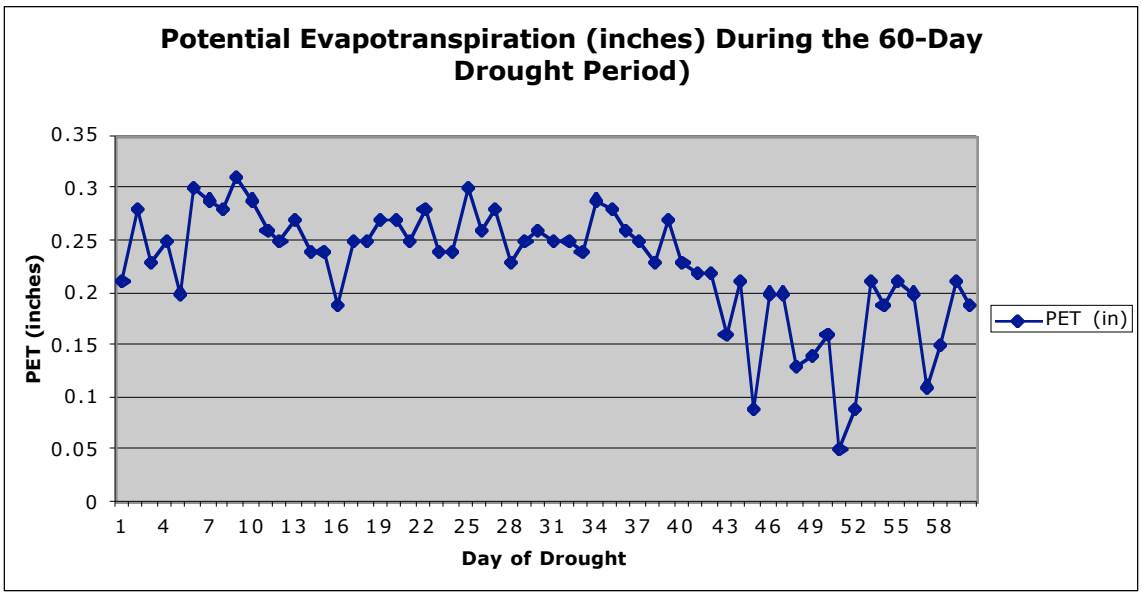


Figure 2. The daily maximum and minimum temperatures during drought.

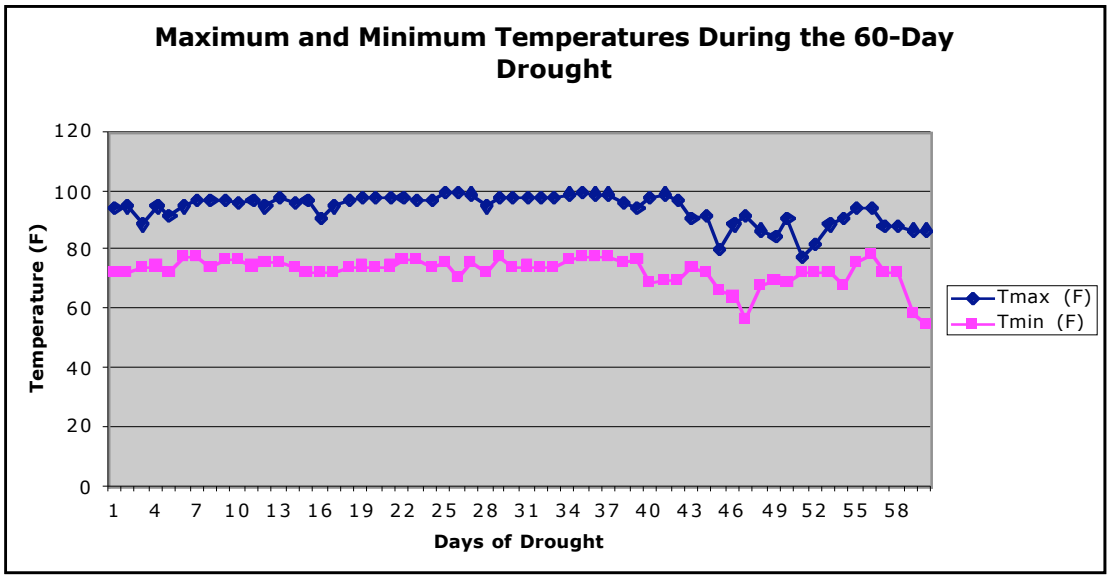


Figure 3. PET during the 60-day drought recovery.

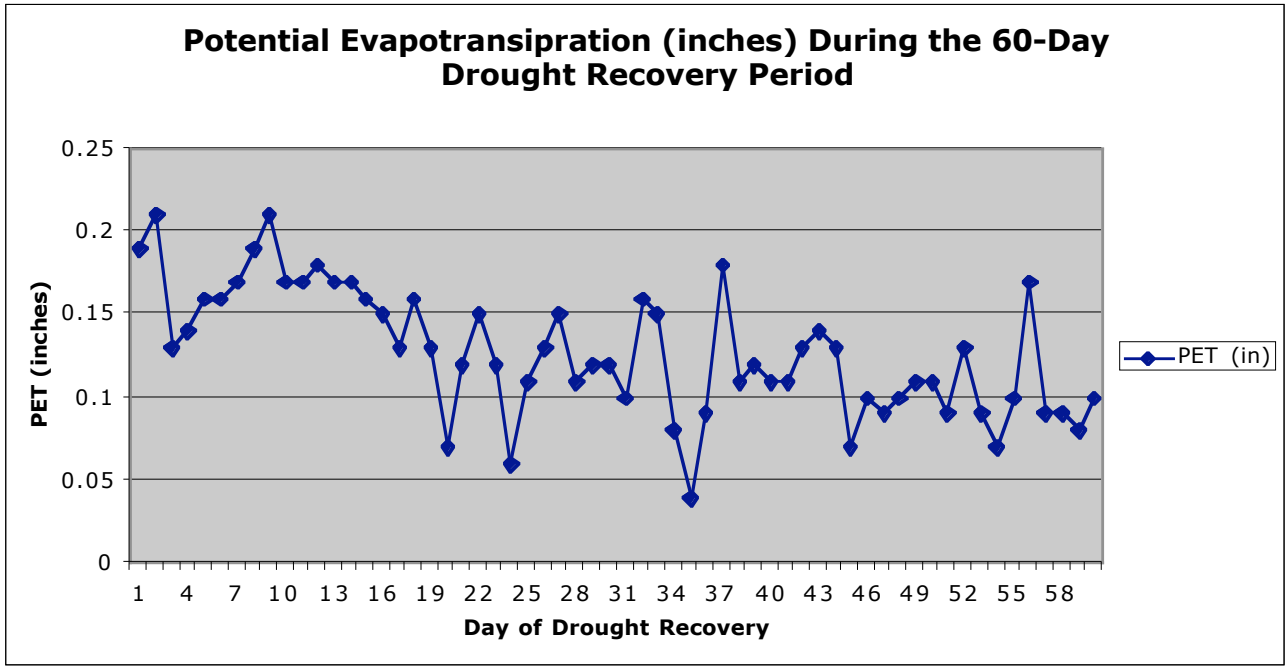


Figure 4. Maximum and minimum temperatures during drought recovery.

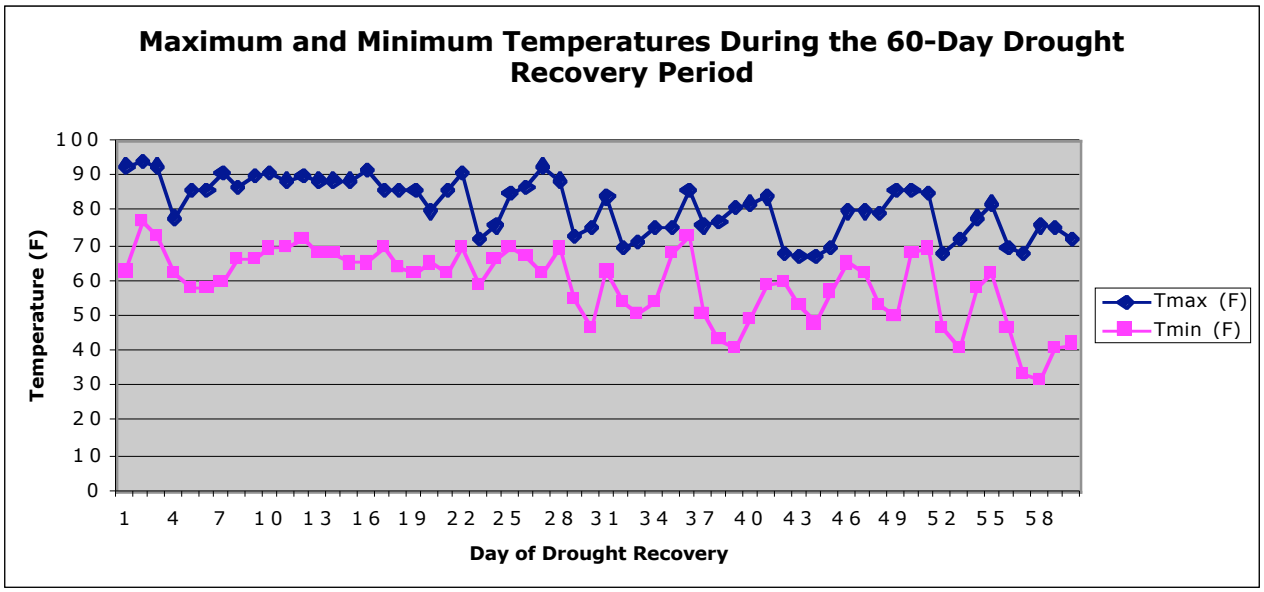


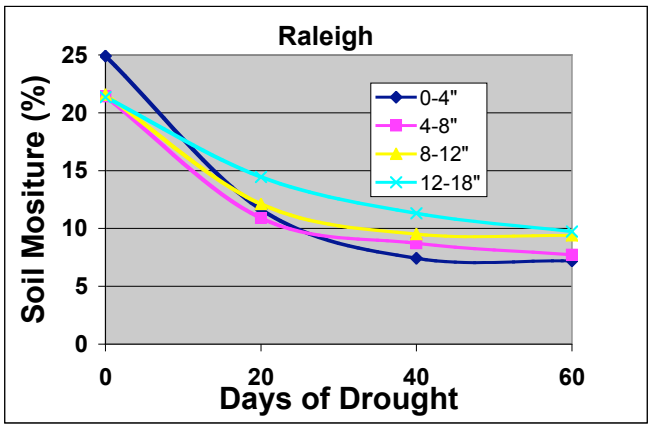
Figure 4 (above) shows how the minimum temperatures dropped below 60 degrees F in the latter half of the recovery period. In fact 22 days had minimum temperatures below 60 degrees with 13 of those days having minimum temperatures near 50 degrees or below. Hence, the 23-day delay in beginning the drought, waiting for the drought simulator to become operational, may have resulted in somewhat decreased turf recovery vigor due to chilling night temperatures.

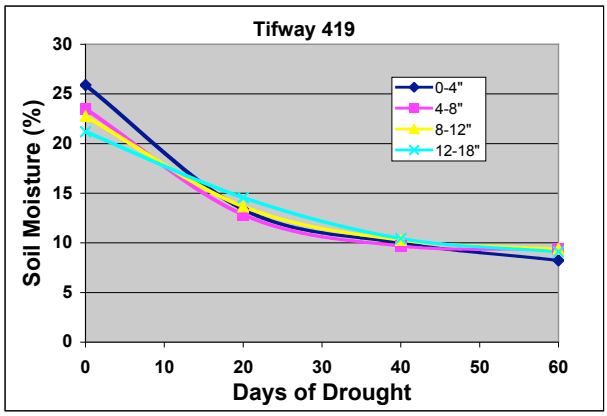
Photo caption: June 29, 2006. Turfgrass Producers of Texas Field Day at the SAWS research site. Calvin Finch (left) from SAWS, John Cosper (center) from Turfgrass Producers of Texas and David Chalmers (right) State Turfgrass Extension Specialist - Texas Cooperative Extension were on hand to discuss the study with more than 40 producers .

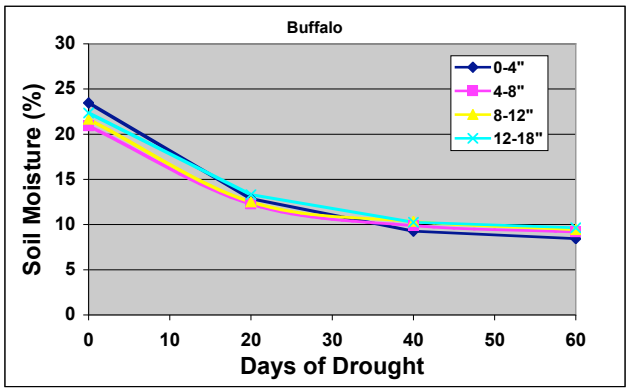
Soil Moisture Content With Soil Depth During Drought

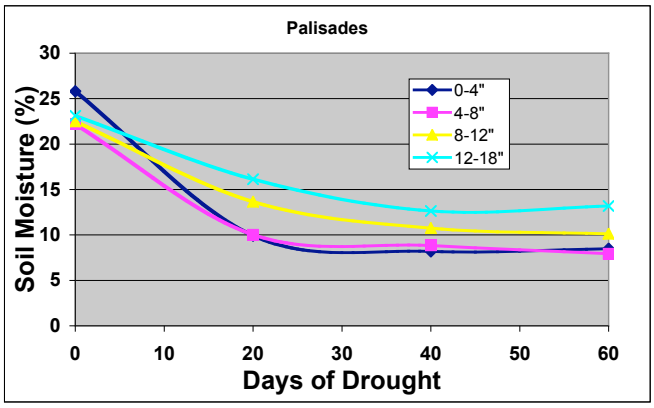
The following four charts display the percent soil moisture on Raleigh St. Augustinegrass, Tifway 419 bermudagrass, Palisades zoysiagrass and 609 buffalograss at four soil depths (0 to 4, 4 to 8, 8 to 12 and

12 to 18 inches). These samples were taken from the field plots after 0, 20, 40, and 60 days of drought. These data are for observation only yet verify soil moisture with depth during the duration of the drought.









Turfgrass Quality During Drought and Recovery

Quality is based on 9 being best and 1 being poorest. A rating of 6 or above is generally considered acceptable. A quality rating value of 9 is reserved for a perfect or ideal grass, but it also can reflect an absolutely outstanding treatment plot. Quality ratings will vary based on turfgrass species, intensity of management and time of year. Quality ratings are relative within species but not among species. Quality ratings are not based on color alone, but on a combination of color, density, uniformity, texture, and disease or environmental stress (Morris & Shearman).

Since this study is about grass drought survival and recovery, there should be great caution in the use of quality data for comparisons between grasses. This is especially important in when considering that all grasses were managed in a way to best gauge drought persistence and recovery.

Table 1. Turfgrass quality (1-9=best) for species and cultivars all species on native soil depth during the drought. Data in columns followed by the same letter are not significantly different at the 0.05 level.
Note: Table heading includes the date the data was taken followed below by the day into the drought (0 to 60).

	7/28/06	8/4/06	8/11/06	8/18/06	8/24/06	8/31/06	9/7/06	9/15/06
Bermudagrass	5	13	20	27	33	40	47	55
Celebration	5.50 b	4.75 abc	6.00 abc	6.00 ab	7.00 a	6.75 a	5.25 a	3.75 ab
Common Bermuda	5.50 b	4.75 abc	4.75 abcde	4.75 abcd	4.75 abcd	4.00 bcd	2.75 bcde	2.25 abcd
GN1	6.00 ab	5.25 abc	6.00 abc	5.50 abc	5.50 abc	5.50 abc	4.00 ab	3.00 abcd
Grimes EXP	6.00 ab	5.75 abc	6.75 a	5.25 abcd	4.50 bcde	4.00 bcd	2.50 bcde	2.25 abcd
Premier	6.25 ab	5.75 abc	4.00 bcde	3.00 de	3.00 defg	1.00 f	1.00 e	1.00 d
Tex Turf	6.50 ab	6.00 abc	5.75 abcd	5.75 abc	6.00 ab	6.25 ab	4.25 ab	4.25 a
TifSport	6.50 ab	5.75 abc	6.25 ab	6.00 ab	5.75 ab	4.75 abc	3.75 abc	2.75 abcd
Tifway 419	6.25 ab	6.25 ab	5.75 abcd	6.00 ab	6.00 ab	5.00 abc	3.50 abcd	3.00 abcd
St. Augustinegrass								
Amerishade	6.50 ab	6.50 a	5.50 abcd	4.75 abcd	3.25 cdefg	2.00 def	1.50 cde	1.50 cd
SA Common	7.00 a	5.50 abc	4.75 abcde	3.75 bcde	2.50 defg	1.50 ef	1.25 de	1.25 cd
Delmar	6.75 ab	6.00 abc	4.75 abcde	4.25 abcde	3.00 defg	2.25 def	1.50 cde	1.75 bcd
Floratam	6.50 ab	6.25 ab	6.25 ab	5.75 abc	4.00 bcdef	3.75 cde	2.25 bcde	2.75 abcd
Palmetto	6.25 ab	6.25 ab	4.75 abcde	4.25 abcde	3.00 defg	1.75 def	1.25 de	1.25 cd
Raleigh	6.50 ab	6.00 abc	4.50 abcde	4.25 abcde	2.25 efg	1.25 f	1.00 e	1.00 d
Sapphire	6.25 ab	5.75 abc	4.25 bcde	3.75 bcde	2.25 efg	1.25 f	1.25 de	1.25 cd
Zoysiagrass								
Cavalier	6.50 ab	5.25 abc	3.75 cde	3.00 de	1.00 g	1.00 f	1.00 e	1.00 d
El Toro	7.00 a	5.25 abc	3.50 de	3.50 cde	2.25 efg	1.00 f	1.00 e	1.00 d
Emerald	6.50 ab	5.75 abc	4.75 abcde	3.75 bcde	1.25 g	1.00 f	1.00 e	1.00 d
Empire	7.00 a	6.00 abc	3.75 cde	3.75 bcde	2.00 fg	1.25 f	1.00 e	1.25 cd
Jamur	6.75 ab	5.50 abc	3.50 de	3.50 cde	2.00 fg	1.00 f	1.00 e	1.00 d
Palisades	7.00 a	5.75 abc	4.00 bcde	4.00 abcde	1.75 fg	1.00 f	1.00 e	1.00 d
Y-2	6.25 ab	4.25 c	2.75 e	2.25 e	1.25 g	1.00 f	1.00 e	1.00 d
Zeon	6.25 ab	4.75 abc	3.50 de	3.00 de	1.25 g	1.00 f	1.00 e	1.00 d
Zorro	6.50 ab	4.50 bc	2.50 e	2.00 e	1.25 g	1.00 f	1.00 e	1.00 d
Buffalograss								
609	6.50 ab	6.25 ab	6.00 abc	6.25 a	5.75 ab	5.25 abc	3.50 abcd	3.25 abc

Table 2. Turfgrass quality (1-9=best) for species and cultivars on native soil depth during the recovery day 61-120). Data in columns followed by the same letter are not significantly different at the 0.05

Note: Table heading includes the date the data was taken followed below by the day into the recovery period (61 to 120).

	9/22/06	9/28/06	10/5/06	10/11/06	10/20/06	10/28/06	11/5/06	11/21/06
Bermudagrass	62	68	75	81	90	98	106	122
Celebration	4.50 ab	6.25 a	6.50 a	3.00 bcd	4.75 abc	4.50 bcd	6.00 ab	3.50 cdef
Common Bermuda	2.75 abcde	3.25 bcdefg	4.50 abc	4.25 ab	4.25 bcd	4.50 bcd	5.75 abc	4.50 bcd
GN1	3.50 abcd	4.25 abcdef	4.00 bcd	3.00 bcd	4.00 bcde	4.25 bcde	5.75 abc	3.75 bcdef
Grimes EXP	3.75 abc	4.25 abcdef	5.50 ab	4.25 ab	5.25 ab	5.00 abc	6.25 a	4.00 bcde
Premier	2.00 cde	2.00 efg	1.25 e	2.50 cd	3.00 def	3.25 cdefg	3.25 efghi	3.00 cdef
Tex Turf	4.75 a	5.50 ab	5.50 ab	3.50 bcd	4.00 bcde	4.00 bcdef	6.25 a	4.50 bcd
TifSport	3.75 abc	4.75 abcd	4.50 abc	3.75 bc	4.25 bcd	4.25 bcde	6.00 ab	4.50 bcd
Tifway 419	4.00 abc	4.50 abcde	4.50 abc	3.25 bcd	4.25 bcd	4.25 bcde	6.00 ab	5.25 abc
St. Augustinegrass								
Amerishade	2.00 cde	2.50 cdefg	2.50 cde	2.75 bcd	3.00 def	2.75 defg	2.75 fghi	3.25 cdef
SA Common	2.00 cde	2.25 defg	2.50 cde	3.00 bcd	3.50 cdef	3.25 cdefg	3.75 efgh	4.00 bcde
Delmar	2.25 bcde	2.50 cdefg	2.50 cde	3.00 bcd	3.00 def	3.00 defg	3.00 efghi	3.25 cdef
Floratam	3.25 abcde	4.25 abcdef	4.00 bcd	4.25 ab	5.25 ab	5.75 ab	5.50 abcd	6.00 ab
Palmetto	2.00 cde	2.25 defg	2.50 cde	2.50 cd	3.25 cdef	3.00 defg	3.25 efghi	3.50 cdef
Raleigh	1.75 cde	2.00 efg	2.00 de	2.50 cd	2.50 ef	2.50 efg	2.50 ghi	2.50 def
Sapphire	2.00 cde	2.00 efg	2.00 de	2.25 cd	2.25 f	2.25 fg	2.25 hi	1.75 ef
Zoysiagrass								
Cavalier	1.00 e	1.50 g	1.25 e	2.00 d	2.00 f	2.50 efg	2.50 ghi	2.25 def
El Toro	2.00 cde	2.00 efg	2.25 de	3.00 bcd	3.50 cdef	3.50 cdefg	4.00 defg	3.50 cdef
Emerald	1.00 e	1.00 g	1.00 e	2.00 d	2.00 f	2.00 g	2.00 i	2.25 def
Empire	1.75 cde	2.25 defg	2.25 de	3.25 bcd	3.50 cdef	3.25 cdefg	4.25 cdef	4.00 bcde
Jamur	2.00 cde	2.00 efg	2.50 cde	3.00 bcd	3.50 cdef	3.75 cdefg	4.50 bcde	4.00 bcde
Palisades	2.00 cde	2.00 efg	2.25 de	3.25 bcd	3.50 cdef	3.50 cdefg	4.25 cdef	4.50 bcd
Y-2	1.25 de	1.25 g	1.00 e	2.00 d	2.00 f	2.00 g	1.75 i	1.50 f
Zeon	2.00 cde	1.75 fg	1.25 e	2.25 cd	2.25 f	2.25 fg	2.25 hi	2.00 ef
Zorro	1.00 e	1.00 g	1.00 e	2.00 d	2.00 f	2.25 fg	2.00 i	2.50 def
Buffalograss								
609	4.00 abc	5.00 abc	6.00 ab	5.75 a	6.25 a	6.50 a	7.00 a	7.00 a

Figure 5. Turfgrass quality for all species, comparing native soil depth with four-inch soil depth. Grasses planted on the four-inch soil profile did not recover from the 60-day drought.

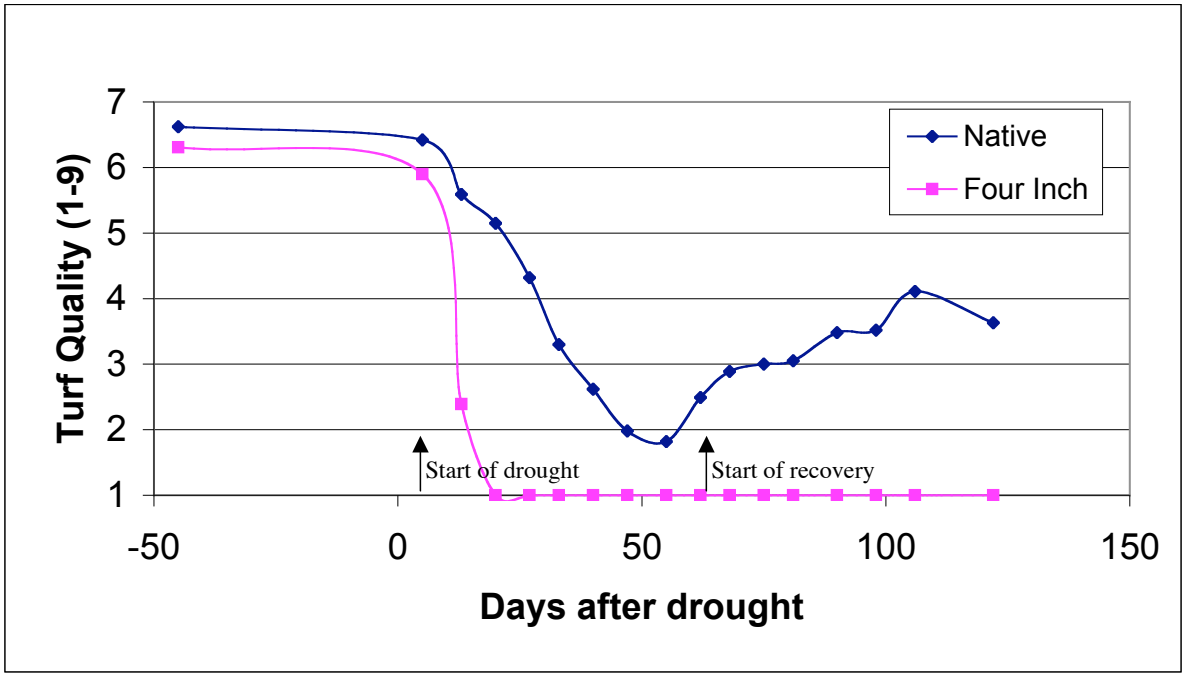


Figure 6a. Turfgrass Quality graphed for buffalograss and bermudagrass cultivars prior to, during drought and during the recovery periods. Data reference is Tables 1 and 2.

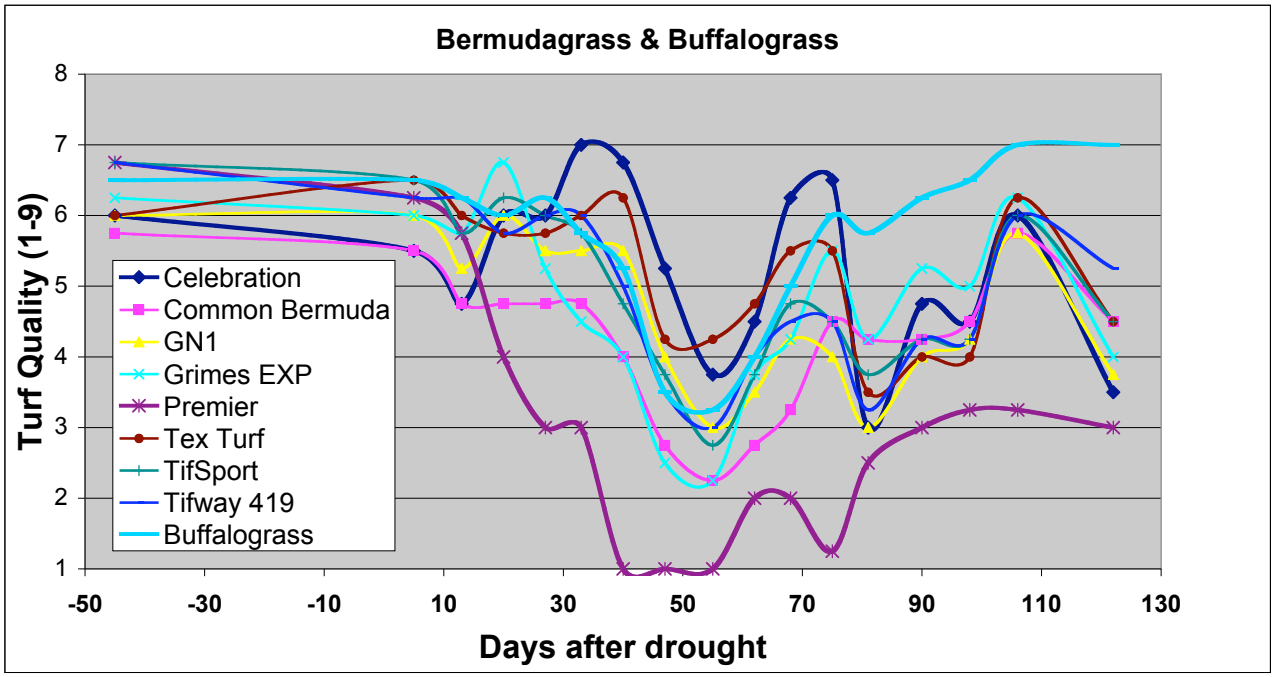


Figure 6b. Turfgrass Quality graphed for St. Augustinegrass cultivars prior to, during drought and during the recovery periods. Data reference is Tables 1 and 2.

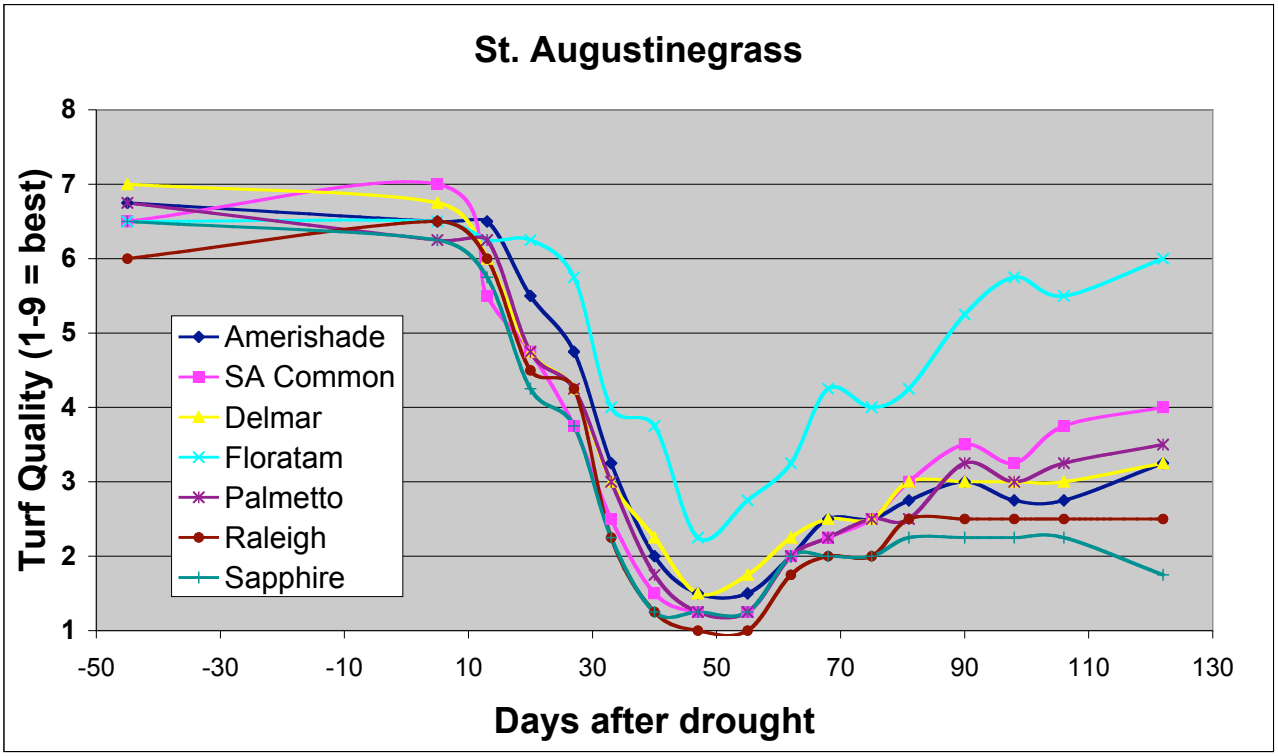
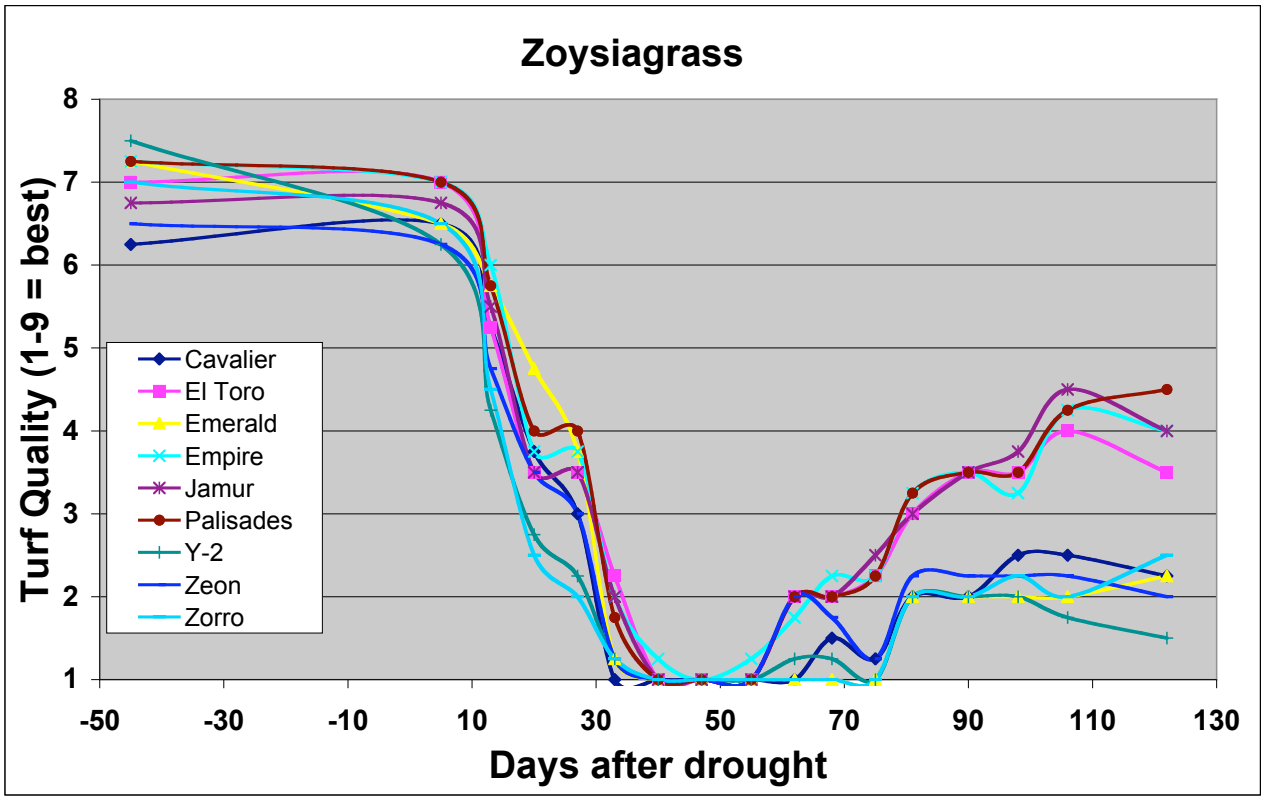


Figure 6c. Turfgrass Quality graphed for zoysiagrass cultivars prior to, during drought and during the recovery periods. Data reference is Tables 1 and 2.



Color Ratings

Color retention ratings are a measure of overall plot color. The scale used is 1 to 9 scale with 1 being straw brown and 9 being dark green. (Morris & Shearman).

Table 3. Turfgrass color (1-9=best) for species and cultivars on native soil depth during the drought. Data in columns followed by the same letter are not significantly different at the 0.05 level. *Note: Table heading includes the date the data was taken followed below by the day into the drought (0 to 60).*

NATIVE SOIL ONLY	6/15/06	8/5/06	8/12/06	8/19/06	8/25/06	9/1/06	9/8/06	9/16/06
Bermudagrass	-39	13	20	27	33	40	47	55
Celebration	6.25 abc	6.50 abc	6.25 ab	6.50 a	7.25 a	5.75 a	5.25 a	2.75 abc
Common Bermuda	5.50 c	4.75 cde	4.75 abcde	5.25 abcd	4.25 bcde	4.00 abc	2.75 bcdef	2.00 abc
GN1	6.00 bc	6.25 abc	6.50 a	5.75 abc	5.75 abc	4.75 ab	3.25 abcde	2.50 abc
Grimes EXP	6.00 bc	5.25 bcde	6.00 abc	5.75 abc	4.25 bcde	3.75 abcd	2.50 bcdef	2.25 abc
Premier	7.25 a	5.50 abcde	3.50 defg	3.00 efg	2.25 efg	1.00 d	1.00 f	1.00 c
Tex Turf	6.75 ab	6.00 abcd	5.75 abc	6.00 ab	6.25 ab	6.00 a	4.50 ab	3.50 a
TifSport	7.25 a	6.75 ab	6.00 abc	6.00 ab	6.00 abc	5.25 a	3.50 abcd	3.00 ab
Tifway 419	7.00 ab	6.75 ab	6.00 abc	6.00 ab	6.25 ab	5.25 a	3.25 abcde	2.50 abc
St. Augustinegrass								
Amerishade	7.00 ab	7.25 a	5.50 abcd	4.50 bcde	3.00 defg	2.00 bcd	1.50 def	1.50 bc
SA Common	7.00 ab	5.75 abcd	4.75 abcde	3.50 defg	2.25 efg	1.50 cd	1.25 ef	1.25 bc
Delmar	7.00 ab	6.00 abcd	4.50 abcde	4.00 cdef	2.50 efg	2.00 bcd	1.50 def	1.25 bc
Floratam	7.00 ab	6.50 abc	5.75 abc	5.25 abcd	3.75 cdef	3.50 abcd	2.25 cdef	2.25 abc
Palmetto	6.75 ab	6.25 abc	4.75 abcde	3.75 defg	2.50 efg	2.00 bcd	1.25 ef	1.00 c
Raleigh	6.50 abc	6.25 abc	4.00 cdefg	3.50 defg	2.25 efg	1.25 cd	1.00 f	1.00 c
Sapphire	7.00 ab	5.75 abcd	4.50 abcde	3.75 defg	2.00 efg	1.25 cd	1.25 ef	1.00 c
Zoysiagrass								
Cavalier	6.50 abc	4.75 cde	3.25 efg	2.50 fg	1.00 g	1.00 d	1.00 f	1.00 c
El Toro	7.00 ab	5.50 abcde	3.00 efg	3.00 efg	1.50 fg	1.00 d	1.00 f	1.00 c
Emerald	7.00 ab	6.25 abc	4.25 bcdef	3.50 defg	1.25 g	1.00 d	1.00 f	1.00 c
Empire	7.25 a	6.00 abcd	3.50 defg	3.25 efg	1.50 fg	1.25 cd	1.00 f	1.25 bc
Jamur	7.00 ab	5.25 bcde	3.00 efg	2.75 efg	1.50 fg	1.00 d	1.00 f	1.00 c
Palisades	7.00 ab	6.00 abcd	3.50 defg	3.25 efg	1.25 g	1.00 d	1.00 f	1.00 c
Y-2	7.00 ab	3.75 e	2.0 g	2.00 g	1.00 g	1.00 d	1.00 f	1.00 c
Zeon	6.50 abc	4.25 de	3.00 efg	2.25 fg	1.00 g	1.00 d	1.00 f	1.00 c
Zorro	7.00 ab	4.25 de	2.25 fg	2.00 g	1.00 g	1.00 d	1.00 f	1.00 c
Buffalograss								
609	6.75 ab	5.75 abcd	4.50 abcde	5.75 abc	5.25 abcd	5.50 a	3.75 abc	3.00 ab

Figure 7a. Turfgrass color graphed for bermudagrass and buffalograss cultivars prior to and during drought. Data reference is Table 3.

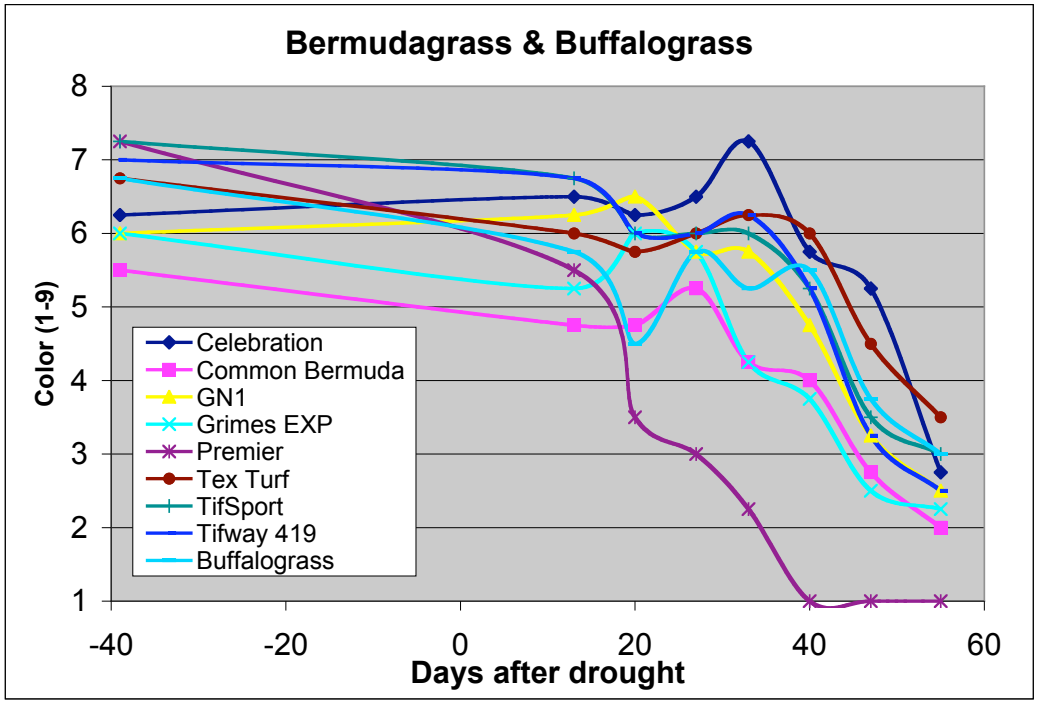


Figure 7b. Turfgrass color graphed for St. Augustinegrass cultivars prior to and during drought. Data reference is Table 3.

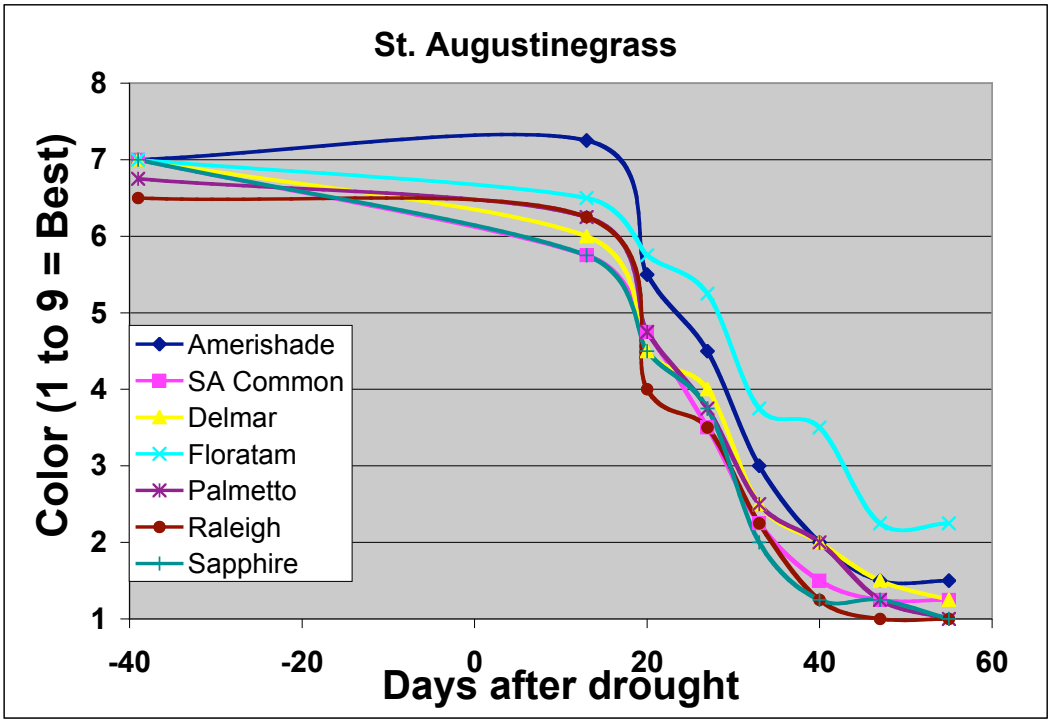
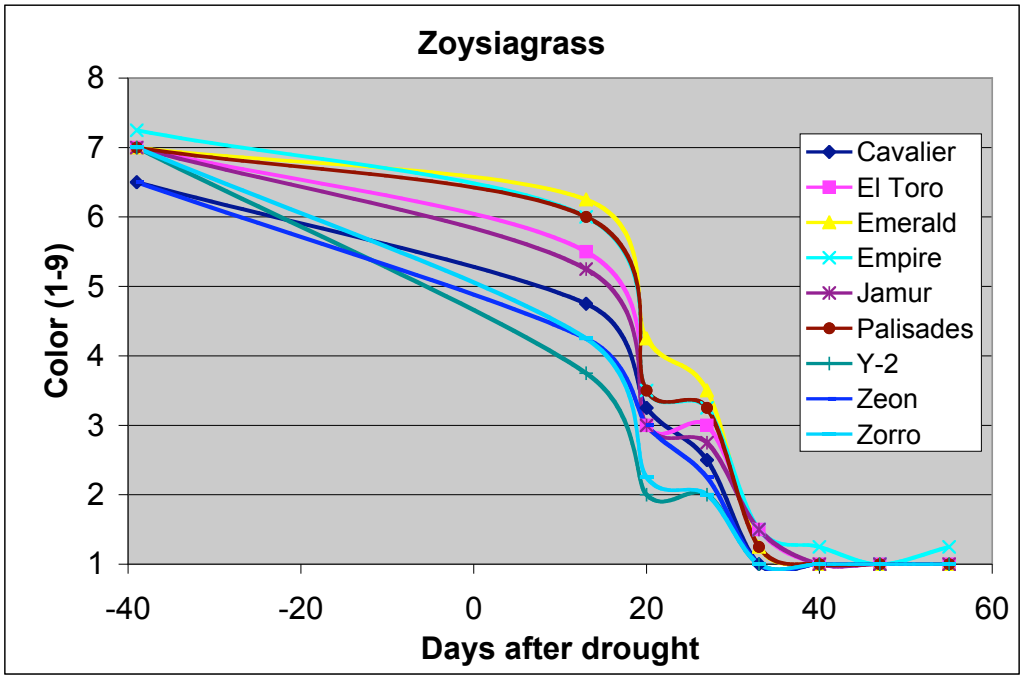


Figure 7c. Turfgrass color graphed for zoysiagrass cultivars prior to and during drought. Data reference is Table 3.



Results: The loss of turf color was seen during the 60-day drought. The trend for color loss mirrors the data on leaf firing ratings during the drought. Comparisons between grasses within species are only valid using the mean separation order from Table 3.

Leaf Firing. Leaf firing is used to indicate drought stress resistance. Leaf firing is a visual browning of leaves due to a loss of chlorophyll, the green pigment in plants, that is caused by excessive stress. Leaf firing is a visual rating that is used to evaluate plant stress. A 1 to 9 visual rating scale is used with 1 being 100% leaf firing, complete dormancy or no plant recovery; and 9 being no leaf firing or 100% green-no dormancy (Morris & Shearman). The image to the left was taken 20 days into the drought period. The browned off large blocks are where the grasses were planted over the 4-inches of soil. Those plots have completely fired. This is a time when the zoysiagrass plots are beginning to brown off first. The data from leaf firing during the drought period is in Table 4.

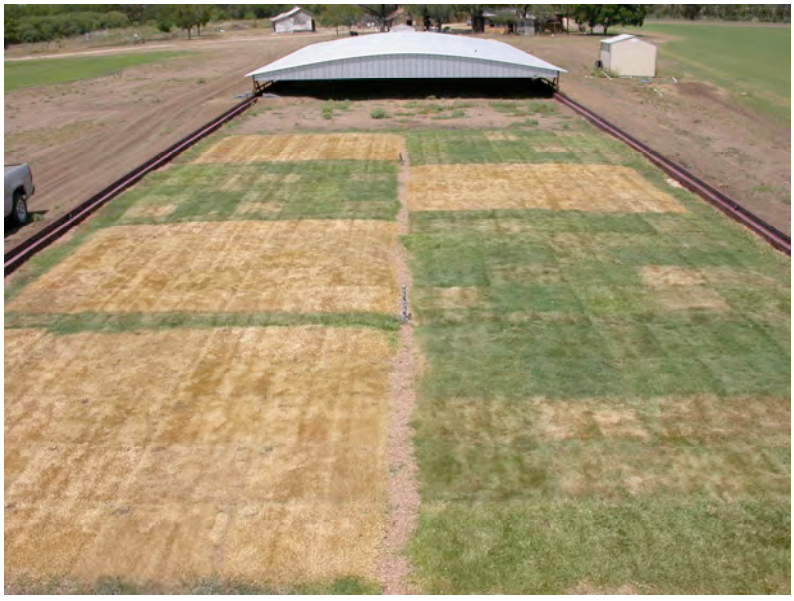


Table 4. Turfgrass leaf firing (1 to 9, where 9 equals no firing) for species and cultivars on native soil depth during the drought. Data in columns followed by the same letter are not significantly different at the 0.05 level. *Note: Table heading includes the date the data was taken followed below by the day into the drought (0 to 60).*

NATIVE SOIL ONLY	8/4/06 13	8/11/06 20	8/18/06 27	8/24/06 33	8/31/06 40	9/7/06 47	9/15/06 55
Bermudagrass							
Celebration	9.00 a	8.00 ab	8.00 a	8.75 a	7.50 a	7.00 a	3.75 ab
Common Bermuda	9.00 a	7.50 abcd	6.50 abcd	6.00 abcd	5.00 bc	3.75 bcdef	2.25 bc
GN1	9.00 a	8.00 ab	7.25 abc	7.00 abc	5.75 abc	4.75 abcde	3.25 abc
Grimes EXP	9.00 a	7.75 abc	6.50 abcd	5.75 bcd	5.00 bc	3.50 bcdef	2.75 abc
Premier	8.75 a	5.00 efgh	4.00 efgh	2.00 f	2.00 de	1.00 e	1.00 c
Tex Turf	9.00 a	7.75 abc	7.50 ab	7.75 abc	7.00 ab	6.25 ab	5.00 a
TifSport	9.00 a	7.75 abc	7.25 abc	8.00 ab	6.50 ab	5.00 abcd	4.25 ab
Tifway 419	9.00 a	8.00 ab	7.75 ab	7.75 abc	6.25 ab	4.75 abcde	4.00 ab
St. Augustinegrass							
Amerishade	8.50 a	6.75 abcde	5.50 bcdef	3.50 def	2.50 de	1.50 e	1.25 c
SA Common	8.00 a	5.75 cdef	4.50 defgh	2.50 ef	2.00 de	1.75 ef	1.00 c
Delmar	8.50 a	5.50 def	4.75 defg	2.75 ef	2.25 de	2.00 def	1.25 c
Floratam	8.75 a	**6.50 abcdef**	6.25 abcde	5.00 cde	3.75 cd	3.00 cdef	2.25 bc
Palmetto	8.75 a	6.00 bcdef	4.75 defg	2.75 ef	2.00 de	1.75 ef	1.00 c
Raleigh	7.75 a	5.75 cdef	4.50 defgh	2.75 ef	2.00 de	1.25 e	1.00 c
Sapphire	8.50 a	5.50 def	4.50 defgh	2.25 ef	2.00 de	1.25 e	1.00 c
Zoysiagrass							
Cavalier	7.50 a	4.50 fgh	3.50 fgh	1.00 f	1.00 e	1.00 e	1.00 c
El Toro	7.25 a	4.50 fgh	4.00 efgh	1.75 f	1.50 de	1.00 e	1.00 c
Emerald	8.50 a	6.50 abcdef	5.00 cdef	1.25 f	1.00 e	1.00 e	1.00 c
Empire	8.25 a	5.25 efg	4.00 efgh	1.50 f	1.25 e	1.00 e	1.00 c
Jamur	8.00 a	4.50 fgh	3.75 fgh	1.50 f	1.50 de	1.00 e	1.00 c
Palisades	8.00 a	5.00 efgh	4.25 defgh	1.75 f	1.25 e	1.00 e	1.00 c
Y-2	6.25 a	3.00 h	2.50 gh	1.00 f	1.00 e	1.00 e	1.00 c
Zeon	6.75 a	5.00 efgh	3.50 fgh	1.00 f	1.00 e	1.00 e	1.00 c
Zorro	7.00 a	3.25 gh	2.25 h	1.00 f	1.00 e	1.00 e	1.00 c
Buffalograss							
609	7.00 a	8.25 a	7.50 ab	6.75 abc	6.00 abc	5.25 abc	3.75 ab

Figure 8a. Turfgrass leaf firing graphed for zoysiagrass cultivars during drought. Data reference is Table 4.

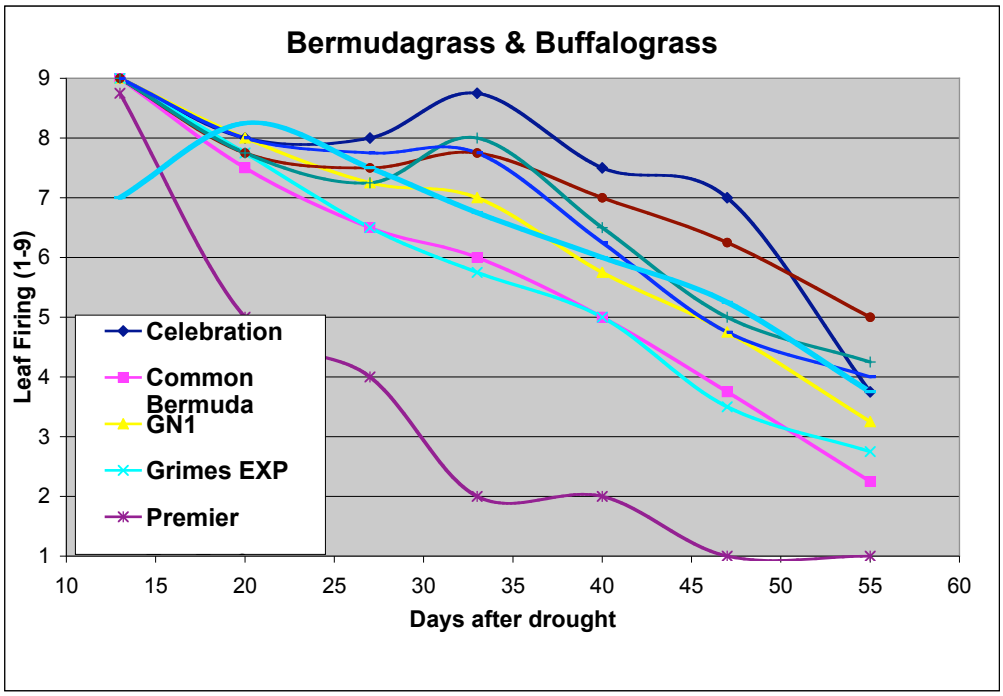


Figure 8b. Turfgrass leaf firing graphed for St. Augustinegrass cultivars during drought. Data reference is Table 4.

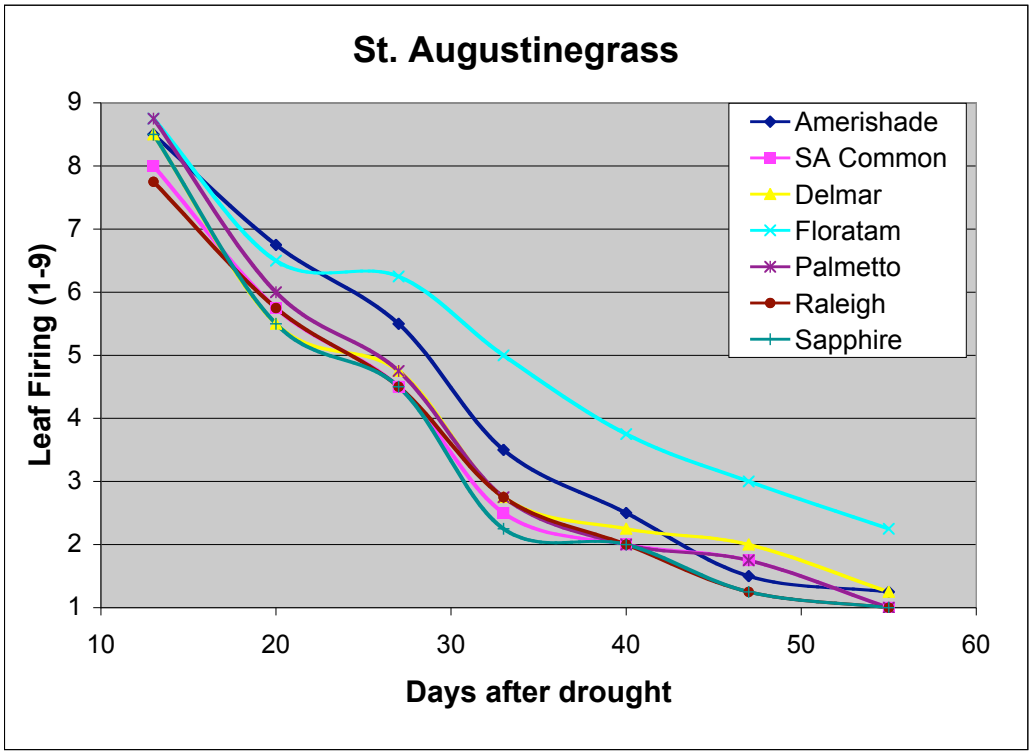


Figure 8c. Turfgrass leaf firing graphed for zoysiagrass cultivars during drought. Data reference is Table 4.

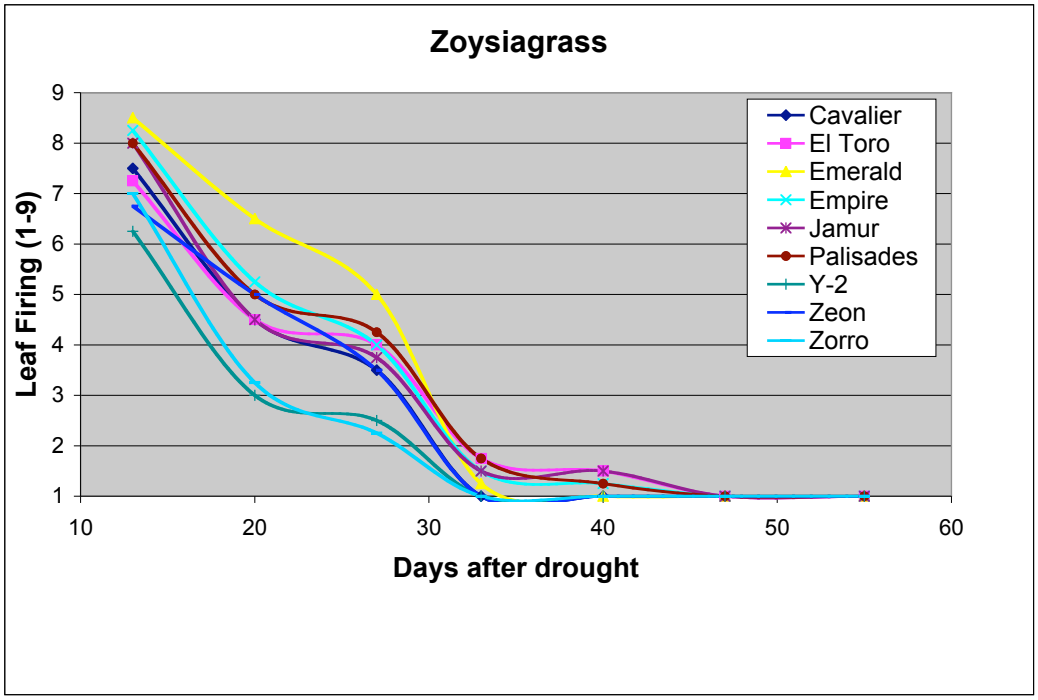
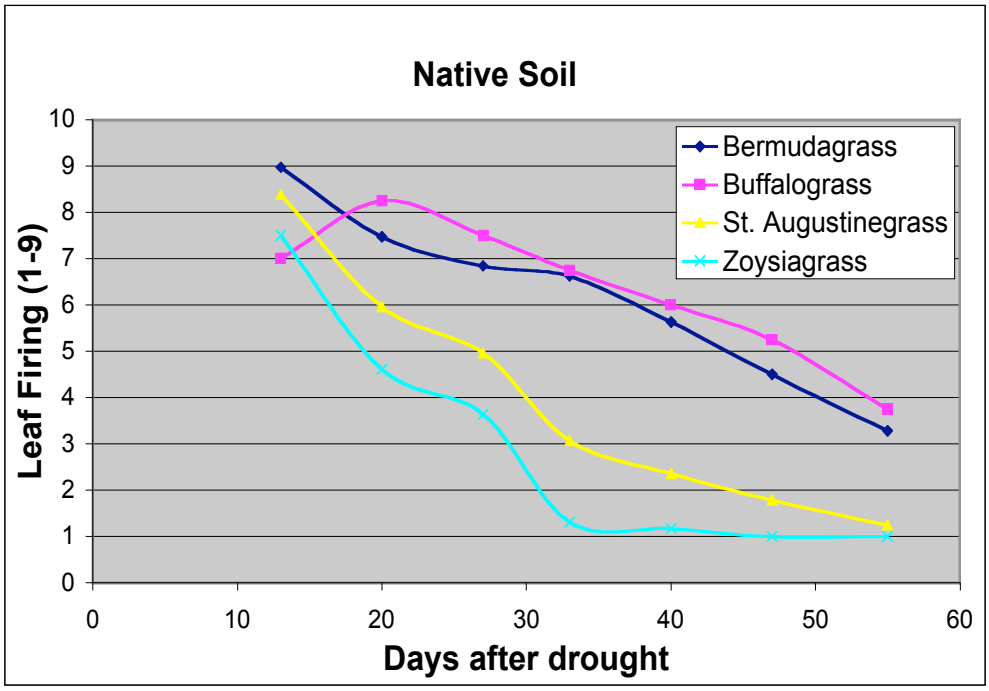


Table 5. Leaf firing data (using a scale of 1 to 9, where 9 equals no leaf firing and 1 equals complete firing) summarized by species for observation dates during drought. Data in columns followed by the same letter are not significantly different at the 0.05 level. *Note:Table heading includes the date the data was taken followed below by the day into the drought (0 to 60).*

NATIVE SOIL ONLY	8/4/06 13	8/11/06 20	8/18/06 27	8/24/06 33	8/31/06 40	9/7/06 47	9/15/06 55
Bermudagrass	8.97 a	7.47 a	6.84 a	6.62 a	5.63 a	4.50 a	3.28 a
Buffalograss	7.00 b	8.25 a	7.50 a	6.75 a	6.00 a	5.25 a	3.75 a
St. Augustinegrass	8.39 a	5.96 b	4.96 b	3.07 b	2.36 b	1.79 b	1.25 b
Zoysiagrass	7.50 b	4.61 c	3.64 c	1.31 c	1.17 b	1.00 b	1.00 b

Figure 9. Leaf firing data summarized by species for observation dates during drought. Data reference is Table 5.



Drought Recovery - Percent Living Ground Cover and Uniformity

The Second Day of a 60-Day Recovery Period is pictured here (and on the cover page) on September 22, 2006. During the recovery period the data collection focused upon percent living ground cover (Table 6, 7 and Figures 10 a, 10b, and 10c) and plot quality (Table 2, and Figures 6a, 6b and 6c). Data collection occurred approximately every 7 days during the recovery period. The one exception was the period of time between the second to last and final data collection. The final data collection included uniformity of plot recovery. Recovery may have been impaired by the 23-day delay in staring the drought. Figure 4 shows the frequency with which the daily minimum temperature dropped below 60 degrees F, during the last half of the recovery period, which may have slowed re-growth.

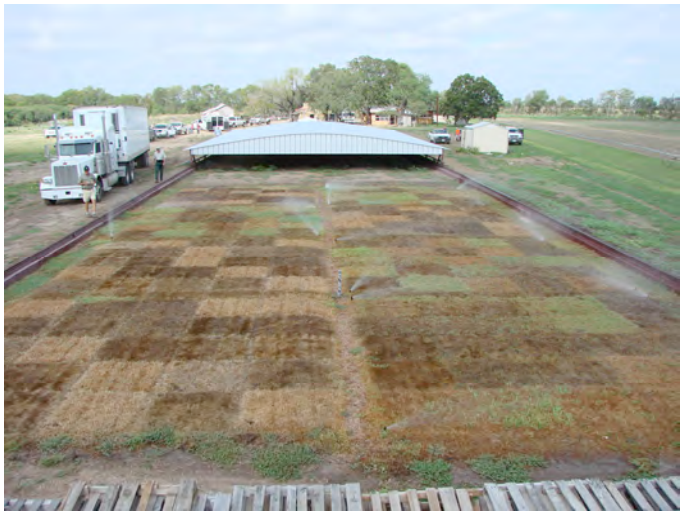


Table 6. Turfgrass percent living ground cover ratings on native soil depth during recovery. Data in columns followed by the same letter are not significantly different at the 0.05 level. *Note: Table heading includes the date the data was taken followed below by the day into the recovery period (61 to 120).*

	9/22/06	9/28/06	10/5/06	10/11/06	10/20/06	10/28/06	11/5/06	11/21/06
Bermudagrass	62	68	75	81	90	98	106	122
Celebration	71.25 a	91.25 a	95.00 a	27.50 bcde	73.75 ab	86.25 a	92.50 a	100.00 a
Common Bermuda	16.25 bcde	37.50 bcdef	80.00 ab	50.00 b	60.00 ab	83.75 a	87.50 ab	98.75 ab
GN1	29.50 abcde	50.00 abcde	53.75 b	20.00 cdef	51.25 bc	78.75 a	87.50 ab	98.75 ab
Grimes EXP	40.50 abcde	52.50 abcd	77.50 ab	47.50 b	71.25 ab	90.00 a	93.75 a	100.00 a
Premier	1.00 de	2.50 f	4.25 d	5.50 ef	16.25 d	28.75 cde	37.50 def	57.50 bcdefgh
Tex Turf	68.75 a	86.25 a	90.00 a	33.75 bcd	55.00 ab	81.25 a	92.50 a	97.50 ab
TifSport	48.75 abc	61.25 ab	77.50 ab	28.75 bcde	66.25 ab	80.00 a	93.75 a	97.50 ab
Tifway 419	50.00 ab	56.25 abc	68.75 ab	33.75 bcd	66.25 ab	83.75 a	92.50 a	98.75 ab
St. Augustinegrass								
Amerishade	7.50 cde	13.75 def	13.75 cd	15.00 def	26.25 cd	21.25 cde	25.00 defg	42.50 efghij
SA Common	3.75 de	8.75 ef	10.00 d	16.25 def	22.50 d	21.25 cde	30.00 defg	55.00 cdefghi
Delmar	10.50 bcde	16.25 cdef	13.75 cd	15.00 def	21.25 d	21.25 cde	25.00 defg	37.50 efghij
Floratam	20.00 bcde	40.00 bcdef	46.25 bc	43.75 bc	68.75 ab	72.50 ab	77.5 abc	88.75 abcd
Palmetto	4.00 de	8.75 ef	10.00 d	13.75 def	17.50 d	18.75 cde	27.50 defg	51.25 defghi
Raleigh	1.75 de	4.75 f	5.50 d	7.50 ef	8.75 d	11.25 de	12.50 fg	25.00 ghij
Sapphire	2.75 de	4.75 f	5.50 d	5.50 ef	6.75 d	9.50 de	11.25 fg	17.50 hij
Zoysiagrass								
Cavalier	0.25 e	2.00 f	2.25 d	3.50 f	6.25 d	8.75 de	15.00 efg	27.50 fghij
El Toro	1.00 de	7.50 f	13.75 cd	15.00 def	21.25 d	35.00 cd	47.50 cde	62.50 abcdefg
Emerald	0.00 e	0.75 f	1.00 d	2.75 f	3.75 d	5.00 de	7.50 fg	25.00 ghij
Empire	2.00 de	8.75 ef	12.50 cd	17.50 def	26.25 cd	31.25 cde	48.75 cd	71.25 abcde
Jamur	1.50 de	7.50 f	10.00 d	16.25 def	21.25 d	42.50 bc	55.00 bcd	68.75 abcdef
Palisades	1.25 de	4.50 f	10.00 d	17.50 def	23.75 d	35.00 cd	48.75 cd	71.25 abcde
Y-2	0.50 de	2.00 f	2.00 d	2.75 f	2.25 d	3.75 e	2.00 g	4.25 j
Zeon	6.75 cde	1.00 f	1.25 d	2.75 f	5.75 d	6.25 de	5.50 fg	17.50 hij
Zorro	0.25 e	1.00 f	2.00 d	2.25 f	4.50 d	5.00 de	5.00 fg	15.00 ij
Buffalograss								
609	42.50 abcd	66.25 ab	80.00 ab	82.50 a	80.00 a	90.00 a	93.75 a	95.00 abc

Figure 10a. Living ground cover ratings for bermudagrass and buffalograss cultivars during the 60-day recovery period following the 60-day drought. Data reference is Table 6. Note: the downward "dip" in living ground cover was due to lowering the mowing height which scalped the bermudagrass cultivars.

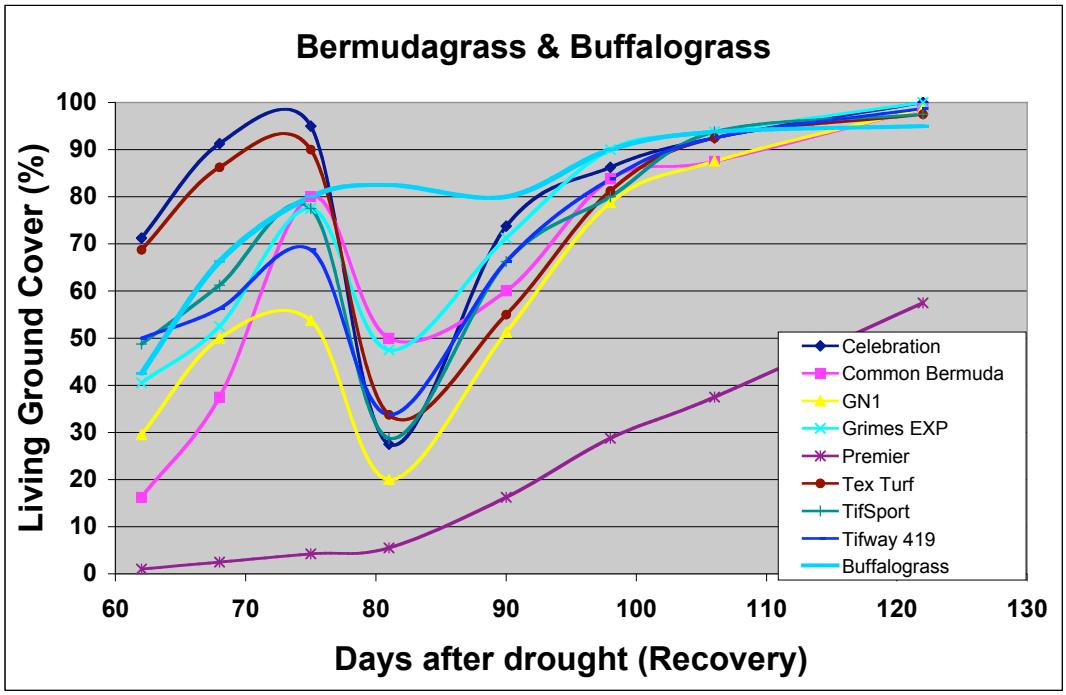


Figure 10b. Living ground cover ratings for St. Augustinegrass cultivars during the 60-day recovery period following the 60-day drought. Data reference is Table 6.

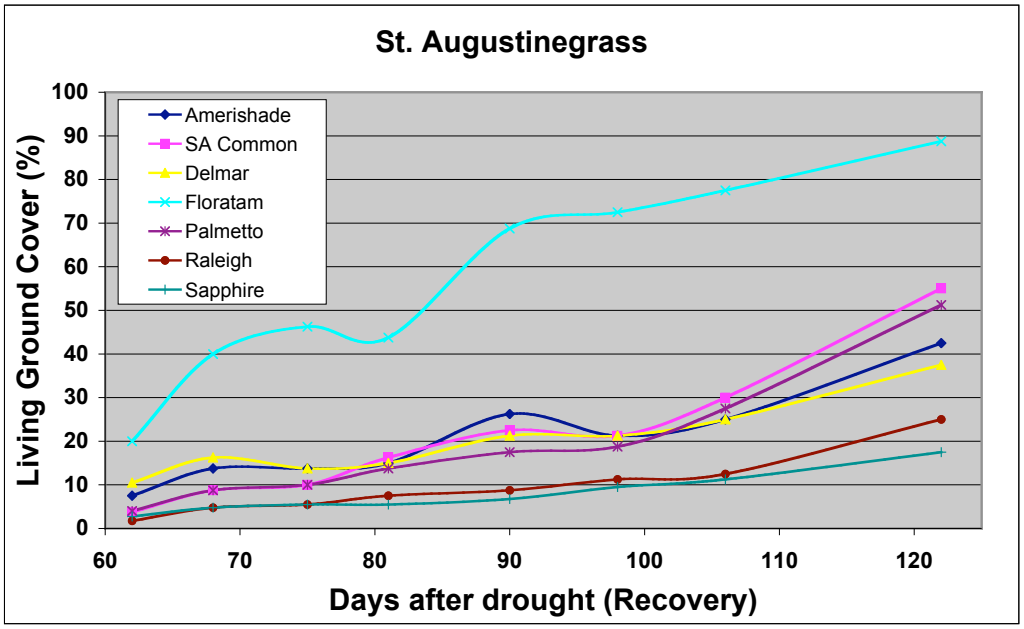
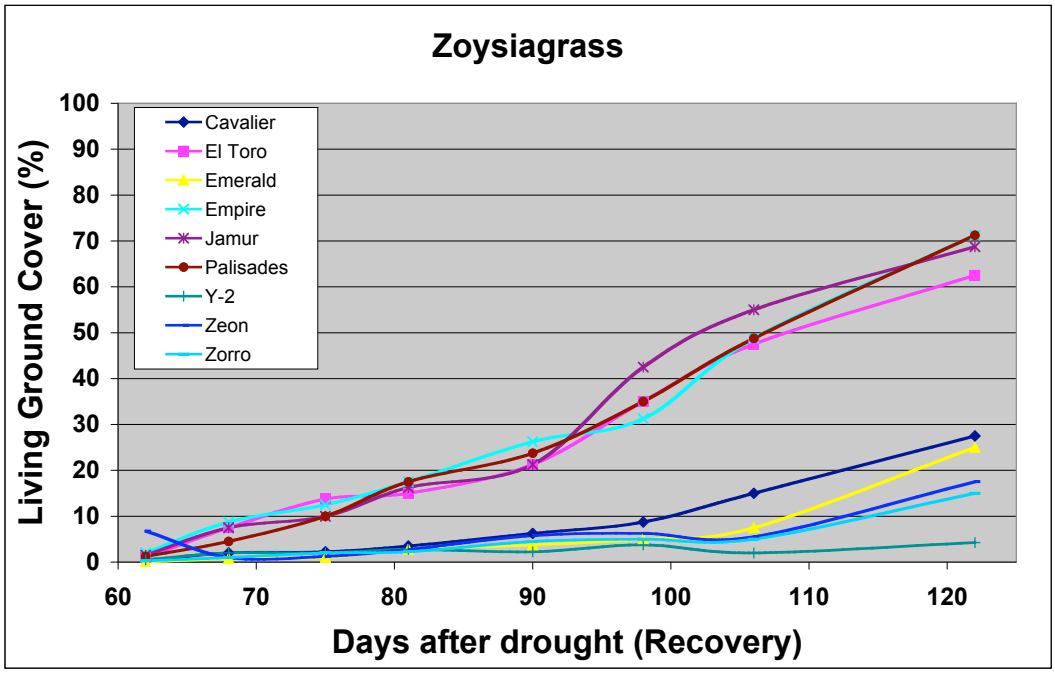


Figure 10c. Living ground cover ratings for zoysiagrass cultivars during the 60-day recovery period following the 60-day drought. Data reference is Table 6.



End of Recovery Period: Percent Living Ground Cover and Recovery Uniformity

One end product of the Year 1 experiment resulted in grasses unable to survive 2006 drought conditions on the constructed 4-inch soil depth. All grasses survived on the native, unrestricted soil depth. Yet, differences in survival on native soil did exist between grasses. Cultivar survival ranged from just over 4 percent for Y-2 zoysiagrass to 100 percent for two bermudagrass cultivars (Table 6 and Table 7). For comparison purposes the end of recovery data is presented in Table 7. The percent recovery resulted in large statistical groupings of grasses. For example the plot recovery in Y-2 zoyziagrass is not statistically different from the grasses in ascending order through Amerishade St. Augstinegrass at 42.5% living ground cover. Another example, in descending order, groups the grass cultivar having 95 % recovery as similar to grass cultivars with equal to or greater than 55% recovery living ground cover.

The data under the heading "Uniformity" in Table 7 represents how well each cultivar had recovered throughout the planted area. These data might provide insight into how grasses might recover; 1) if the grass exhibits a true physiological dormancy mechanism to shut down growth under prolonged moisture stress, 2) that it may be drought tolerant in the absence of a dormancy mechanism, or 3) that it

might escape drought by finding channels in a shrink-swell soil to allow for deeper rooting. The grouping associated with the top uniformity ranking of 9 is similar in recovery uniformity in descending order to include grasses ranked 6 or higher. Throughout the study the bermudagrass and buffalograss cultivars did well in resisting drought and recovering from the drought. Floratam St. Augustinegrass, when compared to other St. Augustinegrass cultivars, persisted well into the drought and was in the top grouping for drought recovery. This clearly demonstrates that grass cultivars within a species can indeed perform differently than others in the group. Recent examples of municipalities wanting to "ban" or "outlaw" all St. Augustinegrasses in efforts at water conservation would lose an important cultivar in the case of St. Augustinegrass. Shade tolerance, a characteristic of St. Augustinegrass, is desirable and cannot be overlooked in selecting grasses for shaded Texas landscapes.

Table 7. End of recovery period percent living ground cover and uniformity of plot recovery. Data in columns followed by the same letter are not significantly different at the 0.05 level.

Cultivar		11/22/06 % Recovery	11/22/06 Stat. Grouping	11/22/06 Uniformity
Celebration	BM	**100.0**	a	**9.00 a**
Grimes EXP	BM	**100.0**	a	**9.00 a**
Common Bermuda	BM	**98.8**	ab	**9.00 a**
GN1	BM	**98.8**	ab	**9.00 a**
Tifway 419	BM	**98.8**	ab	**9.00 a**
Tex Turf	BM	**97.5**	ab	**9.00 a**
TifSport	BM	**97.5**	ab	**9.00 a**
Buffalograss	BU	**95.0**	abc	**9.00 a**
Floratam	SA	**88.8**	abcd	**8.50 a**
Empire	Z	**71.3**	abcde	**8.50 a**
Palisades	Z	**71.3**	abcde	**8.50 a**
Jamur	Z	**68.8**	abcdef	**8.25 a**
El Toro	Z	**62.5**	abcdefg	**8.50 a**
Premier	BM	**57.5**	bcdefgh	**7.25 ab**
SA Common	SA	**55.0**	cdefghi	**6.00 abc**
Palmetto	SA	**51.3**	defghi	**4.75 bc**
Amerishade	SA	**42.5**	efghij	**4.50 bc**
Delmar	SA	**37.5**	efghij	**4.75 bc**
Cavalier	Z	**27.5**	fghij	**6.75 ab**
Raleigh	SA	**25.0**	ghij	**4.50 bc**
Emerald	Z	**25.0**	ghij	**7.25 ab**
Sapphire	SA	**17.5**	hij	**3.00 c**
Zeon	Z	**17.5**	hij	**6.75 ab**
Zorro	Z	**15.0**	ij	**6.00 abc**
Y-2	Z	**4.3**	j	**3.00 c**

Another observation is related to the zoysiagrass cultivars. Even though they fired sooner than most bermudagras cultivars and appeared to enter dormancy, the coarser textured zoysiagrass cultivars (Empire, El Toro and Jamur and Palisades) recovered to greater living ground cover than did the finer textured zoyisgrasses. The fine textured zoysiagrasses have a characteristically dense canopy. The 2.25 inch mowing height was significantly higher than normal for these grasses. That may have put them at a disadvantage for timely recovery since their canopies did not beak down during drought or the recovery

period. Their residual canopies were partially removed, by hand with rakes, 5 weeks into recovery. Therefore the dense canopy associated with these grasses may, to some extent, be self-limiting during recovery from dormancy. This will be evaluated in the Year 2 (2007) study.

Other questions and potential areas of conservation research arise from the Year 1 study.

Would home consumers water to prevent leaf firing and loss of turf quality or turf color?

How resilient are grass species and cultivars to conservation measures? In other words how would these grasses perform under the strictest conservation measures that still allow for turfgrass irrigation?

What irrigation practice prior to significant leaf firing is most appropriate for grasses that survive drought by tolerance, dormancy or escape and how would this impact conservation efforts?

Photo caption: The Year 2 study (pictured at left) being planted (September 22, 2006) using identical methods as used for the Year 1 study. The site is located at the opposite end of the drought simulator. This will allow the researchers to repeat the experiment in 2007 to increase the confidence placed in the results.

IMPORTANT NOTE: Throughout this progress report figures (Figures 1 through 10c) have been used to illustrate the statistically analyzed data that is presented in Tables 1 though 7. As such, comparisons between grasses should only be based upon statistical groupings in Tables 1 through 7 and not on Figures 1 through 10c.

Questions concerning this Year 1 progress report should be directed to:

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