Drought Resistance of Warm-season Turfgrasses Grown in Mediterranean Region of Turkey

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ADDITIONAL INDEX WORDS. leaf firings, green shoot recovery, deficit irrigation

SUMMARY. There is a dearth of information about turfgrass drought resistance and adaptation in the Mediterranean region of Turkey. Turfgrass managers in this region need this information to help them make informed decisions regarding turfgrass selection and management. This research was conducted to assess the drought resistance of bermudagrass (*Cynodon dactylon*), buffalograss (*Buchloe dactyloides*), bahiagrass (*Paspalum notatum*), seashore paspalum (*Paspalum vaginatum*), zoysiagrass (*Zoysia japonica*), centipedegrass (*Eremochloa ophiuroides*), and tall fescue (*Lolium arundinaceum*) under Mediterranean conditions of Turkey. The study was conducted at two locations, Antalya and Mersin, and was repeated in 2006 and 2007 at both locations. One year after establishment, the turfs were subjected to drought stress for 90 days, which was followed by resumption of irrigation for recovery of the turf. Percentage leaf firing, turfgrass quality, and percent green shoot recovery were recorded. There were inter and intraspecies differences detected for percentage leaf firing and shoot recovery. Bermudagrass, bahiagrass, and buffalograss exhibited superior drought resistance as demonstrated by lower leaf firing and better shoot recovery values when compared with other species studied. Centipedegrass and zoysiagrass demonstrated a high leaf firing and very poor shoot recovery, whereas zoysiagrass and tall fescue were unable to recover from the drought stress in the sandy soil. Results showed that 'SWI-1045' (Contessa®) and 'SWI-1044' bermudagrass and 'Cody' buffalograss possessed superior drought resistance with acceptable turfgrass quality up to 30 days under drought stress that can be used for water-efficient turf management under the Mediterranean environment.

In the Mediterranean region of Turkey, turfgrasses are grown under irrigation much of the year to maintain desired turfgrass quality.

We are grateful to Dr. T.P. Riordan for their critical review of the manuscript and their contribution to the study. We extend special thanks to Dr. K.M. Eskridge and Dr. Stephen D. Kachman, Department of Statistics, University of Nebraska, for their advice in statistical analysis.

This research was supported by the Scientific and Technical Research Council of Turkey under the project code TUBITAK TOVAG: 105 O 586.

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The availability of irrigation water is often limited in this region and water conservation for turfgrass management is of interest. Water requirements have been reported to vary by turfgrass species and cultivar (Fu et al., 2004; Kim and Beard, 1988; Youngner et al., 1981) and within cultivars of the same species (Beard and Sifers, 1997; Beard et al., 1992; Kopec et al., 1988; Shearman, 1986, 1989), with warm-season grasses typically being better able to withstand greater water deficits compared with cool-season grasses (Meyer and Gibeault, 1986; Qian and Engelke, 1999). Growing warm-season turfgrasses

in arid and semiarid regions may provide better turf quality and more water savings than using cool-season turfgrasses (Beard, 1989; Brian et al., 1981; Tovey et al., 1969; Youngner et al., 1981). Short and Colmer (2007) demonstrated the opportunity for water conservation when warm-season turfgrass species were used under Mediterranean-like climate in Australia, but data on drought resistance and water conservation are lacking for the Mediterranean region.

Bermudagrass, buffalograss, bahiagrass, centipedegrass, seashore paspalum, and zoysiagrass are warm-season turfgrass species with varying drought resistance (Beard, 1973). Drought in turfgrass is manifested by leaf wilting, leaf firing, slow shoot growth, and loss of turf quality (Fry and Huang, 2004). Leaf firing provides a good assessment of overall turfgrass drought resistance under field conditions when the drought stress treatment begins with the soil at field capacity throughout the root zone (Beard and Sifers, 1997; Carrow, 1996). Leaf firing refers to leaf chlorosis and necrosis starting at leaf tips and margins, and progressing down the leaf in response to progressive drought stress. The turf recovery is considered as an indication of drought resistance under the conditions and duration of the drought stress (Beard and Sifers, 1997). Significant differences in leaf firing and shoot recovery were reported among 11 warm-season turfgrass species during and after the period of induced drought where all cool-season species showed fair to very poor drought resistance (Beard, 1989). Delayed onset of leaf firing and the accompanying decline in turfgrass quality would reduce the amount of irrigation required to maintain canopy color. Our study was conducted to assess the drought resistance and recovery, and turfgrass quality and adaptation of bermudagrass, buffalograss, bahiagrass,

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
1	mmho/cm	dS·m ⁻¹	1
0.4470	mph	m·s ⁻¹	2.2369
305.1517	oz/ft ²	g·m ⁻²	0.0033
1	ppm	mg·kg ⁻¹	1
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

seashore paspalum, zoysiagrass, centipede grass, and tall fescue under Mediterranean conditions of southern Turkey.

Materials and methods

LOCATION. The study was conducted at two locations in Turkey, the West Mediterranean Agricultural Research Institute in Antalya (lat. 36°52'N, long. 30°43'E) and the Alata Horticultural Research Institute in Mersin (lat. 36°37'N, long. 34°42'E). The locations differed strongly for their soil type, sandy vs. silty clay loam. The climate is Mediterranean with a strong marine influence (warm, dry summers and cooler, but mild winters). Mean maximum air temperatures, mean relative humidity, mean wind speed, and mean precipitation covering time of study are presented in Table 1 for both Antalya and Mersin locations. Soil on the Antalya site was a silty clay loam (Paralithic Xerortent) with a 1.4% organic matter (OM) content, EC of 0.24 dS·m⁻¹, pH 8.4, 22 mg·kg⁻¹ phosphorus (P), and 117 mg·kg⁻¹ potassium (K). The Mersin site was a sandy soil (Typic Xerofluvent) with a 1.2% OM, EC of 0.17 dS·m⁻¹, pH 8.3, 12 mg·kg⁻¹ P, and 102 mg·kg⁻¹ K.

PLANT MATERIALS, ESTABLISHMENT AND MAINTENANCE. Warm-season turfgrass species included bermudagrass cultivars Riviera, Sultan, Princess 77, Mohawk, NuMex Sahara, SWI-1044, SWI-1045, and Blackjack; zoysiagrass cultivars Zenith and Companion; buffalograss cultivars SWI-2000,

Bowie, Cody, Texoka, and Bison; bahiagrass cultivar Argentine; seashore paspalum cultivar Sea Spray; and centipede grass cultivar Tifblair. Tall fescue cultivar Eldorado was used as the cool-season species.

The species were seeded at the following rates; bermudagrass and buffalograss at 15 g·m⁻², centipede grass and seashore paspalum at 5 g·m⁻², zoysiagrass at 10 g·m⁻², bahiagrass at 30 g·m⁻², and tall fescue at 50 g·m⁻². The seeding dates for the warm-season grasses were 15 July and 12 Aug. 2005 for the Mersin and Antalya locations, respectively. Tall fescue was seeded on 15 Oct. at both locations. The soils in experimental sites were raked and then rolled after seeding to improve seed-to-soil contact. Irrigation was provided three times daily for 4 weeks at 7 mm per day to encourage germination and enhance establishment. Subsequently, turf was irrigated to prevent visual wilt symptoms. Starter fertilizer (15N-6.6P-12.5K) was applied at 5 g·m⁻² N at time of seeding. After establishment, turfs received 17.5 g·m⁻² N per growing season with applications made as 5 g·m⁻² N in May, June, and July, and 2.5 g·m⁻² N in August using a slow release (33N-0P-0K) fertilizer at both locations. In addition, 17.5 g·m⁻² K per season was applied along with the N for the Mersin location. For tall fescue, applications were made as 5 g·m⁻² N in May, 2.5 g·m⁻² N in June, and 5 g·m⁻² N in October and November. Soil samples were collected in Apr. 2006 and 2007 before

fertilizer applications. Analysis and soil tests indicated P (41 and 38 mg·kg⁻¹, respectively) and K (102 and 108 mg·kg⁻¹, respectively) levels in Antalya, and P (12 and 28 mg·kg⁻¹, respectively) levels in Mersin were sufficient; while, K (44 and 81 mg·kg⁻¹, respectively) levels in Mersin were not sufficient. Plots were hand-weeded in both locations. Turfs were mowed weekly at 50 mm with clippings removed.

ASSESSMENT OF DROUGHT RESISTANCE. Soil water content was determined, as a composite sample from three randomly chosen plots for each block, at initiation of drought stress, at 45 d of drought stress, and at 90 d of drought stress period to determine spatial water content at 20, 40, and 60 cm depths. Soil samples were oven dried at 72 °C for 48 h. Volumetric moisture content (VMC) in the top 20 cm of soil from each plot was measured using time domain reflectometry (Spectrum Technologies, East Plainfield, IL). Turfgrass quality, percentage leaf firing (during drought stress), and recovery (after drought stress) were rated visually at 3-d intervals from the beginning of drought stress treatment until dormancy in the fall. Turfgrass quality ratings were based on a visual rating scale of 1 to 9 with 1 = poorest, 6 = acceptable, and 9 = best. Leaf firing was assessed using a scale of 0% to 100% with 0 = no symptoms and 100 = complete leaf firing, as was previously reported by Beard and Sifers (1997). Turf recovery was assessed as the percentage of green shoot development for

Table 1. Meteorological parameters during the study period in 2006 and 2007 from weather stations located ≈1200 and 200 m (3937.0 and 656.2 ft) from the field sites in Antalya and Mersin, Turkey, respectively.

Location	Month	Mean maximum air temp (°C) ^z		Mean relative humidity (%)		Mean wind speed (m·s ⁻¹) ^z		Mean precipitation (mm) ^z	
		2006	2007	2006	2007	2006	2007	2006	2007
Antalya	June	38.2	43.5	57.9	55.7	4.1	2.1	0.7	1.4
	July	40.0	43.8	55.6	54.2	2.3	2.0	0.3	0.2
	August	42.4	40.5	66.9	68.1	1.8	1.9	3.4	1.0
	September	38.4	40.3	60.8	56.2	2.5	2.0	1.4	0.0
	October	33.4	35.6	68.5	55.2	2.2	2.0	494.7	16.6
	November	26.0	24.4	60.7	68.2	2.2	1.7	126.4	58.2
Mersin	June	28.8	36.1	65.6	57.6	1.7	1.7	3.4	0.0
	July	31.3	38.2	60.2	57.5	1.7	1.7	0.7	0.6
	August	32.3	33.8	66.1	61.9	1.6	1.8	0.0	0.0
	September	30.7	34.0	54.4	54.2	1.5	1.6	13.6	0.0
	October	26.4	35.3	63.4	54.5	1.4	1.4	68.2	75.9
	November	20.5	28.5	51.6	53.8	1.4	1.5	202.8	78.2

^z(1.8 × °C) + 32 = °F, 1 m·s⁻¹ = 2.2369 mph, 1 mm = 0.0394 inch.

60-d postdrought stress period. Turfgrass green cover (turf recovery) was rated using a visual scale of 0% to 100% with 0% = no green vegetation and 100% = green vegetation over the entire plot.

The studies were conducted to evaluate drought stress resistance and recovery from drought stress. Plots were watered twice weekly to promote healthy turf growth until ceasing the irrigation upon initiation of the drought stress period, which was 90 d from 15 June to 15 Sept. for each year and each location. At the beginning of each drought stress treatment, grasses were at 100% green cover and plots were watered to saturation. Percentage leaf firing and quality were recorded during drought stress. Subsequently, to assess post-drought response of the turfgrasses, the plots were saturated with water and normal watering frequency was maintained thereafter for the turf recovery phase until all the warm-season cultivars entered dormancy in the late fall. Percentage green shoot recovery and quality of the cultivars were recorded until the dormancy period, but data are presented for 60 d after rewatering (15 Sept. to 15 Nov.) that encompassed the period of active growth.

EXPERIMENTAL DESIGN AND STATISTICAL ANALYSES. The experimental design was a split-plot with species as the whole plot treatment in a randomized complete block, and the subplot treatment being cultivars nested in species (Federer, 1955). Species within a replicate were randomized (blocked) across the field. Cultivars were nested within species. The whole plots were 5.5 × 12.5 m, and subplots were 1.5 × 1.5 m with a 0.3-m bare soil alleyway between each plot. Hartley's $F_{\max}$ test (Hartley, 1950) was performed to determine homogeneity of variance between locations, Antalya and Mersin, and years, 2006 and 2007. Treatment differences were tested using analysis of variance procedures with PROC MIXED (SAS release 8.0; SAS Institute, Cary, NC). Means were separated using Fisher's protected least significant difference ($P < 0.05$) procedure.

Results and discussion

Based on the Hartley's $F_{\max}$ test (Hartley, 1950), data from 2006 and 2007 were combined, but data from

the Antalya and Mersin locations could not be combined. Therefore, results from the two locations were reported separately. There were significant interactions for turfgrass quality, leaf firing, and turf recovery between years and species on some evaluation dates at both locations (Table 2). The interactions were mainly caused by change in the order of species, namely bermudagrass vs. buffalograss, and centipedegrass vs. zoysiagrass on some evaluation dates between 2 years. However, trends were similar for both years and data were not reported separately.

DROUGHT STRESS PERIOD. The leaf firing and quality assessments for the species and their cultivars are shown in Tables 3 and 4 for the Antalya and Mersin locations. The 90 d drought was a severe period of dehydration stress. Experimental

locations had contrasting soil types, a silty clay loam at Antalya and a highly sandy soil at Mersin. The degree of drought injury depends upon the growing medium (soil), plant, and atmospheric factors (Schmidt, 1973). Since sandy soils drain too well and dry out too quickly, during dry periods they are often incapable of supplying plants with enough water to meet the transpirational requirements (Emmons, 2000). Thus, the Mersin location presented a much harsher soil environment for drought stress. Soil water content by weight at 0–20 cm soil depth was 17% and 13% measured just before drought stress treatment was initiated. It declined to 3.1% and 2.2% by 90 d of drought stress at the Antalya and Mersin locations, respectively (Table 5). VMC values (measured with TDR) were 40.2 at Antalya and 16.3 at Mersin

Table 2. Analysis of variance for turfgrass quality and leaf firing during 90-d drought stress, and turfgrass quality and shoot recovery after irrigation resumed at Antalya and Mersin, Turkey for combined data of 2006 and 2007.^a

Location	Source of variation	df	Drought stress period		Recovery period	
			Quality	Leaf firing	Quality	Shoot recovery
Antalya	Block (B)	2	NS ^b	2 ^x	3	2
	Species (S)	6	21	30	20	20
	Whole plot error (B × S)	12				
	Cultivar (C)	12	26	13	11	NS
	Split-plot error [B × C (S)]	24				
	Year (Y)	1	19	17	13	11
	B × Y	2	4	3	3	2
	Y × S	6	16	15	12	10
	B × Y × S	12	7	9	6	5
	Y × C (S)	12	13	15	2	3
	Residual	30				
Mersin	B	2	1	NS	NS	NS
	S	6	5	10	18	19
	B × S	12				
	C	12	7	11	2	11
	B × C (S)	24				
	Y	1	7	15	14	15
	B × Y	2	3	8	7	8
	Y × S	6	8	16	14	13
	B × Y × S	12	3	7	5	5
	Y × C (S)	12	1	11	14	13
	Residual	30				

^aThe data belong to set of 30 weeks and weekly data were analyzed separately. The numbers indicate total number of weeks where treatment differences were significant. The species and cultivars were as follows: bermudagrass [cultivars SWI-1044, SWI-1045 (Contessa), Princess 77, Riviera, Mohawk, Sultan, NuMex Sahara, and Blackjack], buffalograss (cultivars Cody, Bowie, SWI-2000, Bison, and Texoka), zoysiagrass [cultivars Zenith and Companion (Compadre)], seashore paspalum (cultivar Sea Spray), centipedegrass (cultivar Tifblair), bahiagrass (cultivars Argentine and Pensacola), and tall fescue (cultivar Eldorado).

^bNS = Nonsignificant at $P \leq 0.05$.

^xNumber indicates number of evaluations when treatment differences were significant at $P \leq 0.05$ out of 30 evaluations.

Table 3. Mean percentage of turfgrass leaf firing at the drought stress period for bermudagrass, buffalograss, zoysiagrass, seashore paspalum, centipedegrass, bahiagrass, and tall fescue species and their cultivars in Antalya and Mersin, Turkey, averaged over 2006 and 2007.^z

Species/cultivars	Duration of drought stress in Antalya (d)										Duration of drought stress in Mersin (d)									
	0	6	12	18	24	30	45	60	75	90	Leaf firing (%) ^y									
											0	6	12	18	24	30	45	60	75	90

Bermudagrass																				
SWT-1044	0	0	1	14	12	22	52	73	83	88	0	6	52	82	94	98	100	100	100	100
SWT-1045	0	0	2	13	13	24	62	79	86	91	0	5	32	81	96	98	100	100	100	100
Princess	0	0	5	17	25	49	83	88	92	93	0	10	49	90	98	100	100	100	100	100
Riviera	0	0	3	17	22	43	86	96	98	99	0	3	52	89	97	100	100	100	100	100
Mohawk	0	0	3	31	36	58	74	85	91	94	0	34	77	94	98	100	100	100	100	100
Sultan	0	0	8	29	43	53	76	87	90	94	0	30	62	90	97	100	100	100	100	100
Sahara	0	0	4	28	38	58	79	88	92	93	0	33	72	93	98	100	100	100	100	100
Blackjack	0	0	3	31	35	47	73	83	88	91	0	28	74	95	99	100	100	100	100	100
Mean	0	0	4	22	28	44	73	85	90	93	0	19	59	89	97	99	100	100	100	100
Least significant difference (LSD) (Bermudagrass)	NS ^x	NS	NS	8	12	18	18	NS	NS	NS	NS [‡]	9	10	6	NS	NS	NS	NS	NS	NS

Buffalograss																				
Cody	0	0	3	13	14	29	72	86	93	96	0	20	48	87	96	98	100	100	100	100
Bowie	0	1	5	18	24	50	86	93	96	98	0	21	56	88	96	98	100	100	100	100
SWT-2000	0	0	6	27	28	44	76	88	93	97	0	26	63	88	97	98	100	100	100	100
Bison	0	0	4	27	33	52	83	93	97	99	0	28	60	88	96	98	100	100	100	100
Texoka	0	1	7	24	34	52	81	89	95	99	0	24	57	85	95	97	100	100	100	100
Mean	0	0	5	22	26	45	79	90	95	98	0	24	57	87	96	98	100	100	100	100
LSD (Buffalograss)	NS	NS	NS	NS	NS	17	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Zoysiagrass																				
Zenith	0	0	5	34	57	69	92	98	100	100	0	22	50	77	89	92	99	100	100	100
Companion	0	0	10	43	67	77	94	99	100	100	0	18	49	77	91	94	100	100	100	100
Mean	0	0	7	39	62	73	93	98	100	100	0	20	50	77	90	93	99	100	100	100
LSD (Zoysiagrass)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2	3	NS	NS	NS	NS

Bahia grass																				
Argentine	0	0	0	7	23	51	78	88	92	95	0	12	44	82	93	98	100	100	100	100

Seashore paspalum																				
Sea Spray	0	0	5	18	25	42	74	85	92	96	0	21	76	97	98	99	100	100	100	100

Centipedegrass																				
Tifblair	0	0	8	29	63	79	95	99	99	100	0	24	53	91	97	100	100	100	100	100

Tall fescue																				
Eldorado	0	0	34	60	76	89	99	100	100	100	0	65	93	99	100	100	100	100	100	100
LSD (Species)	NS	0.6	6.4	11.7	17.6	25.3	21.5	15.4	10.5	6.8	NS	16	26	11	NS	4	0	NS	NS	NS
LSD (Cultivars)	NS	0.5	5.5	10.3	12.9	17.2	13.9	9.9	7.1	4.9	NS	11.2	18.8	8.2	4.0	2.7	0.2	NS	NS	NS

^zFisher's protected LSD values are for comparing cultivars within species, species, and cultivars among species.^yTurfgrass leaf firing ratings were based on a 0% to 100% visual rating scale with 0% = no symptoms and 100% = complete leaf firing.^xNS = Nonsignificant at $P \leq 0.05$.

Table 4. Mean turfgrass quality at the drought stress period for bermudagrass, buffalograss, zoysiagrass, seashore paspalum, centipedegrass, bahiagrass and tall fescue species and their cultivars at Antalya and Mersin, Turkey, averaged over 2006 and 2007.^z

Species/Cultivars	Duration of drought stress in Antalya (d)										Duration of drought stress in Mersin (d)									
	0	6	12	18	24	30	45	60	75	90	0	6	12	18	24	30	45	60	75	90
	Turfgrass quality (1–9 scale) ^y																			
Bermudagrass																				
SWI-1044	8.5	8.5	8	7	6.5	5.8	4.1	2.9	2.2	1.8	8.3	7.8	4.3	1.9	1.3	1	1	1	1	1
SWI-1045	8.3	7.9	8	7.1	6.7	5.8	3.3	2.8	2.1	1.6	8.2	7.8	6	2.4	1.1	1	1	1	1	1
Princess	8.1	8	7.7	6.3	6	4.8	2.3	2	1.8	1.4	8.2	6.9	4.7	1.5	1.3	1	1	1	1	1
Riviera	7.8	7.8	7.6	6.7	6.3	4.5	2.1	1.3	1.3	1	8.3	8.3	4.3	2	1.1	1	1	1	1	1
Mohawk	7.3	7.3	6.6	5.2	5	3.8	2.3	1.8	1.2	1.2	6.9	5.3	3.6	2	1.2	1	1	1	1	1
Sultan	7.3	7.4	6.8	5	4.9	3.8	2.2	1.4	1.4	1.1	7.4	5.5	3.8	2.2	1.2	1	1	1	1	1
Sahara	7.2	7.4	6.6	5.3	5.1	3.8	2	1.4	1.2	1.2	7	5.6	3.3	1.8	1.2	1	1	1	1	1
Blackjack	6.9	7	6.8	5.2	4.9	4	2.3	1.5	1.5	1.3	6.8	5.1	2.8	1.8	1.2	1	1	1	1	1
Mean	7.7	7.7	7.3	6	5.8	4.6	2.6	1.9	1.6	1.3	7.6	6.5	4.1	1.9	1.2	1	1	1	1	1
Least significant difference (LSD) (Bermudagrass)	0.5	0.5	0.5	0.6	0.6	0.9	1.1	0.8	0.7	0.4	0.5	0.8	0.9	0.4	NS ^x	NS	NS	NS	NS	NS
Buffalograss																				
Cody	7.9	7.9	7.8	7.3	6.8	5.7	2.8	1.8	1.4	1.2	8	6.1	4.3	2.1	1.5	1.1	1	1	1	1
Bowie	7.6	7.9	7.4	6.5	6.1	4.6	1.9	1.4	1.3	1.2	7.4	6.1	3.8	2	1.3	1	1	1	1	1
SWI-2000	7.7	7.8	7.4	6.4	6.1	4.7	2.4	1.8	1.2	1.1	7.5	5.6	3.3	1.9	1.2	1	1	1	1	1
Bison	7.3	7.6	7	6	5.9	4.6	1.9	1.5	1.3	1.1	7.3	5.4	3.3	2	1.4	1	1	1	1	1
Texoka	6.7	6.8	6.8	5.9	5.5	4.3	1.8	1.3	1	1	7.1	5.9	3.7	2.3	1.5	1	1	1	1	1
Mean	7.4	7.6	7.3	6.4	6.1	4.8	2.2	1.6	1.2	1.1	7.5	5.8	3.7	2.1	1.4	1	1	1	1	1
LSD (Buffalograss)	0.4	0.3	0.4	0.6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Zoysiagrass																				
Zenith	6.4	6.5	6.1	4.8	3.8	2.5	1.6	1.5	1.2	1.1	5.7	4.4	3.4	2.1	1.2	1	1	1	1	1
Companion	6.3	6.3	5.9	4.3	3.2	2.3	1.6	1.5	1.2	1.3	5.7	4.6	3.4	1.8	1	1	1	1	1	1
Mean	6.4	6.4	6	4.6	3.5	2.4	1.6	1.5	1.2	1.2	5.7	4.5	3.4	1.9	1.1	1	1	1	1	1
LSD (Zoysiagrass)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.5	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bahiagrass																				
Argentina	6.2	6.1	6	4.8	4.6	3.3	1.8	1.2	1	1	6.2	5.8	4.3	1.9	1.2	1	1	1	1	1
Seashore paspalum																				
Sea Spray	8.7	8.7	8	6.4	5.8	4.8	2.5	1.5	1.1	1	7.9	6	2.2	1.3	1	1	1	1	1	1
Centipedegrass																				
Tifblair	6.8	6.7	6.3	5.1	3.3	1.8	1	1	1	1	6	5	3.3	1.5	1	1	1	1	1	1
Tall fescue																				
Eldorado	6.8	6.7	4.6	2.9	2.3	1.5	1	1	1	1	6.7	3.5	1.2	1	1	1	1	1	1	1
LSD (Species)	0.6	0.5	0.6	0.8	1	1.4	1.4	NS	NS	NS	0.5	1.2	1.8	NS	NS	NS	NS	NS	NS	NS
LSD (Cultivar)	0.5	0.4	0.5	0.6	0.7	1.0	0.9	0.6	0.5	0.3	0.5	0.9	1.3	0.7	0.3	0.1	NS	NS	NS	NS

^zFisher's protected LSD values are for comparing cultivars within species, species, and cultivars among species.^yTurfgrass quality ratings were based on a 1–9 visual rating scale with 1 = poorest, 6 = acceptable, and 9 = best.^xNS = Nonsignificant at $P \leq 0.05$.

Table 5. Water content of soil samples at 0–20, 20–40, and 40–60 cm in depths as measured at the beginning (15 June), the middle (30 July), and the end (14 Sept.) of 90-d drought stress periods at Antalya and Mersin, Turkey in 2006 and 2007.

		Location			
		Antalya		Mersin	
	Soil depth	2006	2007	2006	2007
Date	(cm) ^z	-----Water content (%) ^y -----			
15 June	0–20	16.7	17.4	13.7	12.7
	20–40	16	16.6	11.2	10.6
	40–60	16.1	15.4	9.0	9.5
30 July	0–20	3.0	3.3	3.0	2.7
	20–40	3.4	3.4	3.1	2.8
	40–60	3.8	4.0	3.1	3.0
14 Sept	0–20	3.1	2.8	2.2	2.1
	20–40	3.1	3.0	2.2	2.0
	40–60	3.5	3.6	2.3	2.2

^z1 cm = 0.3937 inch.

^ySoil samples were weighed immediately after sampling, dried in the oven at 72 °C (161.6 °F) for 48 h and the ratio is given as percent water content [(dry sample/wet sample) × 100].

when plots were fully watered to saturation before initiation of drought stress, compared with dry soil's values ranging from 5 to 2 at 45 and 90 d of drought stress at both locations, respectively. Growing degree days (GDD) values, with a base temperature of 5 °C, for the 90-d drought stress periods were 1513 and 1535 GDD for Antalya, and 1450 and 1428 for Mersin for 2006 and 2007, respectively.

Drought resistant turfgrasses are able to maintain better turfgrass quality and have less leaf firing during drought stress (Huang and Gao, 1999; Qian and Fry, 1997). Green color retention during the progressive drought stress is an important indication of drought resistance (Sifers and Beard, 1999). Mean differences in percentage leaf firing of species under 90 d of drought stress were significant ($P > 0.05$) on most of the evaluation dates at both locations (Table 3). Significant intraspecific variation in leaf firing occurred within bermudagrass early to midway through the drought stress period. Virtually no intraspecific leaf firing variation was observed for buffalograss or zoysiagrass. Interspecific variation in leaf firing was significant throughout drought stress period in Antalya, however, it was significant only for the first 18 d of the 90-d drought stress period in Mersin due probably to more severe heat/drought stress. Percent leaf firing increased, and quality declined two to three times faster at Mersin than at the Antalya

location (Table 3 and 4). All the warm-season species exhibited over 90% leaf firing with a straw brown color after 75 and 24 d of drought stress at Antalya and Mersin, respectively (Table 3). The big difference in days of drought stress to 90% leaf firing at the two locations was due to the highly sandy soil type in Mersin and silty loam in Antalya. Percent leaf firing was similar for bermudagrass, buffalograss, bahiagrass, and seashore paspalum at Antalya (Table 3). Among the warm-season species, centipedegrass and zoysiagrass species showed the poorest green color retention that may indicate an inferior drought resistance mechanism compared with the other warm-season species at Antalya. Bahiagrass showed lower leaf firing than other species during the first 15–21 d of drought stress at both locations (Table 3). Overall, bermudagrass, buffalograss, bahiagrass, and seashore paspalum at Antalya and bahiagrass at Mersin demonstrated better green color retention.

Although more severe at Mersin because of sandy nature of its soil, drought stress caused rapid declines in visual quality at both locations. Mean quality differences among species were significant until 60 and 18 d of drought stress at the Antalya and Mersin locations (Table 4). As the severity of drought stress intensified, differences in quality among the species diminished. Buffalograss, bermudagrass, and seashore paspalum consistently exhibited higher quality ratings than other species at Antalya

(Table 4). These species provided an acceptable quality until 21 d of drought stress at Antalya. However, all the species declined below an acceptable quality at 12 d of drought stress at Mersin (Table 4).

Green color retention was outstanding for bermudagrass cultivars SWI-1044 and SWI-1045, which had less than 25% leaf firing with an acceptable quality at 30 d of drought stress at Antalya (Tables 3 and 4). At Mersin, however, 'SWI-1045' was the only cultivar with an acceptable quality at 12 d of drought stress. Green color retention and quality of 'SWI-1044', 'SWI-1045', 'Princess 77', and 'Riviera' were superior to other bermudagrass cultivars at both locations (Table 4). Low leaf firing and high shoot recovery, low leaf area and high canopy resistance (attributed to high shoot density), horizontal leaf angle, and a slow vertical leaf elongation are important indicators for selecting cultivars with low water use rates and drought resistance (Beard, 1989). Among the bermudagrass cultivars, those high-density, low-growing new cultivars SWI-1044, SWI-1045, Riviera, and Princes 77 [National Turfgrass Evaluation Program (NTEP), 2006] exhibited superior drought resistance; while those lower-density, high-growing cultivars NuMex Sahara, Mohawk, Blackjack, and Sultan showed lower drought resistance. These newer bermudagrass cultivars were also able to retain their color about twice as long as older cultivars. Newer type cultivars possess better genetic color and groundcoverage, narrower-finer leaf texture, and slower vertical growth than older cultivars (NTEP, 2006; Severmutlu et al., 2011). These morphological and physiological differences may be contributing to better color retention of new bermudagrass cultivars under drought stress. Beard and Sifers (1997) also reported significant intraspecific drought resistance differentials within bermudagrass.

Buffalograss cultivars showed significant mean differences for green color retention and quality early in the drought stress. Among the buffalograss cultivars, Cody had the best drought resistance with 29% leaf firing after 30 d and 48% leaf firing after 12 d at Antalya and Mersin, respectively (Table 3). 'Cody' demonstrated a better turfgrass quality than other

buffalograss cultivars at both locations, with an acceptable quality until 30 and 6 d of drought stress at Antalya and Mersin, respectively (Table 4). Buffalograss is relatively drought resistant and has a deep, extensive root system (Marcum et al., 1995; Qian and Fry, 1997). Buffalograss was reported to have good drought resistance because of its deep root system and summer dormancy under extremely dry conditions (Riordan et al., 1993; Qian et al., 1996). It also has been reported to have a low ET rate (Qian et al., 1996) and excellent ability to tolerate drought and then recover (Qian and Fry, 1997). Buffalograss cultivars along with bermudagrass cultivars were ranked highest for drought resistance in our study. Among the buffalograss cultivars, Cody exhibited a superior drought resistance than the other buffalograss cultivars (Table 3). 'Cody' was reported to have the highest drought resistance among seeded buffalograss cultivars (Morris, 1996). It possesses five times the leaf pubescence of buffalograss 'Tatanka' and has a smaller and narrower leaf than 'Texoka' (Severmutlu et al., 2005) that may lower its evapotranspiration level, giving rise to better water use efficiency. Presence of leaf pubescence was shown to reduce absorbance of photosynthetically active radiation (400 to 700 nm) as much as 56% (Ehleringer et al., 1976). This in turn may reduce oxidative stress that would otherwise damage the photosynthetic apparatus, causing a loss of color and quality of turf.

Zoysiagrass cultivars Zenith and Companion showed similar quality with complete leaf firing after 90 and 30 d of drought stress at the Antalya and Mersin locations, respectively (Tables 3 and 4). Zoysiagrass is considered to be more drought resistant than cool-season turfgrasses and intermediate to other warm-season grasses (Hatch and White, 2004). The evapotranspiration rates of zoysiagrass cultivars and germplasm were similar under nonlimiting water availability (Green et al., 1991) but differed markedly in response to drought (White et al., 1993, 2001). When all cultivars were evaluated together, irrespective of species, mean differences of percent leaf firing among cultivars were significant at all evaluation dates. After 15 d of drought stress, tall fescue 'Eldorado'

(46%), zoysiagrass 'Companion' (23%), and bermudagrass 'Blackjack' (21%) exceeded 20% leaf firing while buffalograss 'Cody' and bahiagrass 'Argentine' were below 5% at Antalya while all the cultivars had over 60% leaf firing at this time at Mersin (data not shown). However, at 12 d of drought stress, 'SWI-1045' bermudagrass was the only cultivar with an acceptable quality (6) at Mersin (Table 4). 'SWI-1044' and 'SWI-1045' bermudagrass and 'Cody' buffalograss showed the lowest leaf firing and the highest quality (Tables 3 and 4).

RECOVERY AFTER DROUGHT STRESS. GDD values for 60-d post-drought stress period were 907 and 1086 for Antalya, and 934 and 1007 for Mersin locations in 2006 and 2007, respectively. Mean differences for green shoot recovery of the turf after rewatering of turf plots, among species were significant ($P < 0.05$) throughout the 60 d of recovery (DOR) period from 15 Sept. to 15 Nov. (Table 6). There were no significant intraspecies differences for shoot recovery among bermudagrass, buffalograss, and zoysiagrass cultivars (Table 6). Bermudagrass, buffalograss, and bahiagrass demonstrated superior shoot recovery and regained their quality faster than other species after rewatering (Tables 6 and 7). Although bahiagrass recovered quicker, seashore paspalum was able to recover equally as well after 60 DOR at both locations (Table 6). Zoysiagrass, centipedegrass, and tall fescue showed the lowest shoot recovery and failed to recover in Mersin. They stayed below 26% green shoot cover at Antalya after 45 DOR, while all the other species recovered over 30% at Mersin and 80% at Antalya (Table 6). The mean quality of bermudagrass exceeded the acceptable level after 30 DOR and buffalograss at 33 DOR at Antalya. All the bermudagrass and buffalograss cultivars reached the acceptable quality at Antalya after 45 DOR period (Table 7). Although there were differences on some evaluation dates, species may be ordered for shoot recovery, from high to low, as follows: bermudagrass = buffalograss $\geq$ bahiagrass $\geq$ seashore paspalum $>$ centipedegrass $>$ zoysiagrass $>$ tall fescue.

Drought resistance was outstanding for all of the bermudagrass cultivars, as demonstrated by the

degree of green shoot recovery of the turf during the 60 d following rewatering of the plots (Table 6). 'SWI-1044' at Antalya and 'Riviera' at Mersin recovered better and regained their quality faster than the other bermudagrass cultivars (Tables 6 and 7). 'SWI-1044' bermudagrass was above the acceptable quality level at 21 DOR in Antalya (Table 7). After 30 d of rewatering, green shoot cover varied from 82% ('Princess 77') to 92% ('SWI-1044') at Antalya and from 28% ('Blackjack') to 43% ('Riviera') at Mersin. However, all the bermudagrass cultivars exhibited more than 90% shoot recovery at Antalya and 35% at Mersin at 45 d of rewatering (Table 6). After 54 DOR, only 'SWI-1044' was 100% fully green at Antalya and 'Riviera' exhibited the highest green cover with 67% at Mersin (Table 6). While 'Riviera' recovered better in the sandy soil, 'Blackjack' was significantly slow, indicating a lower drought resistance of 'Blackjack' in sandy soils (Table 6).

Shoot recovery of all the buffalograss cultivars was outstanding and was similar to bermudagrass cultivars. All the buffalograss cultivars exhibited over 87% and 36% green shoot recovery after 45 DOR at Antalya and Mersin, respectively (Table 6). At Antalya, all buffalograss cultivars had equal or above acceptable quality at 45 d. However, none of the cultivars reached acceptable quality during the recovery period at Mersin. Overall, shoot recovery results indicated that 'Cody' showed superior drought resistance and quality at both locations (Table 7). At 21 DOR, 'Cody' exceeded the acceptable quality level at Antalya (Table 7).

Both zoysiagrass cultivars Zenith and Companion demonstrated poor recovery and quality (Tables 6 and 7). Green shoot recovery 45 d of rewatering was very slow with around 15% at Antalya and 1% at Mersin (Table 6). Zoysiagrass and centipedegrass were the first two warm-season species to lose green color under drought stress and were the least responsive to rewatering, indicating poor drought resistance of these species. Using warm-season grasses, Beard (1989) also observed that those species that turned yellow or brown earlier tend to have poorer postdrought stress shoot recovery or poor drought resistance. Centipedegrass and zoysiagrass

Table 6. Mean percentage of turfgrass shoot recovery at the postdrought stress recuperation period for bermudagrass, buffalograss, zoysiagrass, seashore paspalum, centipedegrass, bahiagrass and tall fescue species and their cultivars at Antalya and Mersin, Turkey, averaged over 2006 and 2007.^z

Species	Cultivars	Time of recovery at Antalya (d)						Time of recovery at Mersin (d)					
		3	12	21	30	45	60	3	12	21	30	45	60
		Green shoot (%) ^y											
Bermudagrass	SWI-1044	19	52	83	92	98	81	1	10	25	38	51	58
	SWI-1045	14	53	76	86	94	79	1	9	24	34	49	53
	Princess	12	38	68	82	91	74	1	8	23	33	45	48
	Riviera	4	36	77	86	95	75	1	12	28	43	57	64
	Mohawk	14	56	77	85	96	71	1	10	24	33	44	50
	Sultan	13	53	78	87	94	75	1	10	23	33	44	50
	Sahara	12	54	78	85	95	70	1	9	22	31	43	50
	Blackjack	17	58	81	87	94	72	1	8	18	28	35	36
	Mean	13	50	77	86	95	75	1	10	23	34	46	51
	Least significant difference (LSD) (Bermudagrass)	NS ^x	NS	NS	NS	NS	6	NS	NS	5	NS	11	11
Buffalograss	Cody	15	57	80	90	97	86	9	21	31	43	50	49
	Bowie	9	39	64	75	89	78	3	13	25	30	40	40
	SWI-2000	14	57	82	90	96	81	4	16	24	32	40	35
	Bison	10	43	68	78	87	73	1	10	26	32	36	37
	Texoka	17	53	71	79	90	79	1	18	28	35	46	48
	Mean	13	50	73	82	92	79	3	16	27	34	42	42
	LSD (Buffalograss)	6	NS	NS	NS	7	NS	NS	NS	NS	9	NS	NS
Zoysiagrass	Zenith	3	7	11	14	17	15	0	0	0	1	1	1
	Companion	3	8	10	11	12	9	0	0	0	0	1	1
	Mean	3	7	11	12	15	12	0	0	0	0	1	1
	LSD (Zoysiagrass)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bahiagrass	Argentine	16	58	68	73	81	78	2	13	21	30	36	40
Seashore paspalum	Sea Spray	6	18	50	63	80	80	0	4	15	22	30	36
Centipedegrass	Tifblair	4	15	21	24	26	18	0	1	1	4	6	4
Tall fescue	Eldorado	2	3	3	5	8	9	0	0	0	0	0	0
	LSD (Species)	9.9	19.2	16.4	15	11.6	13	NS	8	10	13	16	18
	LSD (cultivars)	7.7	13.5	11.9	10.9	8.5	8.9	3.4	5.6	7.0	8.9	11.1	12.3

^xFisher's protected LSD values are for comparing cultivars within species, species, and cultivars among species.

^yTurfgrass shoot recovery ratings were based on a 0% to 100% visual rating scale with 0% = no green shoot development and 100% = full green shoot development.

^zNS = Nonsignificant at $P \leq 0.05$.

concentrate their root mass closer to the soil surface compared with bermudagrass, buffalograss, and bahiagrass (Green et al., 1991). This physiological difference may explain the shorter green color retention (and higher leaf firing) of zoysiagrass and centipedegrass than bermudagrass, buffalograss, and bahiagrass that was observed in this study. Qian and Fry (1997) reported that buffalograss exhibited superior drought resistance compared with zoysiagrass when the entire soil profile was subjected to drought stress. The difference between bermudagrass, buffalograss, bahiagrass vs. zoysiagrass and centipedegrass in drought resistance could be associated with differences in root elongation rate, root distribution

patterns, and the capacity to absorb water and nutrients. Under drying conditions, field and greenhouse experiments showed that buffalograss roots elongated faster than zoysiagrass roots, which could contribute to deeper root systems in buffalograss that had a larger proportion of its roots deep in the soil (Huang, 1999; Qian and Fry, 1997). Carrow (1996) also reported that zoysiagrass produced few roots and had low root length density below 20 cm. Zoysiagrass used water near the surface because of the presence of extensive roots in the surface soil, whereas the development of roots in the deeper soil layers by buffalograss enhanced water uptake from deep in the soil profiles (Huang, 1999). Water efflux

(hydraulic lift), where deep roots act as a water transport system that retrieves water from deep in the profile and delivers it to the drying surface soil at night, has been reported in bermudagrass [*Cynodon dactylon* × *C. transvaalensis* (Baker and Van Bavel, 1986)] and buffalograss (Huang, 1999). This "hydraulic lift" in the soil profile helps to support root growth and functions in nutrient uptake in the upper soil profile, which can lead to efficient use of water under surface soil drying conditions resulting in delaying drought stress injury (Huang, 1999). Superior green color retention of bermudagrass and buffalograss at Antalya may be explained by "hydraulic lift." However, the highly sandy nature of the soil in Mersin may have

Table 7. Mean turfgrass quality at the postdrought stress recuperation period for bermudagrass, buffalograss, zoysiagrass, seashore paspalum, centipedegrass, bahiagrass and tall fescue species and their cultivars at Antalya and Mersin, Turkey, averaged over 2006 and 2007.^a

Species	Cultivars	Time of recovery at Antalya (d)						Time of recovery at Mersin (d)					
		3	12	21	30	45	60	3	12	21	30	45	60
		-----Turfgrass quality (1–9 scale) ^y -----											
Bermudagrass	SWI-1044	1.8	3.8	6.3	7.4	8	6.4	1.2	1.6	2.5	3.3	4.6	4.3
	SWI-1045	1.7	3.7	5.9	6.8	7.5	6.1	1.2	1.5	2.5	3.3	4	4
	Princess	1.4	2.7	5.1	6.4	7.2	5.9	1.1	1.5	2.3	3.2	4.2	3.9
	Riviera	1	2.5	5.8	6.7	7.3	5.8	1	1.8	3	3.8	5	4.6
	Mohawk	1.3	3.2	4.8	6.1	6.3	5	1.1	1.5	2.4	3.2	3.8	4
	Sultan	1.3	3.2	5.1	5.5	6	4.7	1.1	1.8	2.3	2.8	3.7	4.4
	Sahara	1.3	3	5.3	5.7	5.9	4.9	1.1	1.5	2.3	3.1	4.2	4.3
	Blackjack	1.5	3.3	5.4	5.7	6	5.2	1.1	1.3	2.1	2.7	3.3	3.2
	Mean	1.4	3.2	5.5	6.3	6.8	5.5	1.1	1.6	2.4	3.2	4.1	4.1
Least significant difference (LSD) (Bermudagrass)	0.6	1	1.3	1	0.7	0.4	NS‡	0.4	0.5	0.6	0.7	0.8	
Buffalograss	Cody	1.7	4	6.1	6.7	7.1	5.7	1.3	1.9	3	3.4	4.2	3.6
	Bowie	1.2	2.6	4.9	5.5	6	4.9	1.2	1.6	2.1	2.5	3.2	2.8
	SWI-2000	1.6	3.8	5.9	6.5	6.8	5.5	1.2	1.9	2.3	2.7	3.3	2.8
	Bison	1.4	3.2	4.7	5.5	6.1	4.9	1	1.6	2.2	2.7	3.3	3.1
	Texoka	1.6	3.5	4.9	5.4	6	5	1	2.3	2.5	3	3.5	3.5
	Mean	1.5	3.4	5.3	5.9	6.4	5.2	1.1	1.8	2.4	2.9	3.5	3.2
	LSD (Buffalograss)	NS ^x	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Zoysiagrass	Zenith	1.1	1.3	1.4	1.6	1.7	1.6	1	1	1	1	1	1
	Companion	1.3	1.3	1.4	1.4	1.3	1.1	1	1	1	1	1	1
	Mean	1.2	1.3	1.4	1.5	1.5	1.4	1	1	1	1	1	1
	LSD (Zoysiagrass)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bahiagrass	Argentine	1.6	3.3	4	4.3	4.8	4.4	1	1.8	2.4	2.8	3.4	3.3
Seashore paspalum	Sea Spray	1	1.4	3.5	4.3	5.5	4.9	1	1.4	1.9	2.3	3.2	2.9
Centipedegrass	Tifblair	1	1.3	1.5	1.8	1.8	1.4	1	1	1.1	1.3	1.3	1.3
Tall fescue	Eldorado	1	1	1	1	1.1	1.1	1	1	1	1	1	1
	LSD (Species)	0.5	1.2	1.4	1.3	0.9	1	NS	0.7	0.9	1.1	1.2	1.1
	LSD (Cultivar)	0.4	0.8	1.0	0.9	0.7	0.6	0.2	0.5	0.6	0.7	0.8	0.8

^aFisher's protected LSD values are for comparing cultivars within species, species, and cultivars among species.

^yTurfgrass quality ratings were based on a 1–9 visual rating scale with 1 = poorest, 6 = acceptable, and 9 = best.

^{*}NS = Nonsignificant at $P \leq 0.05$.

prevented this phenomenon, causing significantly faster color loss and more severe leaf firing than at Antalya.

Although 'Argentine' bahiagrass demonstrated less leaf firing than 'Sea Spray' seashore paspalum, both showed similar shoot recovery. Dehydration avoidance and deep rooting, but not reduced evapotranspiration, were suggested to be likely mechanisms for drought resistance of bahiagrass (Busey, 2003). Bahiagrass was reported to have 82% (Doss et al., 1960) and 46% higher root dry weight than common bermudagrass (Burton et al., 1954). Superior rooting may explain low leaf firing and high shoot recovery of 'Argentine' bahiagrass observed in both locations. It is best adapted to sandy soils (Gates et al.,

2004), which may explain relatively less leaf firing and better shoot recovery of bahiagrass observed in the sandy soil type at the Mersin location. Bahiagrass also can survive well on droughty soils and compensates for low moisture availability with a more open stand (Gates et al., 2004). Stand density of 'Argentine' bahiagrass and 'Sea Spray' seashore paspalum declined overall in the plots under prolonged drought stress. The two species may have a similar mechanism in trying to cope with water scarcity by thinning the stand and supporting the remaining green shoots with the available water.

When all cultivars were evaluated altogether regardless of species, mean differences in shoot recovery among cultivars were significant ($P < 0.05$)

on most of the evaluation dates. Bermudagrass cultivars SWI-1044, SWI-1045, and Riviera, and 'Cody' buffalograss exhibited the highest shoot recovery. At 30 DOR, 'SWI-1044' bermudagrass, and 'SWI-2000' and 'Cody' buffalograss recovered over 90% at Antalya and 'Cody' buffalograss and 'Riviera' bermudagrass over 40% at Mersin (Table 6). Percent shoot recovery of zoysiagrass cultivars was 15% and 1%, centipedegrass was 26% and 6%, and tall fescue was 8% and 0% at Antalya and Mersin, respectively (Table 6). The results show that the species/cultivars exhibit marked differences in drought resistance.

Understanding drought resistant species and cultivars will facilitate the development of better water-use

efficient management practices for areas with limited water resources by growing the most drought resistant species and cultivars with acceptable quality. Results show that 'SWI-1044' and 'SWI-1045' bermudagrass and 'Cody' buffalograss possess superior drought resistance with higher turfgrass quality, which can be used for water-efficient turf management under the Mediterranean environment. The cultivars that maintained acceptable turfgrass quality with less than 30% leaf firing until 30 d of drought stress indicate potential water savings to turf managers in this environment. Moreover, since the mean leaf firing for all warm-season species was below 20% at 15 d of drought stress at Antalya, deficit irrigation may be applied to the warm-season species without significantly reducing the turfgrass quality. The fact that reduction in the quality of warm-season grasses was within acceptable range up to 15 d of drought stress also suggests that many turfs are over watered in the region.

In conclusion, bermudagrass and buffalograss species/cultivars may perform better than other warm-season species and cool-season species that are commonly used in this region and provide quality turf with reduced water-use requirements. These results will be helpful to turfgrass managers seeking to manage and recommend suitable warm-season turfgrass species and cultivars for water conservation for the Mediterranean region. These results may also help expand the use of some of these cultivars under water deficit conditions in Mediterranean-like climates throughout the world.

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