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The Effects of Different Irrigation Levels and Nitrogen Doses on Growth, Quality and Physiological Parameters of Warm-season Turfgrasses

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ABSTRACT

This research was conducted to determine to effects of different irrigation levels and nitrogen doses (ND) on the various warm-season turfgrasses at the Agricultural Training and Research Centre of the Bursa Uludag University Faculty of Agriculture for two years in a row. The experimental design was the randomized blocks in a split-split plot design with three replications. The main plot was irrigation levels (I_1=25%, I_2=50%, I_3=75%, and I_4=100% of pan evaporation), subplots were turfgrass species [hybrid Bermudagrass (*Cynodon transvaalensis x Cynodon dactylon*) cv. Tifdwarf, seashore paspalum *(Paspalum vaginatum* Sw.) cv. Seaspray, zoysiagrass (*Zoysia japonica* Steud.) cv. Zenit], and sub subplots were ND's (monthly 0.0, 1.25, 2.5, and 5.0 g N m^{-2}). Visual turfgrass color and quality, clipping yield, leaf relative water content (RWC), loss of turgidity (LT), chlorophyll content (CC), and electrolyte leakage were measured. According to the results, significant differences were determined among irrigation levels, turfgrass species, and ND's for color, quality, clipping yield and physiological parameters. Turfgrass visual color, quality and clipping yield were shown to decrease significantly with decreases in irrigation water and N fertilizer. The study findings demonstrated that under a non-limiting water supply, irrigation could be decreased by adjusting N fertilizer rates with I_3N_3 treatments can maintain acceptable turfgrass visual color and quality under Mediterranean climatic conditions. In addition, at 25% (I_1) deficit irrigation level, leaf RWC, CC decreased significantly, while an increase was determined in LT. This research indicated that under 75% (I_3) deficit irrigation and N_3 ND, acceptable quality can be maintained with 'seaspray' seashore paspalum under Mediterranean climate performed.

Keywords: Deficit irrigation, Nitrogen fertilization, Turf color, Turf physiology

1. Introduction

Many turfgrass species have been used in Turkey's arid and semi-arid regions, where rainfall is restricted to only four or five months during winter and fall of the year. This situation keeps the issue of efficient use of water lawns on the agenda. Contrary to popular belief, Turkey is neither a country rich in freshwater resources nor the wealthiest country in the region. Turkey lies in a semi-arid zone, with just about one-fifth of the water available per capita in water-rich places like North America and Western Europe. Countries with 10.000 cubic meters of water per capita per year are considered to be water rich. This is far more than Turkey's per capita consumption of 1350 cubic meters. With a population of 100 million people predicted by 2030, this amount will drop to 1000 m^3 per capita/year (Turkey's Policy on Water Issues, 2021).

In order to provide the required functional and aesthetic characteristics, irrigation in turfgrass-covered leisure sites or sports grounds is important (Kneebone et al. 1992). However, water requirements are high, and maintaining a decent grade of turfgrass quality throughout the summer season is costly. Irrigation which was done carefully, substantially impacts the management costs and environmental impact of turfgrass. Turfgrass managers and scientists wish to devise ways to maintain a given level of turf quality and reduce irrigation supplies considerably (Ervin & Koski 1998; Cereti et al. 2009). Previous studies with deficit irrigation have shown that satisfactory turf quality can be maintained substantially by reducing water rather than providing full evapotranspiration (ET) (Fu et al. 2004; DaCosta & Huang 2006; Fu et al. 2007a; Fu et al. 2007b; Colmer & Barton 2017). Wilt-based irrigation has been demonstrated to cut irrigation water use in half, minimize thatch mat layers, and improve lawn quality when compared to non-limiting soil moisture-based irrigation (Fu & Dernoeden 2009).

Due to scarce water resources in semi-arid climates, turfgrasses tolerant of lower irrigation regimes have gained popularity. Heat and drought stress can cause grasses to lose their leaf water potential, close their stomata, raise their canopy temperature, and produce reactive oxygen species (White et al. 1992; Leung & Giraudat 1998; Wang & Huang 2004).

Warm-season turfgrasses, which are the main subject of our research, are more resistant to drought and their water use efficiency is higher than cool-season turfgrasses (Huang 2008; Zhou et al. 2012). However, they can show the expected performance with less amount of fertilization. Therefore, it has an important position in terms of preventing some environmental problems such as water pollution and especially nitrate pollution. Excess nitrogen (N) fertilization pollutes groundwater and rivers because of N leaching (Snyder et al. 1984; Pathan et al. 2007).

Turfgrass cultivation requires the use of N fertilizer to provide fast and uniform growth, good color, high shoot density, and sufficient strength for harvesting (Beard 1973). N management is another essential aspect of water conservation that is sometimes disregarded (Brown et al. 2004). When turf lacks N, it loses quality faster than turf that is properly fertilized when exposed to moisture stress (Feldhake 1981).

In the Mediterranean climate zone, where the experiment is conducted, warm-season turfgrasses are less common than cool-season turfgrass because of low temperatures in the fall and winter seasons, their availability on the seed market, and limited availability of vegetative production sources (Kir et al. 2010; Severmutlu et al. 2011; Aydinsakir et al. 2016). Previous studies in this region focused only on cool-season turfgrass (Bilgili et al. 2011; Uzun & Bilgili 2011; Bilgili & Yonter 2016; Zere & Bilgili 2016).

The objectives of this research were to determine the effects of different irrigation levels and nitrogen doses (ND) on growth, quality and physiological characteristics of three warm-season turfgrass species including seashore paspalum, zoysiagrass and hybrid Bermudagrass under Mediterranean-type environments in Turkey.

2. Materials and Methods

This study was conducted at the Agricultural Training and Research Centre of the Bursa Uludag University Faculty of Agriculture experimental turfgrass plots in 2014 and 2015. The research site was situated in Bursa/Turkey (40° 13’ 36” N latitude, 28° 51’ 35” E longitude, 112 m elevation), with a Mediterranean climate.

The climate data was slightly different between the growing seasons with average temperatures of 16.0 °C and 15.4 °C in 2014 and 2015, respectively (Table 1). The long-term (1950-2015) average temperature, average relative humidity, and annual precipitation were 14.6 °C, 64.7%, and 694.1 mm, respectively.

In the first growing season, relative humidity was slightly higher (9%) and the average temperature was 1 °C above the long-term average (Table 1).

Regarding soil analysis reports, the upper 20 cm of the soil was considered loamy and rich in K. Receivable p level was 30.9 mg kg^{-1} and soil pH was 8.5 (Table 2). Undisturbed and disturbed soil samples were used to determine field capacity and wilting point according to Cassel & Nielsen (1986) and Tuzuner (1990). Total available moisture and average bulk density for a 0-30 cm soil profile were 45.0 mm and 1.35 g cm^{-3}, respectively.

The experiment consisted of three warm-season turfgrass species including, seashore paspalum (cv. Seaspray), zoysiagrass (cv. Zenith) and hybrid Bermudagrass (cv. Tifdwarf). The trials were organized in a split-split plot design with three replications in randomized blocks. The main plots were laid out in accordance with the irrigation levels, and the subplots were the turfgrass species. Finally, the ND’s (0.0, 1.25, 2.5 and 5.0 g N m^{-2} $month^{-1}$) were placed into sub-sub plots, which possessed dimensions of 1 x 2=2 m^2 (Table 3).

Four irrigation levels [25% (I_1), 50% (I_2), 75% (I_3), and 100% (I_4) of pan evaporation] were applied, during the experiment period each year from May to September as described by Emekli et al. (2007). The US Weather Bureau Class A pan evaporation method (Epan) was

Table 1- The climate data of the experimental area

Months	*Temperature (°C)*			*Precipitation (mm)*			*Relative humidity (%)*		
	2014	*2015*	*LT[*]*	*2014*	*2015*	*LT*	*2014*	*2015*	*LT*
January	9.0	5.4	5.5	30.8	112.0	82.9	70.4	79.0	70.0
February	8.6	7.3	6.1	20.4	74.2	70.7	73.7	76.5	68.7
March	10.7	9.1	8.6	42.4	78.2	66.1	69.6	79.1	67.7
April	14.5	11.5	13.0	112.0	95.6	66.0	71.1	70.1	66.1
May	18.3	19.3	17.4	96.8	36.0	43.4	71.7	64.2	62.0
June	22.3	21.7	22.5	94.4	37.8	36.5	70.7	72.0	57.8
July	25.6	25.5	24.8	4.6	0.0	17.7	64.5	60.7	56.2
August	25.7	26.4	24.5	45.4	5.6	13.8	67.9	61.5	57.3
September	20.6	23.6	20.2	115.6	98.1	40.8	76.6	73.2	63.8
October	16.4	16.4	15.0	68.6	93.2	75.5	80.2	83.7	68.7
November	11.3	12.7	10.5	72.4	26.4	79.9	83.0	78.1	69.3
December	9.3	5.6	7.2	143.2	3.0	100.8	87.3	76.6	68.7
Total	-	-	-	846.6	660.1	694.1	-	-	-
Average	16.0	15.4	14.6	-	-	-	73.9	72.9	64.7

[*]LT: long term mean (1950-2015)

Table 2- Soil properties of the experimental field

%Sand	46.25	EC, µS cm^{-1}	468
%Silt	30.99	%Organic matter	2.091
%Clay	22.76	%N	0.106
Texture class	Loam	P, mg kg^{-1}	30.95
pH	8.48	Total K	5180

used to calculate the irrigation levels. The experimental area was irrigated at 3-day intervals utilizing a pop-up sprinkler (PSU-04-15A, Hunter, USA) irrigation system. To create a 90° wetting pattern, four corners of each 4 x 6-meter plot were placed on sprinkler heads, and sprinkling was done at a rate of 7.5 mm h^{-1}, which was lower than the soil infiltration rate (8.0 mm h^{-1}). N (Ammonium nitrate, 26%) fertilization was applied monthly from May to September, which was broadcasted by hand in the middle of each month.

Before irrigation, in the center of each plot at depths of 0.15 m and 0.45 m neutron probe (503 DR Hydroprobe, CPN International, Inc., Martinez, CA, USA) was used to assess the soil water content (SWC). Between two consecutive soil water measurement dates, the ET of turfgrass was calculated as the residual of the soil water balance. Each irrigation treatment's ET was figured out separately using the formula:

$$ET = I + P - RO - DP + CR \pm \Delta SF \pm \Delta SW$$

Where *I* represent the depth of irrigation water (mm), *P* represents precipitation (mm), *SF* represents water transferred in or out of the root zone horizontally by subsurface flow, *SW* represents the change in *SWC* (mm), *RO* represents the depth of runoff (mm), *DP* represents deep percolation below the root zone (mm), and *CR* represents capillary rise. Water meters were used to measure irrigation water, and *P* was calculated using meteorological station data. Because the spreading rate was under the infiltration rate, no runoff occurred. Given the difficulties in determining *SF, DP*, and *CR* from a water table over short periods (Allen et al. 2007), *SF* and *CR* were set to zero. Using moisture measurements for the 0.6 m soil profile to account for percolation, the soil water balance was calculated. Doty et al. (1990) observed on cool-season turfgrasses that a significant portion of grass water uptake occurs in the 0-25 cm soil profile; thus, effective rooting depth was assumed to be 0.3 m. Emekli et al. (2007), Wherley et al. (2015) and Amgain et al. (2018) also used in their studies with similar effective rooting depth.

Turf color, turf quality and clipping yield were all determined in this study. Prior to mowing, turfgrass color was assessed visually on a scale of 1-9 (1= completely yellow, 6= light green; 9= dark green) on each clipping date. Turfgrass quality ratings were evaluated

Table 3- Experimental design of the study

	I			*II*			*III*		
	TS-1	*TS-2*	*TS-3*	*TS-2*	*TS-1*	*TS-3*	*TS-1*	*TS-3*	*TS-2*
25% (I_1)	1.25	2.50	1.25	1.25	5.00	0.00	0.00	2.50	0.00
	2.50	0.00	5.00	5.00	1.25	5.00	2.50	0.00	1.25
	0.00	1.25	0.00	0.00	2.50	2.50	5.00	1.25	2.50
	5.00	5.00	2.50	2.50	0.00	1.25	1.25	5.00	5.00
	TS-2	TS-1	TS-3	TS-1	TS-2	TS-3	TS-3	TS-1	TS-2
50% (I_2)	1.25	1.25	1.25	0.00	2.50	0.00	2.50	2.50	0.00
	2.50	0.00	5.00	5.00	0.00	5.00	0.00	0.00	5.00
	5.00	5.00	0.00	2.50	1.25	2.50	1.25	1.25	1.25
	0.00	2.50	2.50	1.25	5.00	1.25	5.00	5.00	2.50
	TS-3	TS-2	TS-1	TS-2	TS-1	TS-3	TS-1	TS-3	TS-2
75% (I_3)	5.00	1.25	0.00	0.00	2.50	0.00	5.00	2.50	2.50
	1.25	5.00	2.50	2.50	5.00	2.50	0.00	5.00	0.00
	0.00	0.00	5.00	1.25	1.25	1.25	2.50	0.00	5.00
	2.50	2.50	1.25	5.00	0.00	5.00	1.25	1.25	1.25
	TS-1	TS-3	TS-2	TS-2	TS-1	TS-3	TS-1	TS-2	TS-3
100% (I_4)	5.00	0.00	5.00	0.00	1.25	2.50	2.50	0.00	5.00
	1.25	1.25	1.25	2.50	0.00	5.00	5.00	5.00	0.00
	0.00	2.50	2.50	1.25	5.00	1.25	0.00	2.50	2.50
	2.50	5.00	0.00	5.00	2.50	0.00	1.25	1.25	1.25

Irrigation Levels: 1. %25 (I_1), 2. %50 (I_2), 3. %75 (I_3), and 4. %100 (I_4) of pan evaporation, Turfgrass Species: TS-1. Hybrid Bermudagrass, TS-2. Seashore paspalum TS-3. Zoysiagrass, Nitrogen Doses: 1. 0.0, 2. 1.25, 3. 2.5 and 4. 5.0 g N m^{-2} $month^{-1}$

according to National Turfgrass Evaluation Program (NTEP) guidelines using a 1–9 visual rating scale, where 1= poorest, 6= acceptable, and 9= best (NTEP, 2010) based primarily on texture, uniformity, density, and turf color. Drought-induced leaf wilting, rolling, and browning were also considered when rating turfgrass quality, with a score of 6.0 or higher considered acceptable. For each year, clipping yields were evaluated monthly. After reach to 6-8 cm height (18 June, 24 July, 29 August and 09 October in the first year and 05 June, 15 July, 24 August and 05 October in the second year), a 0.5 m × 1.0 m strip of turf at the center of each sub subplot was clipped to 4 cm height. The clipped turf samples were taken to dry. Samples were dried at 70 °C for 24 h and then weighed (Bilgili et al. 2017).

Leaf relative water content (RWC), loss of turgidity (LT), chlorophyll content (CC) and electrolyte leakage (EL) were analyzed to determine irrigation and fertilizer application effects on warm-season turfgrasses. Physiological analyses were done in July 2015, which was mostly high temperature and almost entirely drought month regarding the region.

Leaf RWC and LT were measured by a previously described method by Salisbury & Ross (1992) and Gulen & Eris (2003). Leaf tissues 1.0 cm long were cut from each of the three fully expanded and uniform leaves (replicates) per treatment. Initially, the fresh weight was enrolled, and then samples were settled in a petri dish of distilled water for four hours. After gently blotting the leaf surface with paper, turgid weights were recorded. At the end of this stage, leaf examples have put a drying at 70 °C for 24 h to determine the dry weight. Leaf RWC and LT were measured as follow;

$$RWC (\%) = [(fresh\ weight - dry\ weight) / (turgid\ weight - dry\ weight)] \times 100$$

$$LT (\%) = [(turgid\ weight - fresh\ weight) / turgid\ weight] \times 100$$

The relative CC was measured on the ten whole leaves with the portable chlorophyll meter (Minolta, SPAD-502) for each plot. First, leaves were measured individually at three points: on the upper, middle, and lower parts, and then, average SPAD readings were calculated by Gulen & Eris (2003); Moran & Porath (1980).

Primarily, turfgrass samples were cut 1 cm long three replications per fertilization treatment to determine EL. Leaf tissues were washed kindly in pure water, blotted gently with paper, and put in test tubes. Purified water (20 mL) was filled in test tubes. Then, the samples were leached by vacuum infiltration to let uniform diffusion of electrolytes and shaken on a gyratory shaker (at 250 rpm) overnight at room temperature. After incubation, solutions' electrical conductivity was analysed using a conductivity meter (WTW TetraCon 325; InoLab, Weilheim, Germany). Afterward, leaf tissues were killed by autoclaving solution likewise, and the total conductivity was gauged at room temperature. Finally, percentage of injury was calculated for all temperatures from the EL data using that notation (Arora et al. 1992):

% Injury = [(% L (t) - % L (c)) / (100 - % L (c)] 100 where % L (t) and %L (c) are the percentage EL data for the treated and control examples, respectively.

All data were subjected to analysis of variance (ANOVA). Irrigation level, turfgrass species, N doses and their interactions were separated statistically different groups by using the least significant difference (LSD) test at the 0.05 or 0.01 probability levels by using JMP Pro 13.

Results and Discussion

3.1. Applied Irrigation Water and Evapotranspiration

The total amounts of irrigation water and rainfall (mm) for the first and the second year are shown in Table 4. Total irrigation water amounts ranged from 144.3-577.2 mm in the first year to 188.5-753.8 mm in the second year, while total rainfall amounts were 226.2 mm and 88.3 mm, respectively. Table 5 shows the seasonal ET rates for each treatment group.

Maximum seasonal ET values were obtained in the second season for the I_4 x N_4 treatment in Bermudagrass, seashore paspalum, and zoysiagrass being 860 mm, 856, and 838, respectively. Based on the applied irrigation water amounts and precipitation data, the seasonal ETc values were determined to be ranged from 356 mm to 860 mm in the first season and from 282 mm to 856 mm in the second season in terms of all turfgrasses (Tablo 5).

Table 4- The total amount of irrigation water and rainfall in 2014 and 2015

Irrigation	*Irrigation water applied (mm)*	*Rainfall (mm)*
	2014	
I_1	144.3	
I_2	288.6	226.2
I_3	432.9	
I_4	577.2	
	2015	
I_1	188.5	
I_2	376.9	88.3
I_3	565.4	
I_4	753.8	

In a study conducted with Bermudagrass under a Mediterranean climate, it was reported that the total irrigation water and seasonal water use in 100 percent of Class A pan was 1168.2 mm and 1186 mm, respectively (Emekli et al. 2007). In another study conducted in Mediterranean climate conditions, it was observed that the total amount of water applied to the golf course turf and the total ET were 780.3 mm and 896 mm, respectively (Bastug & Buyuktas 2003). The applied irrigation water and ETc values in our study were found lower than research results of Bastug & Buyuktas (2003) and Emekli et al. (2007).

The relationships between N doses and seasonal ETc values obtained for each irrigation treatments and species are given in Figure 1. Linear relationships with a high correlation coefficient in the increasing direction were determined between N dose and ETc (except for seashore paspalum under irrigation treatment I_1 for 2015). However, the linear relationships obtained for both years in Bermudagrass and seashore paspalum species under irrigation treatment I_4 (100% of pan evaporation) were statistically significant. Turfgrass uses

Table 5. Seasonal evapotranspiration (mm) was determined in irrigation levels, turfgrass species, and nitrogen doses for the 2014 and 2015 experimental years

Irrigation	*Nitrogen*	*Bermudagrass*		*Seashore paspalum*		*Zoysiagrass*	
		2014	*2015*	*2014*	*2015*	*2014*	*2015*
I_1	N_1	356	313	349	295	344	299
	N_2	360	312	356	282	333	298
	N_3	380	315	356	304	343	308
	N_4	377	326	367	308	368	313
I_2	N_1	499	474	472	467	463	461
	N_2	506	476	467	460	485	458
	N_3	505	498	471	483	499	476
	N_4	523	507	494	487	500	477
I_3	N_1	632	673	603	646	638	637
	N_2	635	694	612	649	640	644
	N_3	641	692	649	651	646	655
	N_4	664	696	653	679	648	674
I_4	N_1	764	821	757	810	743	802
	N_2	782	837	769	833	777	826
	N_3	787	844	782	832	788	825
	N_4	814	860	800	856	794	838

more water when the N fertilization dose increases due to the higher growth encouraged by the fertilizer (Carrow & Duncan 2003). Some researchers have observed that reducing the N fertilizer dose can reduce turfgrass ET in the presence of an unlimited water supply; however, these studies have not consistently provided quantitative data on how the N dose affects turfgrass quality (Shearman & Beard 1973; Feldhake et al. 1983). As a result, it's not always obvious how much water may be saved by changing N fertilizer doses. The including turfgrass quality indicators is critical for determining the extent of N fertilizer doses may be utilized to reduce turfgrass water usage.

3.2. Turfgrass Color, Quality and Clipping Yield

During both experimental seasons, irrigation levels, turfgrass species, and N doses substantially impacted visual turfgrass color, quality, and clipping yield. IL x TS and IL x ND two-way interactions were important in some observation for color and quality. Therefore, TS x ND interaction was not important in all date. In addition, most of all two-way, and all three-way interactions were significant for clipping yield (Table 6). Regardless of the effects of the year, the data were analyzed individually for each year because the length of the observation dates varied from year to year (Kopp & Guilard 2002). Irrigation levels, turfgrass species and N doses affect the observed parameters (Table 7 and 8).

The lowest irrigation level (I_1) produced the lowest color, quality, and clipping yield were taken from throughout the trial I_4 irrigation treatment produced the highest turf color and quality ratings, and clipping yield in general. In a similar study that used color as key quality criteria, a reduction in the ET rate of Kentucky bluegrass was related to a decline in quality (Feldhake et al. 1984). Acceptable color and quality were maintained at I_3 and I_4 treatments, whereas I_1 did not produce desirable color quality each experimental season. The turf color and quality values of all turfgrasses included in the study were either not statistically significant or very close to each other according to the month in both experimental years (Table 7 and 8).

The N doses had a substantial impact on turf color, quality, and clipping yield (Table 7 and 8). Overall, the 5 g N m^{-2} treatment outperformed the other N treatments in turf color, quality, and clipping yields. In this study, the 2.5 g N m^{-2} dose produced acceptable turf color and quality while yielding lower clipping yields than the high N dose both years.

Control (0 g N m^{-2}) N doses, on the other hand, resulted in the lowest evaluations for turf color, quality, and clipping yields. According to Bilgili & Acikgoz (2011), increasing doses of N application consistently improved color, quality ratings, and clipping yields on a turf mixture (50% perennial ryegrass, 30% Kentucky bluegrass, 10% chewing red fescue, and 10% creeping red fescue). Salman and

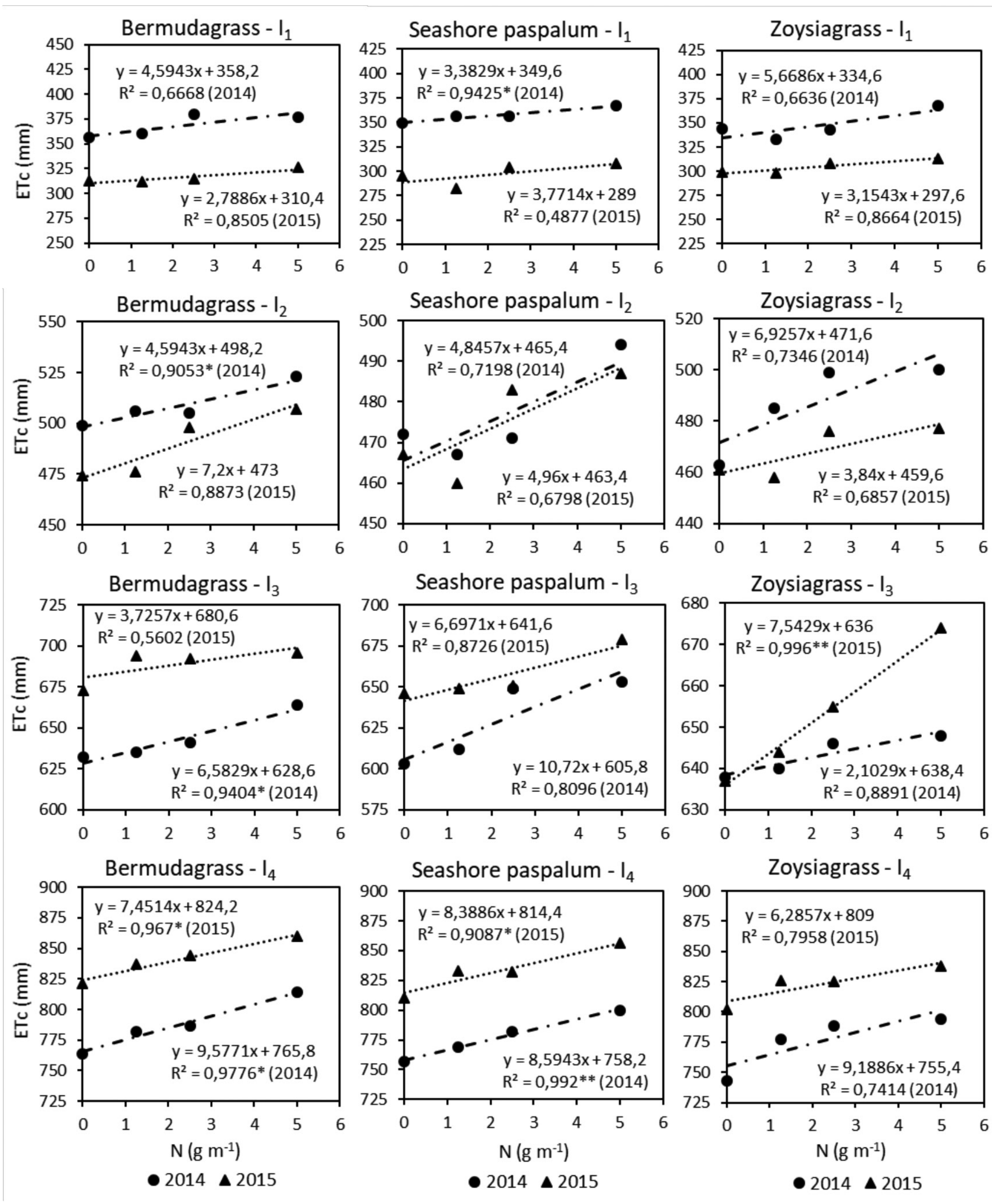

Figure 1- The relationships between N rates and seasonal ETc values obtained for each irrigation treatments and species

Avcioglu (2010) determined that ND of 10 g N m^{-2} was the best dose for turf color and quality on tall fescue and perennial ryegrass in a Mediterranean climate on loamy soil. The I_3 irrigation level and 2.5 g N m^{-2} dose treatment maintained acceptable turfgrass color and quality throughout each experimental season.

The best clipping yield values were obtained from I_4 irrigation treatment in both years, but the lowest values were obtained I_1 treatment. Generally, high values were taken regarding clipping yield from zoysiagrass in both years. Highest clipping yield values were taken from 5 g N m^{-2} dose like I_4 irrigation treatment in both years.

IL x TS interaction color ratings in the first year was found significant only in the July observation. The highest color ratings were obtained from seashore paspalum and zoysiagrass at I_4 irrigation level, and Bermudagrass at I_3 irrigation level. In the second year, IL x

Table 6- Results of variance analysis of some warm-season turfgrass species (TS) color, quality, and clipping yields under different irrigation levels (IL), and nitrogen doses (ND) in the 2014-2015 experimental years

Sources of variation	*2014*				*2015*			
	Color							
	18 June	*24 July*	*29 August*	*09 October*	*05 June*	*15 July*	*24 August*	*05 October*
IL	**	**	**	*	**	**	**	**
TS	ns	ns	ns	ns	**	**	**	**
ND	**	**	**	**	**	**	**	**
IL x TS	ns	*	ns	ns	**	*	ns	*
IL x ND	*	ns	*	ns	ns	ns	ns	*
TS x ND	ns	ns	ns	ns	ns	ns	ns	ns
ILx TS x ND	ns	ns	ns	ns	ns	ns	ns	ns
	Quality							
IL	**	**	**	**	**	**	**	*
TS	*	**	ns	**	**	*	**	**
ND	**	**	**	**	**	**	**	**
IL x TS	ns	**	*	*	**	ns	ns	ns
IL x ND	*	**	**	ns	**	**	*	ns
TS x ND	ns	ns	ns	ns	ns	ns	ns	ns
ILx TS x ND	ns	ns	ns	ns	ns	ns	ns	ns
	Clipping yield							
IL	**	**	**	**	**	**	**	**
TS	**	**	**	**	**	**	**	**
ND	**	**	**	**	**	**	**	**
IL x TS	**	**	**	**	**	**	**	**
IL x ND	ns	**	**	**	**	**	**	**
TS x ND	**	**	ns	**	**	**	**	**
ILx TS x ND	**	**	**	**	**	**	**	**

*,** F-test significant at p≤0.05 and p≤0.01, respectively. ns: not significant

TS interaction color ratings were found significant in the June, July, and October observations. Generally, the highest color ratings were found at I_4 irrigation level in all turfgrass species. However, I_1 irrigation level and zoysiagrass interaction gave the lowest color ratings.

IL x ND interaction color ratings in the first year were found significant only in the June and August observations. I_3 irrigation level x N_4 ND and I_4 irrigation level x N_4 ND gave the highest color ratings both observation dates. In the second year, IL x ND interaction color ratings were found significant only in the October observation and I_4 irrigation level x N_4 ND interaction gave the highest turfgrass color ratings at the same date. IL x ND interaction quality ratings were found significant in the June, July and August observation dates, and in general, I_4 irrigation level x N_4 ND interaction gave the highest turfgrass quality ratings at the same dates in both years. IL x ND interactions clipping yield values were found important in July, August, and October observation dates in the first year but in the second year all dates. Generally, I_4 irrigation level x N_3 ND, I_4 irrigation level x N_4 ND and I_3 irrigation level x N_4 ND interactions gave the highest clipping yield in both years.

IL x TS interactions turfgrass quality ratings were found significant in the July, August and October observation dates in the first year. I_4 irrigation level x all turfgrass species interactions gave the highest quality ratings by taking 6.5 and above ratings. In the second year, IL x TS interaction quality ratings were found significant only in the June observation, and the highest quality ratings were obtained from I_4 x seashore paspalum and I_4 x zoysiagrass interactions at the same date. IL x TS interactions clipping yield values were found significant in all observation dates in both years. Generally, zoysiagrass x I_4 irrigation levels interactions gave highest clipping yields both years.

Table 7- Turf color of some warm-season turfgrass species (TS) under different irrigation levels (IL), and nitrogen doses (ND) in the 2014-2015 experimental years

IL	*Color*							
	2014				*2015*			
	18 June	*24 July*	*29 August*	*09 October*	*05 June*	*15 July*	*24 August*	*05 October*
I_1*	6.1 c	6.0 c	5.8 c	5.7 b	5.5 c	5.8 c	5.8 d	5.3 c
I_2	6.8 b	6.6 b	6.5 b	5.9 ab	6.1 b	6.4 b	6.2 c	6.1 b
I_3	6.9 b	7.0 a	6.8 ab	6.0 a	6.5 a	6.5 b	6.4 b	6.3 ab
I_4	7.2 a	7.0 a	7.0 a	6.1 a	6.8 a	7.0 a	6.7 a	6.6 a
LSD (0.05)	0.26	0.18	0.38	0.25	0.34	0.17	0.18	0.34
TS								
1**	6.7	6.6	6.5	5.9	6.1 b	6.5 a	6.2 b	5.9 b
2	6.8	6.7	6.6	6.0	6.7 a	6.6 a	6.5 a	6.3 a
3	6.8	6.6	6.5	6.0	5.9 b	6.2 b	6.1 b	5.9 b
LSD (0.05)	Ns	Ns	Ns	Ns	0.17	0.20	0.21	0.19
ND								
0.00***	5.1 d	5.1 d	5.0 d	4.8 d	4.7 d	4.9 d	4.7 d	4.5 d
1.25	6.7 c	6.5 c	6.2 c	5.7 c	5.9 c	6.2 c	5.8 c	5.7 c
2.50	7.3 b	7.1 b	6.9 b	6.3 b	6.7 b	7.0 b	6.9 b	6.6 b
5.00	8.0 a	7.9 a	8.0 a	7.0 a	7.6 a	7.7 a	7.7 a	7.4 a
LSD (0.05)	0.20	0.23	0.19	0.22	0.19	0.19	0.20	0.18

*I_1=25%, I_2=50%, I_3=75%, I_4=100%, **1: Hybrid Bermudagrass (Cynodon transvaalensis x Cynodon dactylon) Tifdwarf, 2: Seashore paspalum (Paspalum vaginatum Sw) Seaspray, 3: Zoysiagrass (Zoysia japonica Steud.) Zenith, ***g m^{-2}

Table 8- Turf quality of some warm-season turfgrass species (TS) under different irrigation levels (IL), and nitrogen doses (ND) in the 2014-2015 experimental years

IL	*Quality*							
	2014				*2015*			
	18 June	*24 July*	*29 August*	*09 October*	*05 June*	*15 July*	*24 August*	*05 October*
I_1	6.1 c	5.8 c	5.5 d	5.3 c	4.8 d	5.2 d	5.1 d	5.2 b
I_2	6.2 bc	6.3 b	5.9 c	5.4 c	5.5 c	5.7 c	5.7 c	5.6 ab
I_3	6.5 b	6.5 b	6.6 b	5.8 b	6.1 b	6.1 b	6.2 b	6.0 a
I_4	7.0 a	6.9 a	6.8 a	6.3 a	6.8 a	6.7 a	6.5 a	6.0 a
LSD (0.05)	0.35	0.25	0.16	0.24	0.25	0.30	0.15	0.49
TS								
1	6.3 b	6.3 b	6.2	5.5 b	5.8 b	5.8 b	5.8 b	5.6 b
2	6.7 a	6.5 a	6.2	5.7 a	6.1 a	6.1 a	6.1 a	5.9 a
3	6.3 b	6.3 b	6.2	5.8 a	5.6 c	5.8 b	5.7 b	5.5 b
LSD (0.05)	0.32	0.14	ns	0.16	0.19	0.22	0.22	0.21
ND								
0.00	4.9 d	4.9 d	4.9 d	4.8 d	4.6 d	4.7 d	4.5 d	4.4 d
1.25	6.3 c	6.1 c	5.9 c	5.5 c	5.5 c	5.6 c	5.4 c	5.3 c
2.50	7.0 b	6.9 b	6.5 b	6.0 b	6.2 b	6.3 b	6.3 b	6.1 b
5.00	7.6 a	7.6 a	7.5 a	6.5 a	7.0 a	7.1 a	7.3 a	6.9 a
LSD (0.05)	0.26	0.19	0.19	0.20	0.19	0.20	0.20	0.21

In the first year except for August observation, the rest of all observation dates TS x ND interactions clipping yield values were found important. Both years generally gave the highest clipping yield values were obtained from seashore paspalum x N_4 and N_3 irrigation level, zoysiagrass x N_4 and N_3 irrigation level interactions.

3.3. Physiological Parameters

An ANOVA indicated that statistically significant ($p<0.01$) differences for all physiological parameters. All physiological parameters were affected from irrigation levels, turfgrass species and ND's treatments and two-way interactions and three-way interaction (Table 9).

The results showed that irrigation levels, turfgrass species, nitrogen doses, and their interactions significantly affected RWC (Table 10).

According to IL x TS, the seashore paspalum gave the highest RWC at all irrigation levels. The lowest RWC was generally obtained from I_1 deficit irrigation in all warm-season turfgrasses, while the well-watered irrigation level (I_4) gave the highest RWC. In terms of IL x TS interaction, the lowest RWC in IL x TS interaction was obtained from the lowest irrigation level of zoysiagrass. The lowest RWC value in IL x ND interaction was obtained from the I_1 deficit irrigation level. The well-watered irrigation level (I_4) gave the highest RWC at all N doses. The highest RWC was obtained from the highest dose (5 g m^{-2}) in all irrigation levels. The lowest RWC value in TS x ND interaction was generally obtained from the control fertilization (0 g m^{-2}). In comparison, high N fertilization (5 g m^{-2}) was given the highest RWC in all turfgrass species. The highest leaf RWC values were taken in seashore paspalum among the turfgrasses at all N doses.

Table 9- Results of variance analysis of leaf relative water content, loss of turgor, relative CC, and electrolyte leakage for irrigation levels, turfgrass species, and ND's in the 2015 year

Sources of variation	*2015*			
	RWC	*LT*	*CC*	*EL*
Irrigation levels (IL)	**	**	**	**
Turfgrass species (TS)	**	**	**	**
Nitrogen doses (ND)	**	**	**	**
IL x TS	**	**	**	**
IL x ND	**	**	*	**
TS x ND	**	*	*	**
ILx TS x ND	**	**	**	**

Table 10- Leaf relative water content, loss of turgor, CC and electrolyte leakage regarding irrigation levels (IL), turfgrass species (TS) and nitrogen doses (ND) mean values in the 2015 year

IL	*RWC*	*LT*	*CC*	*EL*
I_1	48.2 d	39.1 a	22.8 b	21.7 a
I_2	55.9 c	32.5 b	23.3 b	15.5 b
I_3	66.8 b	27.5 c	26.6 a	14.1 c
I_4	74.3 a	16.3 d	26.1 a	11.7 d
LSD (0.05)	4.93	3.20	1.44	0.75
TS				
1	51.3 c	36.7 a	20.2 c	23.8 a
2	79.0 a	15.9 c	30.6 a	9.0 c
3	53.7 b	33.8 b	23.4 b	14.5 b
LSD (0.05)	2.26	2.29	0.98	0.80
ND				
0.00	58.1 b	31.9 a	20.9 d	18.5 a
1.25	60.2 b	30.2 a	23.6 c	15.7 b
2.50	57.7 b	30.0 a	25.7 b	15.2 b
5.00	69.3 a	23.2 b	28.6 a	13.7 c
LSD (0.05)	2.95	3.18	1.18	0.67

Leaf RWC is commonly used to measure the water status (Pu et al. 2003). In the last decade, many studies directly estimate leaf parameters such as leaf RWC (Penuelas et al. 1993; Pu et al. 2003). Plants respond to decreased soil and cellular water content with changes in their morphological, physiological, and biochemical properties. Where water is scarce, these characteristics determine the survival of plants (Nilsen & Orcutt 1996). Many other articles described the relationship between drought tolerance and leaf water (Huang et al. 1998; White et al. 2001). Variations in drought tolerance were found among hybrid Bermudagrass, seashore paspalum, and zoysiagrass cultivars. The highest leaf RWC values were determined from seashore paspalum in I_4 irrigation level.

In our study, RWC decreased during drought stress, while grass species treated with high N compared to low N treatment showed higher leaf RWC under all irrigation conditions. The highest LT was observed in all ND's under deficit irrigation, while the lowest LT was kept in full irrigation conditions. Turfgrasses treated with high N showed higher leaf RWC during the drought than turfgrasses treated with low N (Chang et al. 2016). Fertilization is a practice that could increase water use efficiency or reduce water stress effects in arid areas (Carrow 2006; Ahmad et al. 2014). However, there was no substantial relation between lowering fertilization rates and water savings (Ebdon et al. 1999).

LT of turfgrass species used in this study had significant differences. The results showed that irrigation levels, turfgrass species, ND's, and interactions significantly affected LT (Table 9).

The present study results clearly showed that LT increased in all turfgrass species under water deficit compared to the well-watered conditions. While the highest value of LT was obtained from the I_1 deficit irrigation level, the lowest LT was obtained at a well-watered level (I_4). The result showed that LT of hybrid Bermudagrass was highest among the three species, followed by zoysiagrass and seashore paspalum. Five g m^{-2} N dose gave the lowest LT value among N doses. However, other N doses were included in the same statistical group. Our results showed that without N fertilizer and low N fertilizer doses increased LT (Table 10).

According to IL x TS interaction, zoysiagrass gave the highest LT at I_1 deficit irrigation level. The lowest LT was obtained from the well-watered level (I_4) in all warm-season turfgrasses, while the I_1 deficit irrigation level gave the highest LT. The highest LT in IL x ND interaction was obtained from the I_1 deficit irrigation level and low N fertilization levels. The well-watered irrigation level (I_4) gave the lowest LT at all N doses. The lowest LT was obtained from the highest N dose (5 g m^{-2}) in all irrigation levels. The lowest LT value in TS x ND interaction was obtained from the high N fertilization (5 g m^{-2}) in all warm-season turfgrass species. Especially zoysiagrass had the least loss of turgor in all N doses. However, hybrid Bermudagrass generally suffered the most LT.

In our study, the highest LT was observed in hybrid Bermudagrass under I_1 deficit irrigation. Especially seashore paspalum has been the species with the lowest LT under I_2, I_3 and I_4 irrigation levels. On the other hand, the least LT was observed under all irrigation levels in seashore paspalum among the all warm-season turfgrasses. Although the most tolerant turfgrass was a seashore paspalum and the least susceptible was a zoysiagrass, hybrid Bermudagrass and zoysiagrass had the same irrigation levels same drought tolerance levels, suggesting that both species have a range of drought tolerance. Similar to our results, paspalum genotypes were found to have better drought performance than hybrid Bermudagrass (Huang et al. 1997). However, Sever Mutlu et al. (2011) stated that Bermudagrass and buffalograss species/cultivars may perform better than buffalograss, bahiagrass, seashore paspalum, zoysiagrass, centipedegrass warm-season species. Changes in environmental conditions such as soil type or weather can create these differences. They could be due to genetic differences between cultivars with different levels of natural drought tolerance (Jespersen et al. 2019). Drought tolerance and recovery of various warm-season turfgrasses during drought were associated with osmotic adjustment (Qian et al. 1997). More specifically, drought tolerance involves maintaining positive turgor pressure at low tissue water potential and includes osmotic adjustment and dehydration tolerance achieved through protoplasm resistance (Gibeault et al. 1989; Carrow 1996; Jones et al. 2004). Carrow (1996) found that further drought tolerance before stress was associated with low basal osmotic potential, osmotic adaptation, maintenance of positive turgor pressure, and delayed leaf rolling during stress.

Comparative water use efficiencies in turfgrass species differ markedly from their relative drought tolerance because each is a more specifically different physiological phenomenon. Turfgrass species and cultivars have been found to respond differently to drought stress through drought resistance (Levitt 1980; Minner & Butler 1985). Under limited water conditions, plants may survive or even continue to grow by avoiding drought stress, showing tolerance to cellular water shortage, and both together (DaCosta & Huang 2006). Beard (1981) states that turfgrass characteristics and physiological hardiness associated with drought resistance can be much different than those plant characteristics that contribute to reduced water use rates and stresses. It should be recognized that a reduced water use rate will delay the onset of drought, as will a turfgrass species whose root system extends through a more significant portion of the soil profile. However, once the available soil moisture is exhausted, the ability of perennial grasses to survive a subsequent drought is the ultimate concern. Therefore, turfgrasses with severe drought resistance may not necessarily be those possessing the lowest water use rates.

The leaf CC measurements showed a significant difference among irrigation levels, turfgrass species, ND's and interaction effects (Table 9). CC significantly decreased under deficit irrigation conditions compared to the well-watered treatment (I_4). Water stress negatively influenced the CC in some species. The lowest LT was observed at a high N dose (5 g m^{-2}) in all turfgrass species.

In our study, seashore paspalum under all irrigation levels gave the highest CC values in IL x TS interaction. However, hybrid Bermudagrass in all irrigation levels gave the lowest CC. The well-watered irrigation level (I_4) in the seashore paspalum gave the highest CC, while the I_1 deficit irrigation level gave the lowest CC in hybrid Bermudagrass. The highest CC was generally taken from the 5 g m^{-2} N dose and I_3 and I_4 irrigation levels. On the other hand, control plots without N application and I_1 and I_2 deficit irrigation levels gave the lowest CC. The highest CC in TS x ND interaction was obtained seashore paspalum in all N doses. However, hybrid Bermudagrass gave the lowest CC in all N doses. The 5 g m^{-2} N dose gave the highest CC in the seashore paspalum, while the control N dose gave the lowest CC in hybrid Bermudagrass.

In the present study, the CC decreased according to the water stress in all turfgrass species. The CC was statistically in the same group at I_3 and I_4 irrigation levels. However, CC was generally lower in deficit irrigation levels such as I_1 and I_2. Especially under water stress conditions accompanied by extreme heat and radiation, chlorophyll is degraded, so the total content of this pigment in the leaves can determine the stress in the plant (Chylinski et al. 2007). It has been widely reported that decreased CC under limited water supply conditions leads to significant inhibition of leaf photosynthetic rates (Farooq et al. 2009).

The lowest CC was observed in both deficit irrigation and low N doses. The highest CC was obtained from 5 g m^{-2} N dose and I_3 and I_4 irrigation levels. CC in plants is a good indicator for leaf N concentration and is strongly correlated with leaf N and chlorophyll concentration (Blackmer & Schepers 1995; Saud et al. 2017). CC and its function is a direct measure of plant health (Brock, 2005). Chlorophyll levels increase linearly as applied N levels increase; thus, chlorophyll concentration correlates with N concentration in leaves, plant nutrition, and production (Benett et al. 2008).

The results showed that irrigation level, turfgrass species, ND's, and interaction significantly affected EL (Table 9).

The highest EL in IL x TS interaction was obtained from hybrid Bermudagrass in I_1 deficit irrigation level. Seashore paspalum generally shared the lowest EL. All warm-season turfgrasses gave the lowest EL in the well-watered (I_4), while the I_1 deficit irrigation level showed the highest EL. The lowest EL was obtained from the highest N dose (5 g m^{-2}) in all irrigation levels. The lowest EL was obtained with the highest ND (5 g m^{-2}) in all irrigation levels. However, the highest EL was obtained with the control N dose under I_1 deficit irrigation. The well-watered irrigation level (I_4) gave the lowest EL at all ND's. The seashore paspalum gave the lowest EL in TS x ND interaction in all N doses among warm-season turfgrass species. However, the highest EL was obtained from hybrid Bermudagrass in the control N dose.

Similar to our findings many researchers reported that increased drought stress increases EL (Guo et al. 2006; Liu et al. 2008). An increase in EL occurs when the rise in cell permeability (Blum & Ebercon, 1981). Lee et al. (2009) carried out their study deficit irrigation level by 100%, 80%, 60%, and 40%. There were significant differences among turfgrass varieties at all treatment of 100% irrigation level except 80%. The EL results of our research were similar to this research. Jiang & Huang (2002) showed that EL of tall fescue increased during drought stress conditions.

In summary, this research indicated that turfgrass requiring the least water to maintain quality in periods of hot summer months was seashore paspalum. Furthermore, the higher tolerance of seashore paspalum was associated with more effective osmotic regulation, reflected by the minor decrease in leaf RWC and cell membrane stability.

4. Conclusions

A two-year study was carried out to evaluate the visual turfgrass color and quality, as well as clipping yield and except for physiological parameters responses of some warm-season turfgrasses to various irrigation levels and ND's under Mediterranean climatic conditions. From the findings reported the following conclusions could be drawn.

1. The results of this study showed that the I_3 and I_4 irrigation levels under the 2.5 and 5 g N m^{-2} doses produced significantly higher ratings of color, quality and, clipping yields during both years.

2. The 100% (I_4) irrigation and 5 g N m^{-2} doses treatment resulted in a sufficiently dark turf color and quality; to achieve better seasonal turf quality under Mediterranean climatic conditions, this schedule can be adapted by evaluating the level of irrigation and N rate.

3. Based on the results of this study, it is concluded that under deficit irrigation conditions an acceptable turf quality can be sustained at 75% of Class A pan evaporation, and 2.5 g N m-2 doses treatment.

4. This research indicated that turfgrasses requiring the least water to maintain acceptable quality in periods of hot summer months were seashore paspalum cv. Seaspray.

5. Consequently, it was concluded that statistically significant differences were determined physiological effects of different irrigation levels and ND's on various warm-season turfgrasses.

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