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Original Research Article

Evaluation of Drought Tolerance in Some Kentucky Bluegrass (*Poa pratensis*) Cultivars

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ABSTRACT

Drought stress is a major factor limiting the growth of turfgrasses and it has become a problem for turf management, as water availability for irrigation in urban areas is declining. Finding drought-tolerant turfgrasses will facilitate turf management for areas with limited water. This study was conducted to determine the morphological and physiological responses of five Kentucky bluegrass cultivars to drought stress. Treated cultivars were 'Nutop', 'Merion', 'Georgetown', 'Crusade' and 'Barcelona'. A split-split design based on the completely randomized block in three replications was considered. Treatments were irrigated after 30, 50, 70, 90, 110, and 130 millimeter evaporation from class A pan. Drought stresses significantly reduced turf quality, relative water content (RWC), shoot lengths, shoot and root dry weights and number of days to complete leaf wilting, but increased electrolyte leakage (EL) and number of days to recover complete green canopy after re-watering. Under drought stress, 'Nutop' had higher RWC, shoot dry and fresh weights and shoot lengths than other cultivars. 'Merion' had faster recovery from drought stress and higher root weight. Overall, among five cultivars, 'Nutop' and 'Georgetown' were least and most affected by drought stress, respectively

Keywords: Evaporation, Drought stress, Plant recovery, Turfgrass

Bazı Çayır Salkım Otu Çeşitlerinin Kuraklık Toleranslarının Değerlendirilmesi

ÖZ

Kentsel alanlarda sulamanın azalması ile birlikte kuraklık stresi, çim alanların gelişimini etkileyen faktörlerin başında gelmektedir. Kuraklığa dayanıklı çim çeşitlerinin bulunması ile limitli su kaynakları bulunan bölgelerde çim yönetiminin daha kolay yapılması sağlanacaktır. Bu çalışmada beş çayır salkım out çeşidinin kuraklık stresine karşı morfolojik ve fizyolojik tepkisinin belirlenmesi amaçlanmıştır. Denemeye alınan çeşitler "Nutop", "Merion", "Georgetown", "Crusade", ve "Barcelona"dır. Deneme tesadüf blokları deneme desenine göre 3 tekerrürlü olacak şekilde dizayn edilmiştir. Muamele grupları 30, 50, 70, 90, 110 ve 130 mm pan-evaporasyon yönteminden sonra sulanmıştır. Kuraklık stresi çim kalitesini, su içeriğini, sürgün uzunluğunu, sürgün ve kök kuru ağırlığını ve yaprak solma süresini önemli ölçüde azaltırken elektrolit sızıntısı ve solma sonrası yaprakların tekrar yeşerme süresini artırmıştır. Kuraklık stresi altında "Nutop" daha fazla su içeriği, kuru ve taze sürgün ağırlığı ve sürgün uzunluğuna sahip olmuştur. "Merion" ise daha hızlı yenilenme ve daha fazla kök ağırlığına sahip olmuştur. Genel olarak değerlendirildiğinde "Nutop" ve "Georgetown" çeşitleri kuraklık stresinden sırasıyla en az ve en çok etkilenen çeşitlerdir.

Anahtar Kelimeler: Evaporasyon, Kuraklık stresi, Yenilenme, Çim

INTRODUCTION

Kentucky bluegrass (*Poa pratensis* L.) is a cool-season grass and it forms an attractive turf when supplied with sufficient water, which is used widely for lawns, playing fields, and golf courses (Poss *et al.* 2010, Turgeon 2002, Beard 1973). Also, it has moderate to low drought resistance (Beard 1973). All plants stand or survive water insufficiencies with a selection of escape, avoidance, and tolerance mechanisms, all of which help to improve the efficiency of water application, water consumption, or water loss. Drought escape is a rather constricted grouping and generally refers to plants which take advantage of rapid phenological growth when water is existing, followed by dormancy in severe stress (Kramer 1980).

Drought tolerance processes permit the turfgrass to keep turgor and evade dormancy. Plant tolerance to drought stress can be divided into two groups, those plants which stand drought by keeping a low tissue water potential and those plants that tolerate drought by keeping a high tissue water potential (Jones *et al.* 1981). Plants that stand drought accumulate various solutes in a way named osmotic adjustment. Osmotic adjustment lets the plant to keep turgor under severe low-soil water potentials by declining cellular osmotic potential. Osmotic adjustment has been revealed in many grasses (DaCosta and Huang 2006). Another method contains those plants that tolerate drought by keeping high tissue water potential through declined water loss or improved water

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application. Plant water loss can be decreased under water shortage stress by leaf rolling or quick stomatal pore closing and these processes have been established in numerous grasses (Xu *et al.* 2006).

Drought stress creates a severe reduction in turf quality of cool-season grasses. Physiological changes related to act of cool-season grasses in reaction of drought or heat, differ with species or cultivars (Huang *et al.* 1998a, b) and there is significant variability between the cultivars inside the species (Murphy *et al.* 1995).

All of Kentucky bluegrass varieties and investigational hybrids showed wide differences in act under water-restrictive conditions and many physiological factors have been related to drought or summer stress tolerance, containing osmotic adjustment (Perdomo *et al.* 1996), deep rooting (Ebdon and Kopp 2004), and decreased electrolyte leakage (Abraham *et al.* 2004). Drought stress decreased root dry weight, leaf water potential, evapotranspiration, and photochemical efficiency in tall fescue (*Festuca arundinacea* L.), Kentucky bluegrass, and perennial ryegrass (*Lolium perenne* L.) (Aronson *et al.* 1987, Carrow 1996, Perdomo *et al.* 1996, Huang *et al.* 1998a). This study was conducted to determine the morphological and physiological responses of five Kentucky bluegrass cultivars to drought stress that are important as ground covers in semi-arid urban areas.

MATERIALS AND METHODS

Plant Materials

The five cultivars of Kentucky bluegrass were used for this study, including 'Crusade', 'Georgetown', 'Merion', 'Barcelona', 'Nutop'. Turfed plugs were collected from Agricultural Research Station of Mahmoud-Abad, Isfahan, Iran.

Growth Conditions and Treatments

Turfed plugs were washed free of soil and subsequently transplanted into plastic pots (23.5 cm in diameter and 20 cm deep). The soil texture was clay-loam with pH of 7.6 and 2.06% organic matter content. The experiment was conducted at Isfahan University of Technology, Isfahan, Iran from October to August in 2009 and 2010. During establishment of plants (about six months), irrigation was uniformly applied and turf grasses were maintained at a cutting height of 4cm. After full establishment, drying treatments was imposed and Pots were irrigated after 30, 50, 70, 90, 110, 130 millimeter evaporation from class A pan.

Measurements

Turf quality and leaf wilting, recovery were rated weekly. Shoot length, shoot dry weight, shoot fresh weight were measured every 10 days. Electrolyte leakage (EL) and Leaf relative water content (RWC) were determined 3 times during drought stress. Turf quality was rated on a 0-to-9 degree, where 0 = brown, dead turf; 6 = good enough quality for a home lawn; and 9 = optimum color, density, and uniformity (Turgeon 2002). After irrigation was ceased, Leaf wilting was evaluated from 0-to-100%, where 0 = no observable leaf wilting and 100% = completely wilted. When cultivars appeared to be dead, turf recovery was assessed by the percent canopy green cover (%CGC) development following re-watering. Leaf wilting and recovery were estimated by number of days until percentage of them increased to 90%.

The clippings were collected weekly and dried at 70°C for 48 h to determine the clipping produce, which was stated in grams of shoot dry weight per pot. Leaf RWC was measured according to the method of Barrs and Weatherley (1962) on the base of the following equation: RWC= (FW – DW)/(SW – DW) × 100, where FW is leaf fresh weight, DW is dry weight of leaves after being dried at 85°C for 48 h, and SW is turgid weight of leaves after soaking in water for 24 h at room temperature (20°C).

Electrolyte leakage of leaves was measured according to the technique of Blum and Ebercon (1981), with some changes. Leaves were removed and cut into 1 cm^2 sections. After being washed three times with distilled deionized H_2O, leaves were located in test tube containing 20 mL of distilled deionized H_2O. Test tubes were shaken on a shaker for 18 h, and the initial conductivity (C_i) was measured (Hotek Technologies, Model CC_501, USA). Leaves then were placed at 120°C for 30 min, and the conductivity of killed tissue (C_2) was measured after tubes cooled down to room temperature. The relative EL was calculated as (C_i/C_2).

The harvested plant materials were oven-dried at 60°C and dry weights were measured and recorded. The recorded data were considered the weekly plant dry production. At the termination of the research, the last harvest, plant roots were harvested, oven dried at 60°C, and dry weights were determined and recorded.

Experimental Design and Statistical Analysis

The experiment involved three factors (cultivars, evaporation levels [drought stress] and time) arranged in a split-split plot design, based on the completely randomized block test in three replicates. All analyses were done using SAS statistical package (SAS Institute, 1991) and P values less than 0.01 were considered significant.

RESULTS AND DISCUSSION

The significant interaction between cultivar and evaporation level for root dry weight were indicated in Table 1. But, for other parameters there are two main effects (cultivar and evaporation level) and no interaction (Table 2 and 3).

Table 1. Interaction effects of evaporation level and cultivar on dry weight root. (Revise the lettering if more than three then remove the middle, like a-f).

	Cultivar				
Evaporation(mm)	**'Nutop'**	**'Barcelona'**	**'Merion'**	**'Georgetown'**	**'Crusade'**
30	29.2 bcd *(0)***	32.3 a *(0)*	25.2 b-f *(0)*	31.7 a *(0)*	25.2 b-f *(0)*
50	28.9 bc *(1.3)*	27.3 bcd *(15.3)*	23.0 d-g *(8.6)*	26.8 bcd *(15.6)*	23.8 c-f *(6.1)*
70	19.0 fj *(35.1)*	21.5 dh *(33.2)*	21.4 d-g *(12.6)*	11.7 j-m *(62.9)*	20.0 e-i *(2.1)*
90	16.9 gk *(42.3)*	10.2 mn *(68.7)*	19.3 e-i *(23.1)*	9.6 mn *(69.6)*	18.1 f-j *(28.1)*
110	15.1 h-l *(48.2)*	9.1 l-o *(71. 8)*	13.7 i-l *(45.6)*	6.9 mno *(78.3)*	10.0 lmn *(60.3)*
130	9.6 lmn *(67.1)*	4.4 no *(86.4)*	11.13 klm *(55.8)*	2.9 o *(91.2)*	7.1 mno *(71.8)*

*In each column, means followed with the same letters are not significantly different at 1% level of probability (LSD).
**Numbers in parenthesis are percent of decreasing in roots dry weights rather than control (30 mm evaporation).

Table 2. Morphological and physiological characteristics of five Kentucky bluegrass cultivars affected by different levels of drought stress.

	Cultivar				
	'Nutop'	**'Barcelona'**	**'Merion'**	**'Georgetown'**	**'Crusade'**
Turf quality (TQ)	7.09 a	6.90 b	6.97 ab	6.61 c	7.03 ab
Shoot length	1.28 a	1.15 d	1.25 ab	1.20 c	1.22 b
Shoot dry weight	0.16 a	0.14 ab	0.15 ab	0.11 c	0.14 b
Shoot fresh weight	0.92 a	0.91 ab	0.91 ab	0.90 b	0.86 c
EL (%)	20.7 b	20.9 b	22.3 ab	23.6 a	19.9 b
RWC (%)	45.6 a	41.8 bc	42.8 abc	40.7 c	44. 6 ab
Leaf wilting	42.0 a	32.7 b	34.1 b	25.7 c	33.1 b
Shoot recovery	48.5 b	49.9 b	42.9 c	58.3 a	49.9 b

*In each row, means followed with the same letters are not significantly different at 1% level of probability (LSD).

Table 3. Effect of different levels of drought stress on morphological and physiological characteristics of some Kentucky bluegrass cultivars.

	Evaporation (mm)					
	30	**50**	**70**	**90**	**110**	**130**
Turf quality (TQ)	8.1 a	7.6 b	7.1 c	6.7 d	6.3 e	5.7 f
Shoot length	1.51 a	1.37 b	1.27 c	1.17 d	1.05 e	0.95 f
Shoot dry weight	0.26 a	0.17 b	0.14 c	0.11 cd	0.09 e	0.06 e
Shoot fresh weight	1.07 a	0.96 b	0.88 c	0.85 cd	0.83 de	0.80 e
EL(%)	12.3 f	15.2 e	17.8 d	21.4 c	26.3 b	35.9 a
RWC(%)	79.7 a	54.6 b	44.0 c	32.7 d	25.1 d	21.5 d
Leaf wilting	0	41.5 a	36.9 b	32.7 c	28.46 d	28.0 d
Shoot recovery	0	42.0 d	46.7 c	50.4 b	54.6 a	56.0 a

*In each row, means followed with the same letters are not significantly different at 1% level of probability (LSD).

The result showed significant differences in EL and RWC (Table 2). The highest values of RWC were observed in 'Nutop', 'Merion' and 'Crusade'. Moreover, minimum amounts of EL were also recorded in these three cultivars. Furthermore, the lowest value of RWC and maximum amount of EL was observed in 'Georgetown'. Leaf RWC is known as an indicator of water status under drought stress conditions (Makbul *et al.* 2011). Under water shortage, penetrability of cell membrane changes (Blokhina *et al.* 2003) and ability to osmotic adjustment is reduced (Meyer and Boyer, 1981). Plant drought stress significantly reduced RWC values. RWC of non-stressed plants is different from 85 to 90%, while in drought stressed plants; it can be as low as 30% (Mationn *et al.* 1989**).** Electrolyte leakage has been usually used as an indicator of leaf drought tolerance (Martin *et al.* 1987). Membrane leakage often occurs due to injure to cell membranes (Senaratna and Kersie 1983), and can lead to an increased permeability for electrolytes (Fu *et al.* 2004**)**. So EL increased during the drought (Table 3).

For all five cultivars TQ, Shoot dry and fresh weights significantly decreased during drought stress. And 'Georgetown' was the most severely affected under drought condition. In contrast, 'Nutop' and 'Merion' has a better performance in this case under mentioned situation. Drought stress causes significant losses in turf quality of cool-season grasses (DaCosta and Huang 2006, Liu *et al.* 2008).Water deficit produces reactive oxygen species that can causes lipid peroxidation, so chlorophyll content of the leaf decreases and green color changes into yellow (Schlemmer *et al.* 2005). Some researchers reported TQ and RWC decreased while EL increased in Kentucky bluegrass (*Poa pratensis* L.; KBG) under drought stress (Abraham *et al.* 2004).

Shoot length declined gradually under drought for all cultivars at any stress level (Table 3). Shoot length for 'Georgetown' was significantly lower than other cultivars (Table 2). Cell enlargement and growth depends upon hydraulic pressure and water is essential in the maintenance of the turgor (Coder and Daniel 1999). Pessarakli and Kopec (2008) also reported that the drought stress significantly reduced shoot lengths, shoot dry weight and root dry weight in three main sports turfgrasses, Creeping bentgrass (*Agrostis stolonifera*), Rough bluegrass (*Poa trivialis*), and Perennial ryegrass (*Lolium perenne*).

Leaf wilting and shoot recovery of different cultivars are shown in table1. Significant differences were observed among cultivars. 'Georgetown' had faster leaf wilting after 25 days, whereas 'Nutop' had complete leaf wilting after 49 days. The 'Georgetown' recovered more than 90% after approximately 58 days of re-watering; while, 'Merion' recovered more than 90% after approximately 43 days of re-watering. As leaves got dry, turgor pressure was decreased and leaf wilting was observed. In same researches LW level started to increase under drought stress for some Kentucky bluegrass cultivars (Liu *et al.* 2008). Osmotic adjustment sustains cell wall flexibility and makes possible growth during recovery from drought stress upon re-watering (Clifford *et al.* 1998).

Also, osmotic adjustment maintains the meristem viability under desiccation. The various solutes are recovered and metabolized upon re-watering and utilized as energy supply for growth recovery (Huang 2004). Etemadi (2005) reported significant differences in shoot recovery among assessments of Bermuda grasses during drought. The 17-GNl accession recovered 78.2% after 12 days of re-watering; while Tifdwarf, 88-Khl, 7-Gg and 3-Gf recovered more than 90% after 33 days of re-watering.

Roots dry weights of all cultivars substantially decreased under drought at any levels of stresses. Percent of decreasing in roots dry weights was lower in ‘Merion’ during experiment (Table3). By Irrigation after 50 mm evaporation, Root DW significantly declined to 15.30% for ‘Barcelona’ and 15.58% for ‘Georgetown’ compared with control plants. Irrigation after 70 mm evaporation led to 35.11% decrease in Root DW for ‘Nutop’, 33.25% decrease for ‘Barcelona’ and 62.93% for ‘Georgetown’ compared with control. In irrigation after 90 mm evaporation, Root DW significantly declined to 42.32% for ‘Nutop’ ,15.30% for ‘Barcelona’ and 15.58% for ‘Georgetown' compared with control plants. Also, by irrigation after 110 and 130 mm evaporation, all cultivars showed significant reduction in root DW compared with control plants.

After drought stress in fifth treatment (110 mm evaporation),, reduction in Root DW for ‘Merion’ was significantly lower than other cultivars. It declined to 45.59% compared with control plants. ‘Georgetown’ showed higher significant reduction and it reached to 78.26% compared with controls. By irrigation after 130 mm evaporation, the lowest reduction in root DW was 55.79% for ‘Merion’ and the greatest reduction in Root DW was 91.23 % for ‘Georgetown’. Huang and Fu (2000) reported that drought stress reduced the respiration rate and carbon allocation to roots in the surface drying soil. In similar result drought reduced root dry weight in Kentucky bluegrass cultivars (Aronson *et al.* 1987, Carrow 1996, Perdomo *et al.* 1996, Huang *et al.* 1998a).

CONCLUSIONS

‘Nutop’ exhibited superior drought survival by the maintenance of higher grass quality, cell membrane stability , RWC, Shoot dry and fresh weights and shoot lengths, than other cultivars under the same level of water deficit during drought stress. These parameters could explain some of the mechanisms which indicate tolerance to drought.

‘Merion’ also showed more rapid and greater extent of recovery in Turf quality upon re-watering. Post-drought recovery in ‘Merion’ could be associated with the maintaining higher Root weight and new root production after re-watering .Root maintaining effects drought recovery. Lower Shoot length for ‘Merion’ under drought stress may be due to the increased carbon allocation to roots relative shoots. Among five cultivars, ‘Georgetown’ had the least tolerance to drought stress and severely affected by lack of water. Drought tolerance among Kentucky bluegrasses cultivars could be valuable in limited water sites. So that cultivars may be selected that are best adapted for lawns where irrigation in not available or is limited. Also, physiological approach would be the most attractive way to develop new varieties rapidly.

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