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ORIGINAL ARTICLE

Evapotranspiration and quality characteristics of some bermudagrass turf cultivars under deficit irrigation

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Abstract

This study was carried out to determine the effects of deficit irrigation on evapotranspiration and quality of bermudagrass (*Cynodon dactylon* L.) turfgrass cultivars under Mediterranean conditions. Eight bermudagrass turf cultivars 'Blackjack', 'Mohawk', 'Princess', 'Riviera', 'Sahara', 'Sultan', 'Swi–1044' and 'Swi–1045' were used. Irrigation experiments were conducted from June to October 2008. Experimental plots were irrigated at 7 days intervals, at three levels of irrigation based on the potential evaporation as measured by a Class A pan (Epan) as follows I_1 = 0.50 Epan, I_2 = 0.75 Epan and I_3 = 1.00 Epan. Volumetric soil water content was measured using soil moisture meter before and after irrigation. It was found that the irrigation levels affect sward color, visual quality and leaf firing. Among the cultivars, 'Swi–1045' and 'Princess' showed the best color and quality while 'Mohawk' and 'Sultan' gave the poorest color and quality in all irrigation levels. No statistically significant differences between I_1 and I_2 irrigation treatments were obtained in terms of color, quality and leaf firing for bermudagrass cultivars. It is concluded that when the amount of water is limited in arid and semiarid regions such as the Mediterranean, the bermudagrass can be irrigated at a level of 50% of pan evaporation to get an acceptable visual quality with improved water conservation.

Introduction

Water for use in turfgrass irrigation is becoming increasingly limited, which often leads to decline in turf quality, particularly in semiarid and arid regions. Therefore, water conservation becomes a prime concern of turfgrass managers and growers as communities place greater restriction on the use of potable water for irrigating turfgrass in home lawns, parks, athletic fields and golf courses (McCann *et al.* 2008).

Deficit irrigation is defined as supplying the amount of water less than actual evapotranspiration (ETa) measured under well-watered conditions and has become an increasingly popular conservation technique in turfgrass maintenance (Feldhake *et al.* 1984; Fry and Butler 1989). Irrigation deficits can be achieved by lengthening periods between irrigations or applying water more frequently at levels less than ETa, which has been the approach of the aforementioned researchers.

The development of turfgrass cultivars with improved tolerance to limited or low-quality water remains one of the most important research objectives facing the turfgrass industry, especially as turf irrigation practices become more restrictive. Although some turfgrasses can escape drought by going into quiescence (growth cessation and leaf senescence) during prolonged drought periods, most turfgrass managers desire to maintain a green surface during drought periods for aesthetics, playability and safety (Kneebone *et al.* 1992).

Bermudagrass (*Cynodon dactylon* L.), warm-season grass, is one of the most widely used turfgrasses in tropical and subtropical regions. This species, which is native to Africa, produces a vigorous, low-growing turfgrass stand with high density and tolerances to both traffic and

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drought stress. According to the National Turfgrass Evaluation Program (NTEP), bermudagrasses establish rapidly and spread by vegetative propagules, both aboveground (stolons) and belowground (rhizomes). Bermudagrass grows best in full-sun conditions, as most are intolerant of shade (NTEP 2010).

Differences in drought resistance in warm-season turfgrasses have been reported and studied intensively (Hook and Hanna 1994; Jiang *et al.* 1998; Karsten and MacAdam 2001). Garrot and Mancino (1994) pointed out that Bermudagrass irrigated with 834–930 mm water annually under drought conditions would not reduce its quality, durability, color, or ground cover. While Kneebone and Pepper (1984) reported that Bermudagrass used 8 mm water per day (during a year) when it is irrigated excessively (364 mm week^{-1}), Kneebone *et al.* (1992) reported the typical water use of Bermudagrass ranged from 2.5 to 7.5 mm per day, taking a maximum value of 12 mm per day. Meyer and Gibeault (1986) concluded that warm-season species had a greater potential than that of cool-season species in terms of water conservation. Meyer *et al.* (1985) found that the average crop coefficient (a constant to convert reference crop evapotranspiration to crop specific evapotranspiration) of warm season species was 0.7, whereas it was 0.8 for cool-season species. Deficit irrigation applications, which wet most of the zone where capillary roots take water, even though they are shallow, can conserve water by taking advantage of the tolerance of turfgrass to short periods of drought between irrigations (Kneebone *et al.* 1992). Feldhake *et al.* (1984) studied deficit irrigation of three turfgrass species grown in lysimeters and determined that irrigation deficits up to 27% only decreased growth, but greater deficits resulted in significant loss of quality for Kentucky bluegrass (*Poa pratensis* L.) and tall fescue (*Festuca arundinacea* Schreb.). Gibeault *et al.* (1985) observed that mixed turfgrass, consisting of Kentucky bluegrass, perennial ryegrass (*Lolium perenne* L.) and tall fescue underwent little reduction in quality when irrigated at 80% of potential ET based on evaporation from Class A pan (Epan). On the other hand, Fry and Butler (1989) determined that only a very small reduction in visual quality of tall fescue would take place when irrigated at 50% of potential ET every other day. Carrow (1995) found that irrigation at 80% Epan was necessary for tall fescue, and 60–80% Epan was needed for the warm-season grasses. Qian and Engelke (1999) found that minimal irrigation requirements for grasses grown along a linear gradient of irrigation ranged from 26% to 68% of Class A pan evaporation in a study of five turfgrass species along a linear gradient of irrigation.

Jordan *et al.* (2003) observed that creeping bentgrass (*Agrostis palustris* Huds.) putting green turf irrigated every 4 days compared with irrigation every 1 or 2 days, had significantly improved turf quality in one of two study years. Fu *et al.* (2004) reported that tall fescue, bermudagrass and Japanese lawngrass (*Zoysia japonica* Steud.) displayed the same level of turf quality as well-watered turfgrass when irrigated at 60 or 80% of evapotranspiration. DaCosta and Huang (2006) determined that bentgrass species required more than 60% ETa for maintaining acceptable summer quality, but that irrigating at only 40% ETa was sufficient for maintaining acceptable quality during fall months.

Water is one of the most precious natural recourses in arid and semiarid regions including the region where this research has been conducted. Methods of reducing water consumption of turfgrasses in these regions are of major importance. Maintaining good quality turf in an arid and semiarid region is a difficult task and people are searching for turfgrass species or cultivars that will perform well in harsh desert environmental conditions. Although bermudagrasses are adapted to many types of soil and hot climatic regions and regarded as a drought-tolerant species, adequate soil moisture is required to sustain good growth and color (Taliaferro 2003). Therefore, selection

Table 1 Water budget calculations (mm) for eight *Cynodon dactylon* cultivars used in this study

Irrigation levels	Cultivars	Irrigation	Precipitation	Change in soil water content	ETa
I_1 (0.50 Epan)	Blackjack	370	32.2	19.9	422.1
	Mohawk	370	32.2	23.0	425.2
	Princess	370	32.2	20.9	423.1
	Riviera	370	32.2	19.4	421.6
	Sahara	370	32.2	19.4	421.6
	Sultan	370	32.2	21.5	423.7
	Swi-1044	370	32.2	22.5	424.7
	Swi-1045	370	32.2	16.7	418.9
I_2 (0.75 Epan)	Blackjack	555	32.2	7.3	594.5
	Mohawk	555	32.2	6.3	593.5
	Princess	555	32.2	12.0	599.2
	Riviera	555	32.2	11.0	598.2
	Sahara	555	32.2	8.9	596.1
	Sultan	555	32.2	13.1	600.3
	Swi-1044	555	32.2	12.6	599.8
	Swi-1045	555	32.2	14.1	601.3
I_3 (1.00 Epan)	Blackjack	740	32.2	3.1	775.3
	Mohawk	740	32.2	0.5	772.7
	Princess	740	32.2	4.2	776.4
	Riviera	740	32.2	5.2	777.4
	Sahara	740	32.2	0.0	772.2
	Sultan	740	32.2	3.1	775.3
	Swi-1044	740	32.2	6.8	779.0
	Swi-1045	740	32.2	6.3	778.5

ETa: actual evapotranspiration.
Epan: evaporation from class A pan.

of cultivars requiring less moisture with fewer irrigation and water requirements has become an important issue in turfgrass management (Kim and Beard 1988).

The objectives of the study were twofold: (i) to investigate the water use of eight bermudagrass cultivars and (ii) to examine the physiological responses such as color, quality and leaf firing of eight bermudagrass cultivars under various combinations of irrigation levels during the summer months in a Mediterranean region where rainfall is limited according to the long term climatic data.

Materials and methods

The study was conducted between June and October 2008 at the Bati Akdeniz Agricultural Research Institute, Antalya, Turkey. The institute area was located at a latitude of 36°50′N, a longitude of 30°43′E, and an altitude of 17 m. The research area has a typical Mediterranean climate: hot and dry in summers and mild and rainy in winters. Long term monthly climatic data and the data measured during the experiment by a climatic station near the institute are given in supplementary Table S1.

The soil of the research area has a loamy texture, is unsalted and rich in calcium carbonate and alkali. Its weight based field capacity (1/3 atm), permanent wilting point (15 atm) and bulk density in the upper 30 cm depth are 16.7%; 8.2% and 1.42 g cm^{-3}, respectively. Some physical and chemical properties of field soil and irrigation water determined *in situ* and in the laboratory are given in Tables S2 and S3.

Eight bermudagrass cultivars 'Blackjack', 'Mohawk', 'Princess', 'Riviera', 'Sahara', 'Sultan', 'Swi–1044' and 'Swi–1045' were used in the study. The cultivars imported for adaptation in Antalya region (Turkey) were seeded at a rate of 15 g m^{-2} on 15 July 2005. After 2 years of the adaptation study, the current study was conducted. The cultivars received 17.5 g m^{-2} N 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 fertilizer (33N–0P–0K). The cultivars were mowed at a level of 5 cm above ground when it was 10–12 cm tall (Ritchie *et al.* 2002). The mowing intervals ranged between 9 and 16 days depending on climatic conditions and growth phase.

Plots were arranged in a randomized split-plot design, with irrigation levels as the main plots and cultivars as the subplots. Three levels of irrigation were based on the potential evaporation as measured by a Class A evaporation pan (Epan) (Bastug and Buyuktas 2003). The pan located next to the plots was placed on a wooden support at a height of 15 cm above soil surface and readings were recorded daily. The main plots having a size of 10.5 × 12.5 m consisted of I_1 (0.50 Epan), I_2 (0.75 Epan) and I_3 (1.00 Epan) irrigation treatments. Irrigations started on 15 June 2008 and ended 8 October 2008. The size of the sub-plots was 1.0 × 1.5 m and consisted of eight bermudagrass cultivars. A buffer space (0.3 m wide) was left between the sub-plots. Each cultivar and irrigation treatment was replicated three times summing to a total of 72 plots. As recommended by Carrow *et al.* (1990) for loamy soils, plots were irrigated once a week. The treatments were irrigated using mini sprinklers arranged 3 × 3 m and discharging 75 L h^{-1} at a pressure of 0.2 MPa.

The volumetric soil water content was measured weekly, before and after irrigation, using Time-Domain

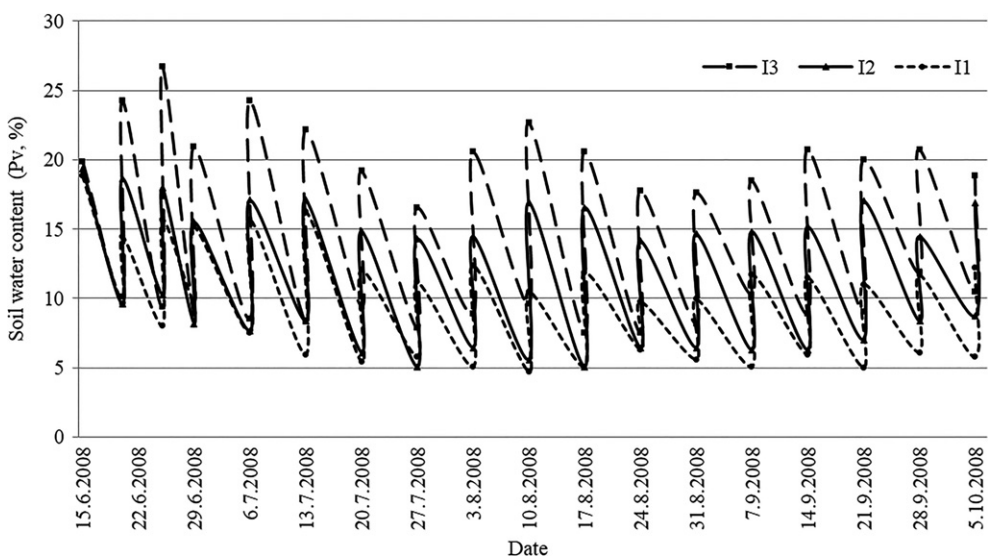


Figure 1 Change in soil water content (0–15 cm,% vol) for the Blackjack cultivar over sixteen weeks in response to three irrigation treatments, I_1 = 0.50 evaporation from class A pan (Epan); I_2 = 0.75 Epan; and I_3 = 1.00 Epan.

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Reflectometer (a soil moisture meter, model 300; Spectrum Technologies Inc., Aurora, USA) to monitor soil water depletion. A pair of stainless steel 15 cm probes was inserted vertically into the soil profile at two locations per plot, from which the data were averaged to determine soil water content for each plot.

The equation used to compute bermudagrass cultivars ETa (mm) is given below.

$$\mathrm{ETa} = I + P - \mathrm{Dp} \pm \Delta\mathrm{SW}$$

where I = irrigation water (mm), P = precipitation (mm), Dp = deep percolation (mm) and ΔSW = change in moisture content of profile (mm). For the calculation, I was measured using water meters, and P was observed at the meteorological station. Doty *et al.* (1990) noted that a large portion of grass water uptake (approximately 60%) was in the upper 0–0.25 m soil profile, while the rest was at the depth of 0.25–0.75 m. Therefore, the effective rooting depth was regarded as 0.30 m in our calculations. In the study, it is assumed that the soil water

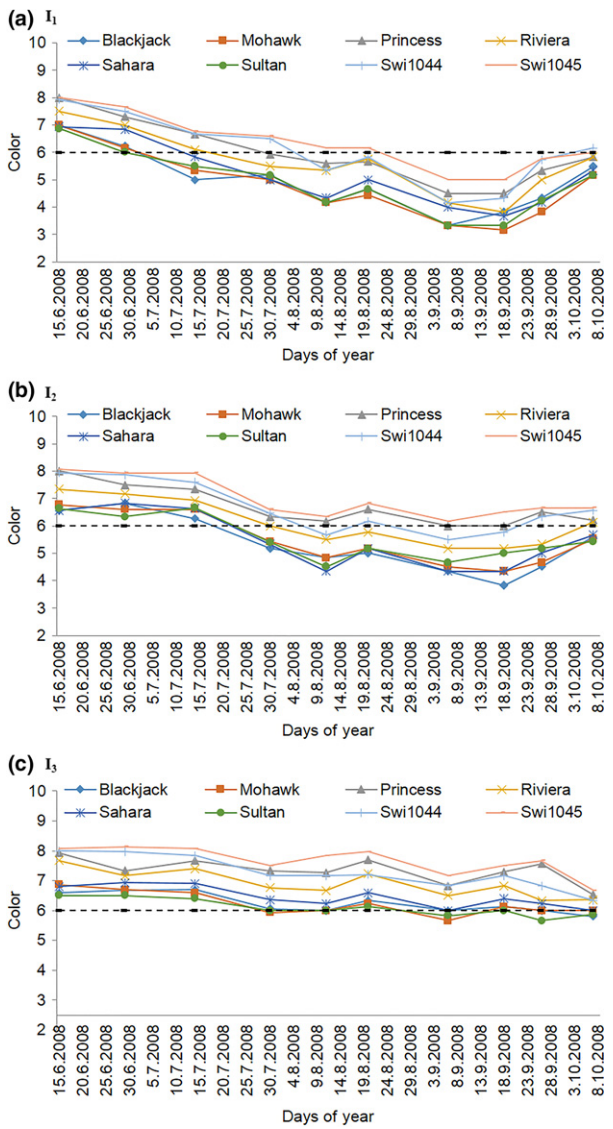


Figure 2 Change in color scores of eight bermudagrass cultivars over 16 weeks in response to three irrigation treatments, I_1 = 0.50 evaporation from class A pan (Epan) (a), I_2 = 0.75 Epan (b) and I_3 = 1.00 Epan (c). The color scale is 1 = brown, dead turf through to 9 = optimal. The dashed line is the minimum acceptable color.

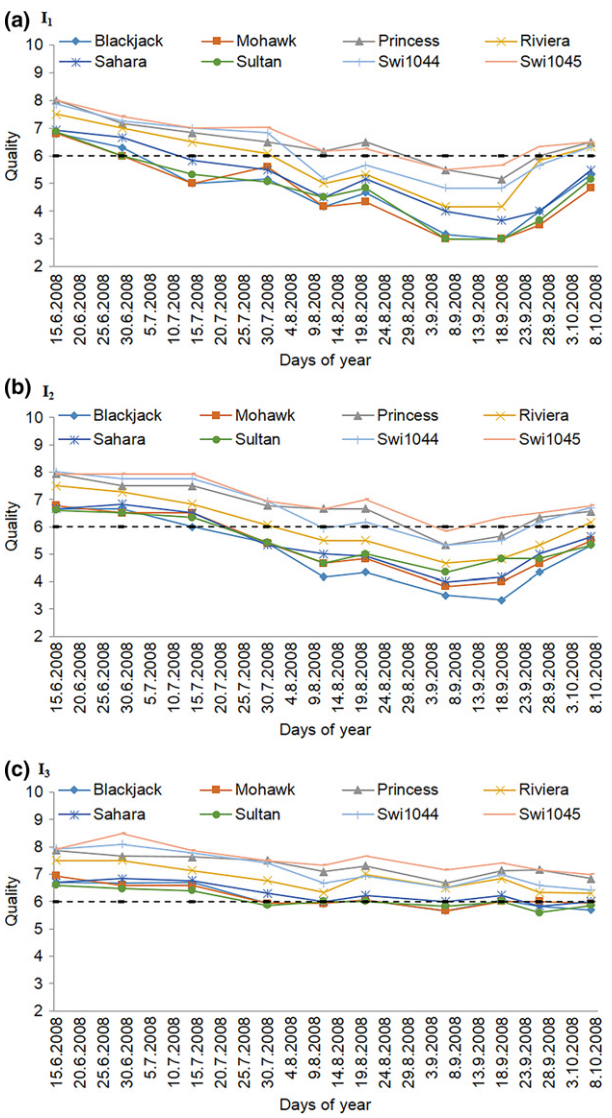


Figure 3 Change in quality scores of eight bermudagrass cultivars over sixteen weeks in response to three irrigation treatments, I_1 = 0.50 evaporation from class A pan (Epan) (a), I_2 = 0.75 Epan (b) and I_3 = 1.00 Epan (c). The quality scale is 1 = poorest through to 9 = best. The dashed line is the minimum acceptable color.

content measured at 15 cm depth represents the average water content of the bermudagrass rooting depth.

The main turfgrass characteristics considered in the study were color, quality and leaf firing. These parameters were determined once a week. Measurements were obtained during mid-afternoon hours on cloudless days. Turfgrass color was based on a 1–9 visual rating scale, where 1 = straw brown, 6 = light green (acceptable) and 9 = dark green (optimum) (Turgeon 1999). Turfgrass quality ratings were based on NTEP guidelines using a 1–9 visual rating scale, where 1 = poorest, 6 = acceptable and 9 = best (NTEP 2010) which were based on combination of color, density and uniformity. Leaf firing based on a visual estimate scale of 0% to 100%, where 0% = firing and 100% = 100% no firing (NTEP 2010). Leaf firing refers to leaf chlorosis starting at leaf tips and margins. Initial injury is a yellowing but often progresses into a tan-brown color with death of the tan-brown areas (Carrow and Duncan 2003).

The effect of irrigation on color, quality and leaf firing characteristics of cultivars was also statistically analyzed using SPSS software program (Version 14.0, SPSS Inc., Chicago, USA). Because the abovementioned variables were not ratio or interval and the group number was more than three, a non-parametric test of Kruskal–Wallis test was used instead of the variance analysis. Additionally, the sources of the differences among the groups were also determined.

Results and discussion

The objective of this study was to determine the response of eight bermudagrass cultivars to three levels of deficit irrigation. The measured cumulative evaporation and ETa of the treatments during the study are presented in Table 1. While the total and average daily evaporation in the 115–day period was 740 mm and 6.4 mm day^{-1}, deficit irrigated treatments received a total of 555 mm (0.75 Epan), and 370 mm (0.50 Epan). The average ETa during the experimental period in I_1, I_2 and I_3 irrigation treatments were found to be 422.6, 597.9 and 775.9 mm, respectively. The applied water, precipitation, change in soil water content and ETa in all treatments are presented in Table 1. The change in volumetric soil water content before and after irrigation for 'Blackjack' (as an example) is given in Figure 1. The soil water content under other cultivars showed a similar pattern, thus the data are not presented here. While the highest soil water content was measured in I_3 treatment, the lowest one was found to be in the I_1 treatment.

The change in color grading numbers over time (7 days intervals) is given in Figure 2. The figure was obtained according to the Turgeon (1999) color scale for numerical evaluation of the change in turfgrass color during the experiment in irrigation treatments. The color grading number increased as they moved from I_1 to I_3 in the following months. The results demonstrated that irrigating all of the bermudagrass cultivars at I_3 was sufficient to sustain acceptable turfgrass color over the 16-week study period (Figure 2c).

Although decreased in August and September, an acceptable color grading number (above six) was obtained from 'Princes' and 'Swi–1045' cultivars during all of the study period in I_2 irrigation treatment which was irrigated as much as 0.75 Epan (Figure 2b). Additionally, excluding the month of September, 'Swi–1045' cultivar gave an

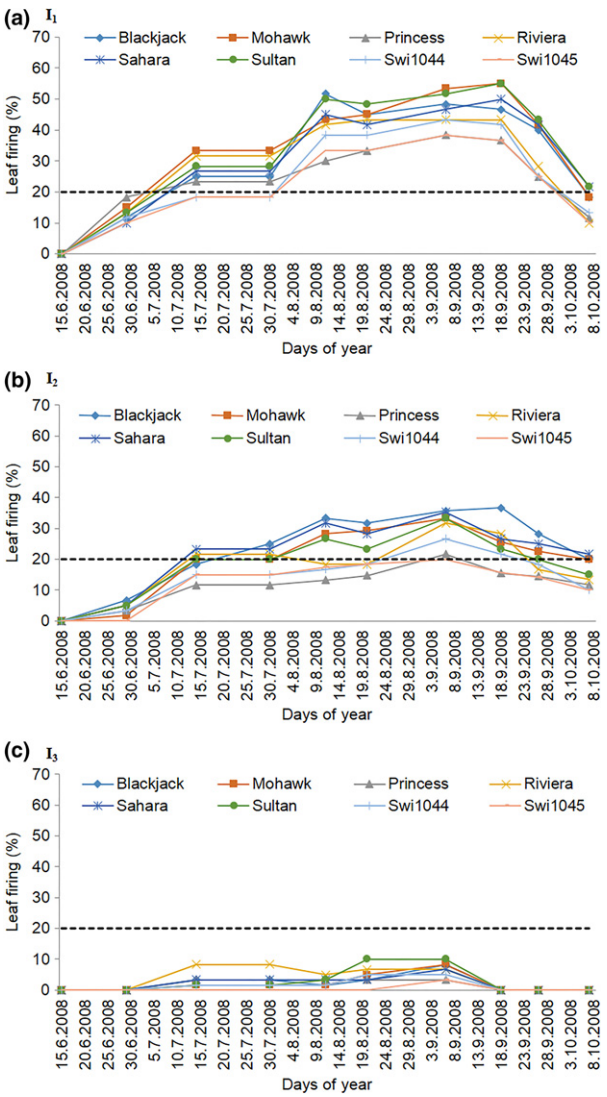


Figure 4 Percentage of leaf firing in eight bermudagrass cultivars over 16 weeks in response to three irrigation treatments, I_1 = 0.50 evaporation from class A pan (Epan) (a), I_2 = 0.75 Epan (b) and I_3 = 1.00 Epan (c).

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Table 2 Non-parametric Kruskal-Wallis test results for color grading scores for eight *Cynodon dactylon* cultivars across three irrigation treatments

	Irrigation				All Samples	
	Indicators	I_1 (0.50 Epan)	I_2 (0.75 Epan)	I_3 (1.00 Epan)		
Cultivars	*n*	30	30	30	90	
Blackjack	Mean	4.92 (0.20)†[a]	5.29 (0.19)[a]	6.13 (0.10)[b]	5.45 (0.11)	$H = 20.14$
	Median	5.00	5.25	6.20	5.50	$P < 0.01$
Mohawk	Mean	4.76 (0.23)[a]	5.44 (0.17)[a]	6.17 (0.09)[b]	5.46 (0.12)	$H = 22.21$
	Median	5.00	5.40	6.00	5.65	$P < 0.01$
Princess	Mean	5.93 (0.21)[a]	6.66 (0.14)[a]	7.26 (0.12)[b]	6.62 (0.11)	$H = 24.57$
	Median	5.80	6.50	7.50	6.70	$P < 0.01$
Riviera	Mean	5.60 (0.20)[a]	6.05 (0.15)[a]	6.83 (0.11)[b]	6.16 (0.11)	$H = 22.72$
	Median	5.50	6.00	7.00	6.00	$P < 0.01$
Sahara	Mean	5.11 (0.22)[a]	5.42 (0.19)[a]	6.36 (0.10)[b]	5.63 (0.12)	$H = 19.00$
	Median	5.00	5.50	6.50	6.00	$P < 0.01$
Sultan	Mean	4.84 (0.21)[a]	5.50 (0.15)[a]	6.01 (0.08)[b]	5.45 (0.10)	$H = 19.86$
	Median	5.00	5.50	6.00	5.50	$P < 0.01$
Swi1044	Mean	6.02 (0.23)[a]	6.59 (0.17)[b]	7.13 (0.14)[b]	6.58 (0.11)	$H = 14.29$
	Median	6.00	6.45	7.00	6.50	$P < 0.01$
Swi1045	Mean	6.31 (0.18)[a]	6.97 (0.13)[b]	7.56 (0.12)[c]	6.95 (0.10)	$H = 24.28$
	Median	6.00	6.65	7.65	6.90	$P < 0.01$

†The values in parenthesis are standard error of mean. Mean values within a row followed by a different letter are significantly different at 0.01. Epan, evaporation from Class A pan; *H*, Kruskal–Wallis Test Statistics; *P*, Kruskal–Wallis Test Probabilities.

Table 3 Non-parametric Kruskal–Wallis test results for visual quality grading scores for eight *Cynodon dactylon* cultivars across three irrigation treatments

	Irrigation				All Samples	
	Indicators	I_1 (0.50 Epan)	I_2 (0.75 Epan)	I_3 (1.00 Epan)		
Cultivars	*n*	30	30	30	90	
Blackjack	Mean	4.76 (0.22)†[a]	4.97 (0.23)[a]	6.13 (0.08)[b]	5.29 (0.13)	$H = 23.21$
	Median	5.00	5.00	6.00	5.50	$P < 0.01$
Mohawk	Mean	4.62 (0.24)[a]	5.27 (0.20)[a]	6.17 (0.08)[b]	5.35 (0.13)	$H = 24.64$
	Median	4.75	5.35	6.00	5.65	$P < 0.01$
Princess	Mean	6.43 (0.15)[a]	6.69 (0.15)[a]	7.29 (0.08)[b]	6.80 (0.08)	$H = 19.44$
	Median	6.50	6.80	7.30	7.00	$P < 0.01$
Riviera	Mean	5.79 (0.20)[a]	5.97 (0.18)[a]	6.82 (0.09)[b]	6.19 (0.11)	$H = 18.41$
	Median	6.00	6.00	6.90	6.50	$P < 0.01$
Sahara	Mean	5.18 (0.22)[a]	5.41 (0.20)[a]	6.29 (0.07)[b]	5.62 (0.11)	$H = 19.14$
	Median	5.50	5.50	6.10	6.00	$P < 0.01$
Sultan	Mean	4.74 (0.22)[a]	5.39 (0.15)[a]	6.06 (0.06)[b]	5.40 (0.11)	$H = 22.76$
	Median	5.00	5.00	6.00	5.50	$P < 0.01$
Swi1044	Mean	6.15 (0.22)[a]	6.63 (0.18)[a]	7.13 (0.11)[b]	6.64 (0.11)	$H = 11.44$
	Median	6.50	6.50	7.00	6.65	$P < 0.01$
Swi1045	Mean	6.59 (0.15)[a]	6.98 (0.13)[a]	7.55 (0.09)[b]	7.04 (0.08)	$H = 22.98$
	Median	6.50	7.00	7.50	7.00	$P < 0.01$

†The values in parenthesis are standard error of mean. Mean values within a row followed by a different letter are significantly different at 0.01. Epan: evaporation from Class A pan; *H*: Kruskal–Wallis Test Statistics; *P*: Kruskal–Wallis Test Probabilities.

acceptable color grading even in the I_1 irrigation treatment, resulting that 50% of irrigation water could be saved under severe water shortage conditions (Figure 2a). Hanks *et al.* (2005) reported also that crested wheatgrass (*Agropyron cristatum* Gaertn.) turf color declined in early and midsummer, but recovered in late summer when irrigated at 50% of crop evapotranspiration. A similar trend in color grading number was also obtained in this study.

The change in quality over time (7 days intervals) is given in Figure 3. The turfgrass quality scores were higher

with greater irrigation levels. They declined over time at all irrigation levels, but recovered during September and October in the I_1 and I_2 treatments. The results demonstrated that irrigating all of the bermudagrass cultivars at I_3 was sufficient to sustain acceptable turfgrass quality over the 16-week study period (Figure 3c). Feldhake *et al.* (1984) demonstrated that irrigating above 73% ETa three times weekly was necessary for maintaining adequate Kentucky bluegrass quality. An acceptable quality was obtained from I_2 treatment for 'Swi-1045' cultivar during all of the study period (Figure 3b). Excluding the month of September, the results indicated that acceptable bermudagrass quality could be achieved at even greater irrigation deficits (I_1) (Figure 3a) for 'Princess' and 'Swi–1045' cultivars, allowing use of less water under drought conditions.

Leaf firing was the primary symptom of plant water stress leading to quality loss in grasses (Figure 4). Leaf firing increased most rapidly in I_1 treatments. The highest leaf firing was obtained from 'Mohawk' and 'Sultan' cultivars in I_1 irrigation treatment. Although only 20–30% of leaf firing was observed in I_2 treatments, this ratio was deemed acceptable throughout the study. It is concluded that bermudagrass cultivars except for 'Riviera' and 'Sultan', irrigated at I_3 (Figure 4c), never showed signs of leaf firing during the study period, indicating that soil moisture was sufficient to meet transpiration demand. An acceptable leaf firing percentage, less than 20%, was obtained in I_2 treatment for 'Princes' and 'Swi–1045' cultivars (Figure 4b), indicating that irrigation as much as 75% of the pan evaporation would be sufficient.

The effect of irrigation on color, quality and leaf firing characteristics of cultivars was also statistically analyzed. Mean, standard error of the mean and median values regarding color grading numbers, quality and leaf firing for different irrigation treatments as well as the Kruskal–Wallis test statistics (H) and probabilities (P) are presented in Tables 2, 3 and 4, respectively.

The Kruskal–Wallis test revealed that the differences in parameters at the 1% significance level in terms of color grading numbers, quality and leaf firing in all cultivars were found to be statistically different except for 'Sultan', 'Swi–1044' and 'Swi–1045' cultivars in color grading numbers and 'Swi–1044' and 'Swi–1045' cultivars in quality characteristics. In other words, irrigation water level is affecting the quality characteristics in almost all cultivars. Statistically significant results were obtained between I_3 and I_2 but not between I_1 and I_2 irrigation treatments. This means that, in case of no water shortage, the bermudagrass can be irrigated as much as 100% of evaporation measured in Class A pan. However, in case of water shortage, the bermudagrass cultivars can be irrigated as much as 50% evaporation measured in Class A pan, resulting in 50% of water saving, which is a significant amount of water taking global warming into consideration.

Table 4 Non-parametric Kruskal–Wallis test results for leaf firing grading scores for eight *Cynodon dactylon* cultivars across three irrigation treatments

	Irrigation				All Samples	
	Indicators	I_1 (0.50 Epan)	I_2 (0.75 Epan)	I_3 (1.00 Epan)		
Cultivars	*n*	30	30	30	90	
Blackjack	Mean	31.17 (3.25)†[a]	28.50 (3.14)[a]	2.00 (0.57)[b]	20.56 (2.05)	$H = 42.36$
	Median	32.50	30.00	0.00	15.00	$P < 0.01$
Mohawk	Mean	33.83 (3.33)[a]	24.83 (2.87)[a]	1.83 (0.61)[b]	20.17 (2.04)	$H = 43.91$
	Median	37.50	25.00	0.00	20.00	$P < 0.01$
Princess	Mean	24.00 (2.21)[a]	15.17 (1.75)[a]	1.67 (0.44)[b]	13.61 (1.35)	$H = 47.24$
	Median	20.00	15.00	0.00	10.00	$P < 0.01$
Riviera	Mean	28.67 (2.84)[a]	22.50 (2.49)[a]	3.50 (0.76)[b]	18.22 (1.70)	$H = 40.04$
	Median	35.00	25.00	0.00	15.00	$P < 0.01$
Sahara	Mean	31.00 (3.06)[a]	27.00 (3.00)[a]	2.00 (0.57)[b]	20.00 (1.97)	$H = 42.87$
	Median	32.50	30.00	0.00	15.00	$P < 0.01$
Sultan	Mean	34.00 (3.33)[a]	23.67 (2.66)[a]	2.67 (0.75)[b]	20.11 (1.99)	$H = 45.00$
	Median	35.00	25.00	0.00	15.00	$P < 0.01$
Swi1044	Mean	24.83 (2.75)[a]	18.50 (2.31)[a]	1.50 (0.43)[b]	14.94 (1.59)	$H = 44.31$
	Median	25.00	17.50	0.00	10.00	$P < 0.01$
Swi1045	Mean	22.33 (2.45)[a]	14.83 (1.77)[a]	0.33 (0.23)[b]	12.50 (1.39)	$H = 48.14$
	Median	27.50	15.00	0.00	10.00	$P < 0.01$

†The values in parenthesis are standard error of mean. Mean values within a row followed by a different letter are significantly different at 0.01. Epan, evaporation from Class A pan; H: Kruskal–Wallis Test Statistics; P: Kruskal–Wallis Test Probabilities.

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Similar results have been reported in various studies for different local conditions and crop cultivars. Emekli *et al.* (2007) reported that there was no statistical difference in terms of color grading number for the irrigation treatments, which were irrigated as much as 100% and 75% evaporation measured in Class A pan and concluded that 75% evaporation would be sufficient under the Mediterranean conditions to obtain an acceptable visual quality.

Bastug and Buyuktas (2003) reported that the best color quality for a cool season turfgrass under the Mediterranean conditions could be attained when irrigated as much as 75% of Class A pan and concluded that the results could be extended to the warm season grass.

Conclusions

This study was conducted to determine the response of eight bermudagrass cultivars to different levels of deficit irrigation applications under Mediterranean conditions. Although, among the cultivars, 'Swi–1045' and 'Princess' showed the best color and quality, the differences between I_1 and I_2 irrigation treatments were not statistically significant in terms of color, quality and leaf firing for bermudagrass cultivars. Some of the results regarding water requirement of turfgrass showed already that turfgrass could be irrigated as much as 75% of pan evaporation. However, the result obtained in this study showed that when the amount of water is limited in arid and semiarid regions such as the Mediterranean, the bermudagrass can be irrigated as much as 50% of pan evaporation to get an acceptable visual quality, as well as water conservation.

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Supporting Information

Additional Supporting Information may be found online in the supporting information tab for this article:

Table S1. Long-term monthly and growing season climatic data of the study area.
Table S2. Some physical and chemical properties of the soil used in this study.
Table S3. Quality parameters of the irrigation water used in this study.

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