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RESEARCH ARTICLE

Comparative Drought Resistances among Eleven Warm-Season Turfgrasses and Associated Plant Parameters

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Abstract

Comparative drought resistances of 11 perennial warm-season turfgrasses were evaluated in the field after withholding irrigation for 48 days in summer I and 57 days in summer II. There were significant variations among the grasses in their drought resistances. From two years study of field shoot recovery from drought stress, the relative rankings among the 11 warm-season turfgrasses was as follows. 'Arizona Common' and 'Texturf 10' bermudagrasses [*Cynodon dactylon* (L.) Pers.], 'Tifgreen' hybrid bermudagrass [*C. dactylon* (L.) Pers. x *C. transvaalensis* Davy], and 'Georgia Common' centipedegrass [*Eremochloa ophiuroides* (Munro.) Mack.] possessed good drought resistances, whereas 'Texas Common' St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze] and 'Tifway' hybrid bermudagrass [*Cyndon dactylon* (L.) Pers. x *C. transvaalensis* Davy] possessed poor drought resistances. 'Texas Common' buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.], 'Pensacola' bahiagrass (*Paspalum notatum* Flugge.), and 'Adalayd' seashore paspalum (*Paspalum vaginatum* Swartz), 'Meyer' zoysiagrass (*Zoysia japonica* Steud.), 'Emerald' zoysiagrass (*Z. japonica* Steud. x *Z. tenuifolia* Willd. ex Trin.) were found to rank intermediate. Visual leaf firing showed the highest correlation (r=-0.84) to shoot recovery from drought stress. Visual leaf rolling (r=-0.59) and canopy-air temperature differential (r=-0.64) also showed very significant correlations, whereas leaf water potential (r=0.54) showed relatively lower correlation.

Keywords: Canopy-air temperature, Leaf firing, Leaf rolling, Leaf water potential, Percent shoot recovery

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Introduction

Many urban turfgrass areas in Texas are vulnerable to serious water supply shortages in the immediate future, especially under moderate to severe drought condition (Texas Department of Water Resources, 1981). In this situation, water availability for growing turfgrass will be less and the cost will increase. Therefore, there is a need to identify drought resistant turfgrass species and cultivars, and the plant responses parameters that are associated with better drought resistance that can be utilized in turfgrass breeding programs. Drought resistance has three primary components: dehydration avoidance, dehydration tolerance, and escape.

Only a limited number of drought resistance studies have been conducted on turfgrasses. Beard (1966), Dernoeden and Butler (1978), and Gaskin (1966) investigated the intraspecific drought resistances among Kentucky bluegrass cultivars and blends. They found significant drought resistance variations among cultivars. A more extensive comparative drought resistance study with cool-season turfgrass species was conducted by Minner (1983) and Minner and Butler (1985). They differentiated 55 Kentucky bluegrass (*Poa pratensis* L.), 34 perennial ryegrass (*Lolium perenne* L.), and 42 fine-leaf fescue (*Festuca* spp.) cultivars.

Fuentealba et al (2016) investigated the transpiration responses of 5 warm-season turfgrass species, such as *Zoysia japonica* (Steud), *Zoysia matrella* L., common bermudagrass (*Cynodon dactylon* L. Pers. var. *dactylon*), African bermudagrass(*Cynodon transvaalensis* Burtt-Davy), hybrid bermudagrass (*C. dactylon* L. var. *dactylon*×*C. translvaalensis* Burtt-Davy) and St. Augustinegrass [*Stenotaphrum secundatum* (Walter) Kuntze]. Jiang and Carrow (2007) also investigated the interspecific and intraspecific drought stress using broadbald spectral reflectance among hybrid bermudagrass, seashore paspalum, zoysiagrass, St.Augustinegrass and one cool-season tugrasses, seeded tall fescue. However, comparative interspecific drought resistance study is still lacking.

The objectives of this study were (1) to establish the comparative drought resistances of eleven warm-season turfgrasses commonly used in warm-humid and/or semi-arid climates, and (2) to elucidate plant parameters that are effective predictors of drought resistance that could be used in turfgrass breeding programs.

Materials and Methods

Comparative drought resistance study was conducted with 11 turfgrasses during two summers at the Texas A&M University Turfgrass Research Field Laboratory in College Station, Texas.

A special plot area was constructed for this study. The root zone consisted of a 60 cm deep sand having 50% of the particles in the 0.25 to 0.5 mm range, placed over a clay base. The root zone was raised 60 cm above the surrounding area to prevent lateral water encroachment from outside the plot. A 10 cm diameter corrugated plastic drainage line was positioned in the center of the plot to allow rapid, excess water drainage. 'Texas Common' St. Augustinegrass sod was transplanted on the perimeter slope to prevent soil erosion.

Eleven major warm-season turfgrasses were selected for the experiment. They were 'Arizona Common' and 'Texturf 10' bermudagrasses [*Cynodon dactylon* (L.) Pers.], 'Tifway' and 'Tifgreen' hybrid bermudagrass [*C. dactylon* (L.) Pers.×*C. transvaalensis* Davy], 'Meyer' zoysiagrass (*Zoysia japonica* Steud.), 'Emerald' zoysiagrass (*Z. japonica* Steud.×*Z. tenuifolia* Willd. ex Trin.), 'Texas Common' St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze], 'Georgia Common' centipedegrass [*Eremochloa ophiuroides* (Munro.) Mack.], 'Texas Common' buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.], 'Pensacola' bahiagrass (*Paspalum notatum* Flugge.), and 'Adalayd' seashore paspalum (*Paspalum vaginatum* Swartz).

Plugs of 10 cm diameter of each turfgrass were transplanted from the nearby Cultivar Characterization Plot. They were positioned on a 90 cm spacing in a randomized block design with four replications. These turfs were grown for 75 days from 16 May to 30 July to allow full rooting establishment. Irrigation was applied for 30 minutes daily via rotary, pop-up sprinkler heads. This provided approximately 10 mm of water per day. Irrigation was gradually decreased to once every 3 days during the last two weeks. Nutrient solution (Miracle-Gro, Stern's Nurseries, Geneva, NY, USA) was used for fertilization. It was applied biweekly at rates of 13, 25, and 13 kg·ha^{-1} for N, P, and K, respectively. Iron sulfate was applied at a rate of 250 kg·ha^{-1} followed by irrigation. Each turf was trimmed to a 20 cm diameter every two weeks. The grasses were mowed manually by lawn shears weekly at their optimum cutting heights until the initiation of water stress. No pesticides were applied during the study period.

On 30 July, all irrigation was terminated, causing the entire plot area to be exposed to progressive water stress. When it rained, a rainout shelter with transparent plastic cover was installed above the plot to prevent any water input. The turfs were mowed infrequently during water stress period as needed to eliminate protruding seed heads and excessive vertical shoot growth that might have influenced the visual rating. No disease or insect damage occurred during the water stress and recovery periods.

Leaf firing (LF) and rolling (LR) were visually rated daily at 1200 h using a scale of 0 to 9; 0 being no symptoms and 9 being complete leaf firing or rolling. Canopy temperatures were monitored by infrared thermometer. Concurrently, air temperatures 90 cm above the turf canopy were also measured via copper-constant thermocouple. These data were used to calculate the canopy-air temperature differentials (ΔT). Leaf water potential (LWP) of the third youngest fully expanded leaf blade was measured twice a week with a hydraulic press (J-14, Campbell Scientific, Inc., Logan, UT, USA) with three replicates.

After 48 days of severe water stress, water was reapplied for 30 min every day to determine the post-stress shoot recovery. Percent shoot recoveries were visually rated twice a week for 18 days. Turfgrass quality and leaf firing have been used as parameters for drought resistance assessment in the past (Aronson et al, 1987; Burton et al, 1954; Feldhake et al, 1984; Minner, 1983; Minner and Butler, 1985; Peacock and Dudeck, 1984). However, Gaskin (1966) used % survival during his glasshouse and growth chamber studies. Since drought resistance should also represent the dormancy mechanism by which plants can survive (Beard, 1989), percent shoot recovery was used in this study to represent overall comparative drought resistance of each turfgrass under water stress, whether achieved by dehydration avoidance or dehydration tolerance, or both.

There were modifications in the second-summer field study. Pea gravel, 10 cm deep, was placed between the sand layer and clay subbase to facilitate lateral water drainage. Turfgrass spacing was reduced to 60 cm. The grasses were grown for 70 days, and then exposed to water stress from 26 July through 21 Sept. for 57 days. However in the 30th and 31st days, there were sudden thundershowers on the plot without rainout shelter coverage, which was good enough to saturate the pots with rain water in the middle of the drought period. After 20 more days of drought, the shoot recovery was rated without additional watering.

Results and Discussion

The comparative drought resistances expressed as percent shoot recoveries of 11 warm-season turfgrasses are summarized in Table 1. Water stress continued for 48 and 57 days in summer I and II, respectively. A very slight rain occurred on day 17 and more intense shower on day 41 of the first summer without coverage. However, the drought stress investigations continued to progress until day 48. Rain showers occurred eight times during the second summer study period. However, use of the rainout shelter eliminated the rain input to the plot except on days 30 and 31. Subsequently, there were rainy or cloudy days during which the plastic tarp was in place. Thus, water input to the plot area during the second summer may have affected the overall performances of each species. For example, the fast-growing species such as bermudagrass, bahiagrass, and St. Augustinegrass exhibited some shoot recovery and then reverted to the water stress state. In contrast, slow-growing species, such as zoysiagrass, centipedegrass, and buffalograss, did not respond to the two mid-stress rains as was observed for the above species.

In both years, two zoysiagrass cultivars, three bermudagrass cultivars, and centipedegrass showed good shoot recoveries, whereas St. Augustinegrass showed poor recovery. 'Tifway' hybrid bermudagrass showed poor recovery in the first summer stress, but in the second summer it showed relatively good recovery. This was, as mentioned earlier, because some rain input occurred during mid-stress period. Even in a subsequent water stress period 'Tifway' hybrid bermudagrass showed some degree of shoot recovery. At the beginning of an actual recovery period, the percent green shoots were already higher than usual. Buffalograss, bahiagrass, and seashore paspalum ranked intermediate in drought resistance in the first test and medium to low during the second summer water stress.

Based on two years of field studies, three bermudagrasses and centipedegrass showed good drought resistances, while 'Tifway' hybrid bermudagrass and St. Augustinegrass showed poor drought resistance. Buffalograss, bahiagrass, and seashore paspalum ranked intermediate. The intermediate drought resistance of 'Tifway' hybrid bermudagrass was confirmed by concurrently conducted intraspecific bermudagrass cultivar drought studies in both summers (Beard and Sifers, 1997). The good drought resistance of centipedegrass was consistent during both years. These field studies for centipedegrass were also confirmed in a concurrently conducted centipedegrass intraspecific drought field study including five other cultivars.

In this study, intraspecific differences were found among bermudagrass cultivars. 'Tifway' hybrid bermudagrass showed lower drought resistance than any of the other three *Cynodon* cultivars (Beard and Sifers, 1997).

Table 1. The comparative drought resistances, expressed as percent shoot recoveries, of eleven perennial warm-season turfgrasses after progressive water stress[z] during both summer I and II of the field studies.

Turfgrass species	Cultivar	Summer I on day 18	Summer II on day 11
		Percent shoot recovery	
Zoysiagrass	Meyer	98a	94a
	Emerlad	99a	89a
Bermudagrass	Tifgreen	96a	97a
	Arizona Common	94a	97a
	Texturf 10	96a	94a
Centipedegrass	Georgia Common	95a	81ab
Buffalograss	Texas Common	80a	53c
Bahiagrass	Pensacola	74a	81ab
Seashore paspalum	Adalayd	80a	58bc
Bermudagrass	Tifway	46b	81ab
St. Augustinegrass	Texas Common	32b	58bc

[z]Progressive water stress continued for 48 and 57 days in summers I and II, respectively.
a-c: Means with the same letter in a column are not significantly different at P=0.05 level in Duncan's multiple range test.

Since aesthetic value has an important role for turfgrass in the human environment, quality of turfgrasses should be taken into consideration under moderate to severe drought conditions. LF best represented this quality during these studies. A leaf firing value of 5 represents the minimum acceptable leaf firing. The number of days to reach this LF 5 in the first summer is shown in Table 2.

'Tifway' hybrid bermudagrass and St. Augustinegrass reached LF 5 very soon. Buffalograss, seashore paspalum, and bahiagrass followed. However, the bermudagrasses and a centipedegrass maintained good quality turf until the end of the water stress period in both years. This indicates that these grasses are excellent not only in their survival, but also in their quality during extended water stress.

The two zoysiagrass cultivars exhibited good drought stress resistance through both 48 and 57 days. In a subsequent third, longer study with nine *Zoysia* cultivars, they showed significant differences in leaf firing after 158 days of drought and three cultivars had 72 to 92% green shoot recovery at 30 days after the initiation of irrigation (Beard and Sifers, 1997). This indicates an intermediate drought resistance rankings. It should be noted that since 3/4 of the plot area was bare sandy soil, actual time elapsed for LF 5 on fully vegetated surfaces under water stress would be shorter than droght resistance prediction reported herein.

Table 2. Comparative leaf firings of eleven warm-season turfgrasses under progressive water stress during both summers I and II of the Drought Resistance Field Studies.

Turfgrass species	Cultivar	Number of Days for LF 5	Summer I on day 34	Summer II on day 52
			Leaf firing[z]	
Zoysiagrass	Emerald	-	1.3a	2.3ab
	Meyer	-	1.5a	2.0a
Bermudagrass	Tifgreen	-	2.3a	1.8a
	Texturf 10	-	2.0a	1.3a
	Arizona Common	-	1.8a	1.3a
Centipedegrass	Georgia Common	-	2.8a	1.8a
Bahiagrass	Pensacola	34	5.0b	3.0ab
Seashore paspalum	Adalayd	32	5.3bc	7.8c
Buffalograss	Texas Common	23	7.0cd	5.5bc
Bermudagrass hybrid	Tifway	15	7.3d	4.3ab
St. Augustinegrass	Texas Common	16	8.5d	5.5bc

[z]Rating based on the scale from 0 to 9; 0 being no firing and 9 being complete firing.
a-d: Means with the same letter in a column are not significantly different at *P*=0.05 level in Duncan's multiple range test.

Table 3. Simple correlations of four parameters measured on days 20 and 34 under progressive water stress to drought resistance of eleven perennial warm-season turfgrasses during the summer I field water stress study. Drought resistance was represented by post-stress green shoot recoveries 18 days after rewatering.

Variable	LF	LR	ΔT	LWP
	Correlation coefficient			
Shoot recovery on day 20	-0.87 **	-0.50 **	-0.46 **	0.30 *
Shoot recovery on day 34	-0.84 **	-0.59 **	-0.64 **	0.54 **

LF, Leaf firing; LR, Leaf rolling; ΔT, Canopy-air temperature differential; LWP, Leaf water potential.
*, ** Correlation coefficient differs significantly from zero based on the 0.05 and 0.01 level of probability, respectively.

Plant response parameters by which turfgrass breeders can simply and quickly predict the drought resistance of different species or cultivars are needed for screening purposes. To determine the effectiveness of using plant parameters, such as leaf firing, leaf rolling, canopy-air temperature differential (ΔT) and LWP, to predict drought resistance, simple correlations to post-stress shoot recovery were examined. The plant parameters measured on days 20 and 34 during the water stress and shoot recovery measured on day 18 after rewatering in study I were selected in this evaluation.

All parameters showed significant correlations to shoot recovery (Table 3). Generally, the data from day 34 showed higher correlation coefficients than those from day 20. There was a negative correlation between leaf rolling and shoot recovery on both days. This indicates that leaf rolling is simply indicative of water stress degree rather than a preventive drought stress mechanism. Highly significant correlations of leaf rolling to leaf firing (r=0.40 and 0.52, respectively) supported this.

These results suggest that among the potential plant predictors assessed, leaf firing was found to be the best predictor of drought resistance. However, those species having a dormancy mechanism should be considered, separately. Among the four parameters, leaf firing possessed the highest correlation coefficient on both days, while LWP showed the lowest. This was because leaf firing was an expression of both dehydration avoidance and tolerance, except for dormancy, while the LWP response is a result of just dehydration avoidance. Other researchers also mentioned that the ability to maintain green cover for longer periods under water deficit is an important criterion of drought resistance (Karcher et al., 2008; Richardson et al., 2008; Zhou et al., 2013a; Zhou et al., 2013b).

Conclusions

There are variations in drought resistance among the perennial warm-season turfgrass species and also among cultivars in the *Cynodon* species. In this study, zoysiagrass, most bermudagrasses, and centipedegrass showed good drought resistances, whereas St. Augustinegrass and 'Tifway' hybrid bermudagrass showed poor drought resistance. Bahiagrass, buffalograss, and seashore paspalum exhibited intermediate drought resistance. However, zoysiagrass could rank intermediate in drought resistance when a much longer water stress period is considered.

Plant parameters, such as leaf firing, leaf rolling, canopy-air temperature differential and leaf water potential, are potential methods for predicting drought resistance for the eleven warm-season turfgrasses. Leaf firing was found to be the best predictor.

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