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The Effects of Regulated Deficit Irrigation in Growth Response to *Büchloe dactyloides* (Bowie and Cody) Compared with *Festuca arundinacea*

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Abstract

Now days, turf management has encountered with water deficit, mostly due to low precipitation also industrial, agricultural and household demand and consumption. So, the objective of this project was to identify drought tolerance of warm and cool season turfgrass cultivars to different levels of regulated-deficit irrigation. The field experiment was set out in a split-plot based on completely randomized experimental design with three replications at the experimental farm of the Department of Horticultural Science, Agricultural College, Ferdowsi University of Mashhad, Mashhad, Iran. Water treatments (40, 70, 100 percentages of regulated deficit irrigation) (RDI) were considered as main plot and turf grass types as subplots. Irrigation value was according to daily reference of evapotranspiration (ETO). In all measured traits, Bowie and Cody genotypes of buffalograss showed better response as compare to fescue genotype. There was significant difference in turf quality traits of turfgrass (such as color, texture and quality after clipping) dealt with different level of drought stress. Cody has shown the lowest quality for color index. Whereas, the finer leaves have recorded in Cody and Bowie, but not significantly to each other. However tall fescue represented the rough leaves among others. Boffalograss cultivars preserved more relative water content (RWC) in contrast to that of fescue. Results suggested that buffalograss cultivars likely can cope with severe drought stress so as to maintain its morphological quality and also is able to justify its physiological traits under severe water stress. The research results indicated that buffalograss cultivars need lower levels of irrigation compare to tall fescue.

Keywords: Buffalograss, Drought, Grass, Resistant.

INTRODUCTION

Having drought tolerance cultivars is one strategy to reduce turfgrass water consumption in urban landscape (Carrow, 1995). Drought stress is one of several environmental factors greatly limiting plant production and distribution worldwide. Previous studies have shown that drought stress can lead to water deficit in plant cells, inhibiting plant growth and development (Xu *et al*., 2007). Thus, water issues and production of drought tolerance plant is now a long-term concern in turfgrass management and will impact billions of dollars of turfgrass environmental horticultural industries soon (Huang, 2008). Drought stress is one of the most harmful factors limiting turfgrass growth and development. A large variability of drought resistance has been well addressed among turfgrass species and cultivars (Huang, 2008). Providing enough water for turfgrass in arid and semiarid regions is a major problem. Mechanisms of drought resistance are encompasses of drought avoidance, tolerance and escape (Levitt, 1980; Beard, 1973). As native grasses are excellent volunteer species not only due either to their aesthetic values or less maintenance quality but also due to their biotic and abiotic resistance quality in arid and semi-arid regions of the world (Bormann *et al*., 2001). Therefore, native plants are providing excellent choices for large commercial landscapes as well as residential gardens (Pessarakli and Kopec, 2008).

Regulated deficit irrigation (RDI) is the water-saving method under which crops are exposed to a certain level of water stress either during a particular period or throughout the course of growing season (Pereira *et al*., 2002; English and Raja, 1996). Regulated deficit irrigation (RDI) is a term for the practice of regulating or restricting the application of irrigation water limiting the turf water use to below that of a fully watered turf. Soil-water deficiency is a common phenomenon in arid and semi-arid areas of the world. Nonetheless, water saving strategies such as regulated deficit irrigation most likely allows optimizing water efficiency consumption in such areas and thereby improving plant quality (Costa *et al*., 2007). A number of studies delved into the analyzing the economics of deficit irrigation and have concluded that this techniques are able to increase net income (English, 1990). It has been stated that the potential profits of deficit irrigation derived from two factors; increased irrigation efficiency and reduced costs of irrigation. In many countries water requirement of green space is equal to 50% or more of the total water that consumed by the city. The water requirement occurs mainly in three to four of hot months. Grass species and cultivars are basically different in terms of water consumption. For example, water consumption is much lower in chewing fescue than Kentucky bluegrass (Pereira *et al*., 2002). The amount of water in turf grasses is not necessarily associated with drought tolerance (Beard, 1973). Because of this, scientists and specialists of grass and managers involved with a dual problem facing. To meet this importance, applying high-quality grass will reduced water inputs. In fact, the lack of available water and progressive drought stress are two most important problems threating the grass industry (Jiang and Fry, 1998). The objective of this study was to investigate the water use and physiological and morphological response of buffalograss and tall fescue placed under various of irrigation frequency during summer months in arid and semi-arid environment. Therefore, main reason of selecting these types of species is the good tolerance of both of species to drought resistance. Drought stress and water shortage is now being a critical issue worldwide, especially for those countries that are located in arid and desert area. So the necessity use of drought tolerant plant species has to be placed on the agenda. The objective of this experiment was to better understand the morpho-physiological responses of buffalograss and tall fescue species subjected to different levels of regulated deficit irrigation.

MATERIALS AND METHODS

The experiment was carried out at the experimental farm of the Department of Horticultural Science, Agricultural College, Ferdowsi University of Mashhad,. This research project was conducted in a split-plot experiment based on completely randomized design with three replications. Water treatments (40, 70 and 100 percentages of regulated deficit irrigation) (RDI) were considered as main plot and turf grass types were subplots.

Turf grasses were consisting

Plant species

Two cultivras of Büchloe dactyloides (Nutt.) (Cody and Bowie) from USA.

Festuca arundinacea. From Mashhad, in Khorasan province, Iran have been used in this research.

Culture and maintenance

Turf grass plots were established by directly sowing the seeds at spring season. The rate of seedling was 15 g m^{-2} for buffalograss and 30 g m^{-2} for tall fescue according to seed size. Characteristics of loamy soil which has been used in this study represented in Table 1. The plot size was 2 m2 (1m × 2m) and covered with a thin layer of leaf compost and manure. Irrigation was carried out daily (4 or 5 times a day) during establishment. In spring plants were subjected to water stress for 35 days in the field.

Table 1. Characteristics of loamy soil which has been used in this study

Texture	pH	CEC (meq 100 g^{-1})	Organic matter (%)
Loamy	7.14	6.6	0.721

Irrigation and climatic condition

Irrigation timing was once every 2 days. Irrigation depths varied with daily reference evapotranspiration (ETO). Evaporation pan was used to estimate ETO; multiplying daily pan evaporation measurement by pan coefficient (Kp= 0.77 for the study area) yielded the reference evapotranspiration which equals to irrigation depth. Long term averages of maximum and minimum temperature are 23 ºC and 8.6 ºC, respectively. All weed species, both grasses and forbs, were hand pulled during study.

Data collection

After applying the treatments leaves were cut off the different positions of each plots and warped, and after that they were used according to the applied method for each examination.

Relative water content (RWC)

Relative water content (RWC) was calculated through Yamasaki and Dillenburg (1999) method. Individual leaf was first removed from stem and then weighed to obtain fresh mass (FM) at the harvest stage. In order to determine the turgid mass (TM), leaves were submerged into distilled water inside a closed petri-dish. During the imbibition period, leaf samples were weighed periodically, after gently wiping the water from the leaf surface with tissue paper. At the end of the imbibition period, leaf samples were placed in a pre-heated oven at 80°C for 48 h, in order to obtain dry mass (DM). All mass measurements were made using an analytical scale, with precision of 0.0001g. Values of FM, TM and DM were used to calculate RWC using the following equation:

$$RWC (\%) = [(FM–DM)/(TM–DM)] \times 100$$

Electrolyte leakage (EL)

Samples of 0.1 g of fresh leaves or roots were immersed in the centrifuge tube with 15 ml of deionized water. The tubes were shacked for 24 h on a shaker device. Leaves or roots then kept into autoclave for 30 min at 120 °C. The conductivity of the solution in perished tissues (Cmax) was measured via conductivity meter. Relative EL was calculated as the percentage of cinitial over Cmax (Blum and Ebercon, 1981).

Total chlorophyll content

Total chlorophyll was determined by spectrophotometry according to Dere *et al*. (1998):

(Methanol method) $C_c = (1000\ A470) - (2.860\ C_a) - (129.2\ C_b)/245$.

C_a = Chlorophyll a, C_b = Chlorophyll b, C_c = Total chlorophyll.

Growth parameter

Plant height and fresh and dry weight of plants were measured to represent growth parameters of stress induced plants.

Color

Leaf color was assessed using a visual inspection score through 1to 9 scale, according to in the National Turfgrass Evaluation Program (NTEP) in the USA (Salehi and Khosh-Khui, 2004). One (1) defines very poor turf color (light green) and nine (9) defines very ideal visual color (dark green).

Texture and quality after clipping

The visual rating of texture is based on 1 to 9 rating scale with 1 equaling coarse and 9 equaling fine tissues. After clipping quality have also evaluated based on aforementioned index (As 1= poorest, and 9= best quality).

Statistical analysis

All data were subjected to analysis of variance (ANOVA) using JMP8 software and means were compared using LSD test ($P<0.05$).

RESULTS

According to the data, significant differences were found among irrigation levels for color, texture and quality after clipping ($P<0.01$) (Table 2). Physiological parameter such as, RWC, EL, total chlorophyll content, height, fresh and dry weight were statistically significant, too ($P<0.01$) (Table 3). Apart from height and color, the other traits were evidently significant among cultivars ($P<0.05$). Results indicated that interaction of irrigation levels and cultivars were significant in case of El, dry weight, color and texture ($P<0.01$) (Table 3).

Color

Turf color was drastically influenced by irrigation levels and turf-type ($P<0.01$) Even interaction of irrigation levels and turf- types has affected on turf color ($P<0.05$) (Table 2). The weakest efficiency for turf color was noted in Cody. There were no significant difference among other grasses (Table 4). Turf color was decreased with increase of water deficiency (Fig. 1a). The best acceptable turf color (darkest color) was observed in 100% RDI with average of 7.49 (1-9 scale) and the lowest color quality was belonged to the treatment of 40% RDI (=6.74) (1-9 scale) (Fig. 1a).

Texture

Texture of grasses was drastically affected during the course of drought stress. This traits were also significant regarding irrigation levels, turf-type and interaction of irrigation levels and turf- type ($P<0.01$) (Table 2). The most slander leaves were belonged to Cody and Bowie without significant difference among them whilst the rough leaves obtained in tall fescue (Table 4).

Quality after clipping

Turf quality after clipping was drastically varied depends on the irrigation levels and turf-type (P< 0.01) (Table 2). Tall fescue gained the lowest quality after clipping than other turf grasses (Table 4). Fig. 1c showed that the most severe stress (40% RDI) has resulted in the lowest turf quality (Mean = 6.25) (1-9 scale).

Table 2. Analysis of variance of irrigation levels and turfgrass types on visual quality

S.o.V	df	Color	Texture	Quality after clipping
Irrigation levels (RDI)	2	1.50 **	4.27**	2.78**
Error a	6	0.02	0.05	0.04
Turfgrass (T)	2	0.18**	16.29**	8.21**
T*RDI	4	2.01**	1.3**	0.1ns
Error b	12	0.03	0.08	0.03

ns,**,* Non significant and significant at 1 and 5 percent of probability, respectively.

Table 3. Analysis of variance for irrigation levels and turfgrass types on physiological growth

S.o.V	df	RWC	EL	Height of plantping	Chlorophyll content	Fresh weight	Dry weight
Irrigation levels (RDI)	2	1.50 **	4.27**	2.78**	25.2**	22.05**	4.36**
Error a	6	0.02	0.05	0.04	0.74	0.17	0.07
Turfgrass (T)	2	0.18**	16.29**	8.21**	40.6**	1.62**	0.33**
T*RDI	4	2.01**	1.3**	0.1ns	0.26ns	0.44ns	0.49**
Error b	12	0.03	0.08	0.03	0.54	0.21	0.04

ns,**,* Non significant and significant at 1 and 5 percent of probability, respectively; RWC= Relative water content, EL= Electrolyte leakage

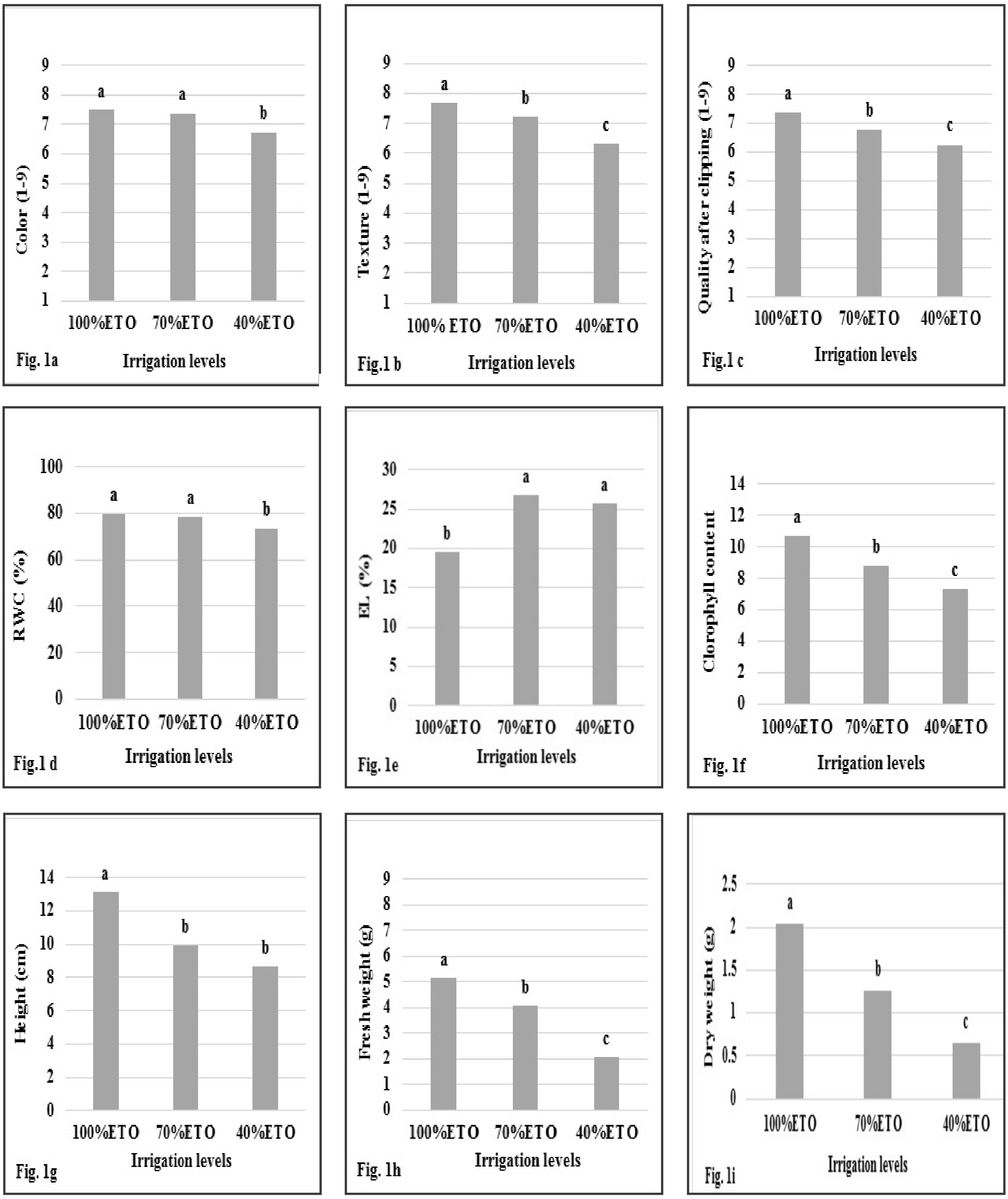

Fig. 1. The effects of irrigation levels on a- color, b- texture, c- quality after clipping, d- RWC, e- EL, f- chlorophyll content, g- plant height, h- fresh weight, i- dry weight in each fig, means with the same letter were not significantly different at 5% level.

Relative water content (RWC)

The results of analysis of variance showed that effect of turf-type and irrigation levels and their interaction effect was significant ($P<0.01$) on RWC (Table 3). buffalograss cultivars preserved more water content compared to tall fescue species (Table 4). In this experiment, the water content (RWC) has decreased from 79.85% in100% RDI to 73.51% in 40%RDI (Fig 1d).

Electrolyte leakage (EL)

Table 3 results are representative of the main factors and their interaction effects for EL.

These results showed all factors had significant effect on EL. According to Fig. 1e, there was a gradual increase in EL with increasing water stress, while EL was highest in middle and most severe water stress treatment (70-40% RDI). Among different turfgrasses in this experiment, Bowie showed the most EL and tall fescue showed lowest value of it (Table 4). EL values range varied from 17.36% to 29.39% (Fig. 2).

Interaction between irrigation levels and cultivar-type is presented in Table 5. The lowest Electrolyte leakage (15.71%) was belonged to 100% RDI in Bowie. Surprisingly this genotype was able to maintain its cell EL stable, when it exposed to 40% RDI. A drastic change in leaf EL of tall fescue and to a lesser extend in Cody can deduced from Table 5.

Total chlorophyll content

As expected drought stress has reduced total chlorophyll content of turfgrass leaf (Fig. 1f). The results of analysis of variance showed that effects of turf-type and irrigation levels was significant ($P<0.01$) however, the interaction results between turf-type and irrigation level did not show any significant effects on total chlorophyll content (Table 3). The amount of total chlorophyll decreased significantly in all levels of drought treatment (Fig. 1f). *Festuca arundinacea* maintained a relatively higher total chlorophyll content than buffalograss cultivars (Table 4).

Diminished chlorophyll content of turfgrass leaves by drought stress in our experiment are in agreement with Jiang and Huang (2001) who observed similar patterns when applied drought stress on tall fescue and Kentucky bluegrass. In another report by Abraham *et al*. (2008) drought stress caused a reduction in total chlorophyll content in Sesamum indicum plants.

Table 4. Physiological growth parameters of different turf grass in drought stress condition

Turf grass	Color (1-9)	Texture (1-9)	Quality after clipping (1-9)	RWC (%)	El (%)	Chlorophyll content	Height of plant (cm)	Fresh weight (g)	Dry weight (g)
Cody	7.05 b	7.87 a	7.25 a	80.69 a	10.53 ab	7.63 b	10.53 ab	4.01 a	1.45 a
Bowie	7.23 ab	7.85 a	7.46 a	79.84 a	9.68 b	7.79 b	9.68 b	4.04 a	1.39 a
Fescue	7.33 a	5.53 b	5.71 b	71.25 b	11.46 a	11.39 a	11.46 a	3.29 b	1.09 b

Means in the same column followed by the same letter were not significantly different at the 5% level.

Table 5. Interaction effect of irrigation treatments and turf-type on EL.

	Turf grass types		
Irrigation levels	Cody	Bowie	Fescue
40% ETO	25.77 cd	15.88 f	35.66a
70% ETO	29.03 bc	20.49 e	30.61a
100% ETO	20.77 e	15.71 f	21.90de

Means in the same column followed by the same letter were not significantly different at 5% level.

Growth parameters

Among plants subjected to deficit irrigation during the experiment, *Festuca arundinacea* showed highest value of plant height (11.46 cm) and Bowie showed lowest plant height (9.68 cm) Bowie and Cody cultivars of buffalograss showed the highest value of fresh and dry weight of plant (shoots) (4.04- 1.39 g and 4.01- 1.45 g, respectively) drastically but not significantly, however lowest fresh and dry weight belongs to *Festuca arundinacea* (3.29 and 1.09 g, respectively) (Table 4).

Severity of drought stress has resulted in variation of plant growth and development. Deficit irrigation reduced plant height (Fig. 1g) fresh and dry weight (Fig. 1h and 1i). The higher value of plant height (13.11 cm) and fresh and dry weight (5.17 and 2.04 g, respectively) occurred in 100 % of RDI. However, the plant height and fresh and dry weight of grasses were significantly inhibited only when plants exposed to severe water treatment (40% RDI) compared to the other level of stress (Fig.1 f, g and h).

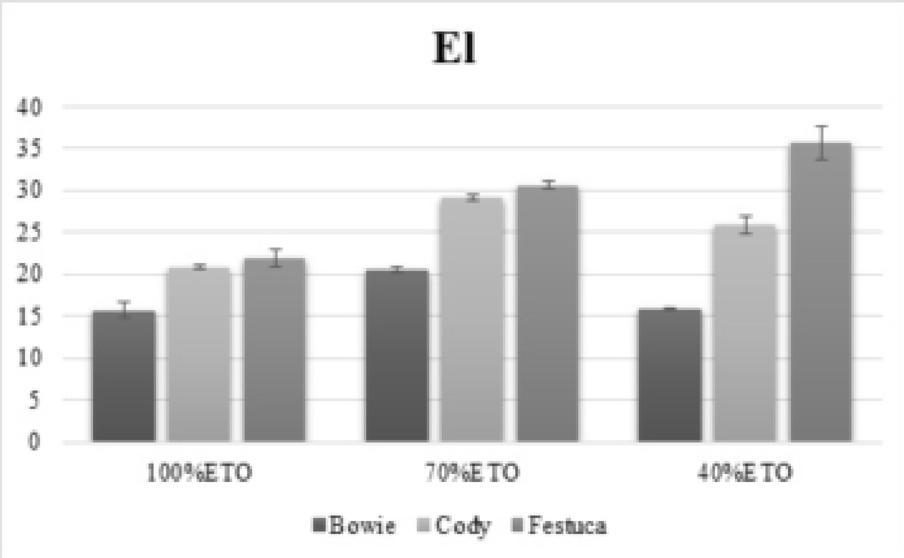

Fig. 2. Interaction effect of irrigation levels and turf grass types on EL. Error bars represent ± standard error.

DISCUSSION

Bowie and Cody showed better response than Festuca genotyple in all measured data (Table 4). The results presented also indicated the differences among irrigation levels for quality traits (color, texture and quality after clipping). Our results are in line with Sanchez-Blanco *et al*. (2009) and Saeedi Pooya *et al*. (2013) results, where they found water stress decreases turf quality.

Relative water content is one of the important physiological parameter in assessing water stress. The capacity of Cody and Bowie to maintain higher leaf RWC than tall fescue under water stress condition likely attributed to their natural ability to postpone dehydration through stomata. Significant difference had been reported between cultivars. It has been shown that resistant cultivars of turfs can maintain high RWC than sensitive ones (Ritchie *et al*., 1990). Abraham *et al*. (2004) reported that RWC of low, moderate, and high drought resistance group of Texas bluegrass, kentucky bluegrass, and their hybrids was influenced during the course of drought stress, but RWC of the high resistance group of aforesaid turfs was higher than the moderate groups, so as to tolerate severe stress condition. Such high RWC in resistant cultivars most probably is because of their better ability for water uptake at low soil water potential (Volaire *et al*., 1998).

It was found by several researchers that drought stress predominantly resulted in reductions of leaf RWC (Sammar Reza *et al*., 2012; Mohsenzade *et al*., 2006; Shahrokhi *et al*., 2011; Saeedi Pooya *et al*., 2013).

Cell membrane stability plays a critical role in maintaining cell turgor and physiological functions, particularly during plant dehydration stress, and electrolyte leakage, which is a reliable indicator of membrane senescence. This trait is being used to estimate cell membrane stability (Blum and Ebercon, 1981; Shahrokhi *et al*., 2011). Another parameter affected by water stress is the electrolyte leakage. The severe and middle drought stress treatments induced significant increases in electrolyte leakage compared to the control plants. We suggest that the increase in electrolyte leakage that we have demonstrated under water stress is at least partly due to the combined effects of both reduced water uptake. Kirnak *et al*. (2001); Dhindsa *et al*. (1981) have linked this augmented level of electrolyte leakage to reductions in leaf chlorophyll concentrations (due to leaf senescence) while Premachandra *et al*. (1992); McDonald and Archbold (1998) have shown that the reductions in water use can be the most probable reason for electrolyte leakage. In fact, the resistant genotypes exhibited better membrane stability than susceptible ones under severe drought stress, as demonstrated by the lower EL of resistant genotypes (Jiang and Huang, 2001).

Generally, total chlorophyll content of the leaves has decreased under drought stress in all cultivars. The reduction in chlorophyll content under drought stress was also reported on wheat (Synerri *et al*., 1993).

In our experiments, inflicted drought stress through deficit irrigation reduced the basic plant growth parameters (Fig. 1 f, g and h). Shoot growth responses to drought stress ensued reduced clipping production, verdure, shoot density, and color which was reported by Huang *et al*. (2008). The most common damaging effects of low moisture level or low water potential are the decline in fresh and dry matter production and plants height (Saeedi Pooya *et al*., 2011). Such decrease may be pertained to the reduction of photosynthesis apparatus activity under water deficit conditions. Similar findings were reported by Ashraf and Yasmin (1995) and Saeedi Pooya *et al*., (2011) in grasses.

CONCLUSIONS

Our study in buffalograss cultivars is the first experiment about effect of drought stress on this genotypes. Under severe drought stress the buffalograss cultivars Bowie and Cody showed acceptable tolerance, and their morpho-physiological properties were significantly better than control (100 % ETO). They need lower levels of irrigation compare to tall fescue. We estimated their need to irrigation compare to tall fescue. It can be a great benefit to test these genotypes in landscape of arid or semi-arid regions such as Iran.

Further study with other genotypes of buffalograss and tall fescue is needed to better understand their morpho-physiologial responses to different biotic and abiotic stresses. Our results will be very helpful and effective and can be used for resistance species in urban landscape.

The results of our investigation can be used for further studies to produce the best mixture of turf grass for dry area.

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