DESERT

Desert
Online at http://desert.ut.ac.ir

Desert 23-2 (2018) 295-306

Improving early growing stage of *Festuca arundinacea* Schreb. using media amendments under water stress conditions

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Received: 20 May 2018; Received in revised form: 13 August 2018; Accepted: 16 September 2018

Abstract

Developing strategies to tackle water stress in lawns in arid climate regions is significantly important. In such conditions, using growing media amendments as well as native plants can relieve drought stress in different growing stages of the plants. This study was carried out to investigate the effects of some types of soil amendments on the emergence and early seedling establishment of tall fescue (*Festuca arundinecea* Schreb 'GazBorkhar ecotype') under water stress conditions. The experiment was performed in a factorial trial based on a completely randomized design with three replications. The first factor, water stress, was applied based on field capacity (FC) at three levels (80% FC (control), 60% FC and 40% FC). The second factor, growing media amendments, was applied at nine levels of municipal solid waste (MSW), vermicompost (5% and 10% w/w), Stockosorb® (1% and 3% w/w) or zeolite superabsorbent (4% and 8% w/w) which were mixed with loam soil, and the loam soil was used as a control treatment. The results showed that using an irrigation system at 60% FC during seed emergence and early seedling growth did not reduce the quality of the turf grass, and also, in many cases, led to a higher quality lawn compared to the control, leading to water saving in turf grass management. Using MSW and manure vermicompost as soil amendments could maintain soil moisture and water supplement for the improvement of morphological, physiological and visual quality of this ecotype of *Festuca arundinacea* Schreb.

Keywords: Irrigation; Manure; Municipal solid waste (MSW); Superabsorbent; Tall fescue; Vermicompost

1. Introduction

In urban landscapes, turf grasses are key elements for recreational and ornamental uses. However, obtaining high quality turf grasses turns out to be a challenge in many regions of the world as a result of water shortage and drought stress conditions (Beard, 1973; Gibeault *et al*., 1989). Blum (1996) stated that drought, as a multi-dimensional stress, can influence plants at different levels of organs. The reaction of plants to drought stress is complex because it reflects the combined effects of stress and relevant responses of the plant's organs. Siddique *et al*. (1999) reported that drought negatively affects almost all the plant growth processes. To overcome the negative effects of drought in urban landscaping, especially in arid and semi-arid regions, using native plants is recommended. There are economic constrains as well as ecological drawbacks to use imported non-native species for landscaping. The use of imported grass seeds in such areas imposes high costs on national institutions. In addition, these imported seeds are generally not compatible enough with existing drought stress conditions of the region or they may become invasive species. Native grasses have higher ecological flexibility than their corresponding genetically improved species due to their genetic diversity. *Festuca arundinacea* Schreb, one of the most economically important forage and turf grass species, is one of the widely used grass species that can be found abundantly in cold and dry regions with sporadic drought (Bor, 1970; Saha *et al*., 2005). Some cultivars such as *Festuca*

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arundinacea cv 'Grande' was reported as drought tolerant (Caturegli *et al*. 2015).

Low rainfall, high temperatures, wind and evaporation, which have significant effects on growth stages of plants, can lead to the occurrence of drought (Magrokosho and pixley, 1995). Germination is the first and most critical stage of plants growth and development and is a vital process in seedling emergence (De Villiers *et al*., 1994). Some environmental factors, especially temperature, humidity and soil salinity, strongly influence this growth stage (Basra *et al*., 2004). Furthermore, uniformity of germination, mean germination time and seed emergence are the most important factors affecting seed quality (Soltani *et al*., 2006), hence, reduction in germination and damage to the plants in the emergence stage due to stress conditions are the main causes of final quality losses in plants (Daneshmand *et al*., 2012). Any plant that can exhibit greater level of tolerance to drought stress in the germination stage would be more successful during the first period of growth. This is the reason why researchers seek to find some solutions to increase seedling establishment under abiotic stress conditions (Katergi *et al*., 1994).

One of the solutions to alleviate drought stress in different growth stages of plants is the addition of soil amendments to the growing media. Two of the most important growing media amendments are composts and super absorbents. There are two sources of initial materials for producing composts; the first group is based on manures and animal wastes and the second group is produced based on municipal solid waste and sewage sludge (Gregorie, 2004). These materials affect the performance of turf grasses. For example, turf grasses growing in bio solid-amended soils established faster and showed improvements in density, color and resistance to foliar diseases (Loschinkohl and Boehm, 2001, Linde and Hepner, 2005, Loschinkohl and Boehm, 2001). Lucero *et al*. (1995) also stated that poultry litter had positive influence on *Festuca arundinacea* Schreb. and *Poa pratensis* L. growth, and can be a suitable source of fertilizer for pasture renovation and production if applied in an appropriate amount (Lucero *et al*., 1995). It was also shown that sewage sludge increased growth and green color in tall fescue and in mixed sward of perennial ryegrass and Kentucky bluegrass (Schumann *et al*. 1993); while manures and crop residues were shown to restore productivity in eroded soils (Larney and Janzen, 1996). Similar results were reported regarding the use of yard trimmings on *Cynodon dactylon* and *Paspalum notatum* (Harrell and Miller, 2005).

The other material group which can be used as soil amendment is super absorbents. Super absorbents, which have the ability to absorb large amounts of water, are divided into different categories and include various compounds. Some, such as zeolites, are minerals and can be extracted from mines. Zahedi *et al*. (2009) reported that the use of zeolite in dry lands exposed to drought stress could lead to the improvement of quality and quantity in some canola cultivars. Moreover, zeolite application reduced water stress damage in grape (Valadabadi *et al*., 2010).

Other types of super absorbents are synthetic, which are formed from polymeric materials with network structures (physical or chemical cross linking) which have high water absorption capability and inflation. Some properties such as penetration rate, density, soil structure, compaction, texture, aggregate stability and evaporation rate can be affected by these polymers (Abedi-koupai and Asadkazemi, 2006). Stockosorb® (Acrylic acid polymer) is an example of this group. Shi *et al*. (2010) reported that the presence of Stockosorb® near the roots of *Populus popularis* could increase the tolerance of this species to drought and salinity by three mechanisms: a) under water shortage, roots can be benefitted by hydrophilic polymers, which can act as a water reservoir; b) under salinity conditions, Stockosorb®, due to high water capacity, holds Na^+ and Cl^- ions in the soil solution and thus prevents the accumulation of excessive toxic ions in organs. In addition, exchangeable K^+ ions in Stockosorb® improve the ratio of K^+/Na^+ in plants; c) hydrophilic polymers, which are mainly responsible for water- and salt-holding capacities in plants, help the plants tolerate interactive effects of drought and salt stresses (Shi *et al*., 2010).

Considering the above-mentioned points, it appears that a growing media which can enhance the water holding capacity and moisture content to a minimum level has better effects on maintaining the quality of plants. The main goal of this experiment is to study the effects of some types of soil amendments on the emergence and early seedling establishment and morphological and physiological characteristics of the native ecotype of tall fescue under water stress conditions.

2. Materials and Methods

This research was carried out at the Department of Horticultural Science and Landscape, Ferdowsi University of Mashhad, Iran, during the winter 2014. The experiment was performed in a factorial trial based on a completely randomized design with three replications. The first factor was irrigation levels (80%, 60% and 40% field capacity (FC)) and the second factor was growing media mixtures (Table 1). The growing media was prepared by using two kinds of vermicompost (municipal solid waste and manure) (Table 2), a synthetic (Stockosorb® 660) and a mineral super absorbent (Zeolite) mixed with the soil (Table 2). Stockosorb® 660 was bought from a German company, Evonic/ degussa®, and its chemical compound was crossed linked polyacrylic acid homopolymer partially potassium neutralized. Zeolite was supplied from Semnan Negin Powder® company and its formula was clinoptilolite $KNa_2Ca_2(Si_{29}Al_7)O_{72}.24H_2O$ in major Phase (Table 3).

Table 1. The ingredients of the growing media and their abbreviations

Growing media ingredients	Abbreviation
Municipal solid waste vermicompost + soil (5: 95% W/W)	Vr5
Municipal solid waste vermicompost + soil (10: 90% W/W)	Vr10
Manure vermicompost + soil (10: 90% W/W)	Vm10
Manure vermicompost + soil (5: 95% W/W)	Vm5
Synthetic superabsorbent, Stockosorb® 660 + soil (1: 99% W/W)	S1
Synthetic superabsorbent, Stockosorb® 660 + soil (3: 97% W/W)	S3
Mineral superabsorbent, Zeolite + soil (4: 96% W/W)	Z4
Mineral superabsorbent, Zeolite + soil (8: 92% W/W)	Z8
Loam soil (control treatment)	C

Table 2. Selected physical and chemical attributes of the growing media

Growing media	pH	EC (ms/cm)	O.M (%)	Texture	Sand (%)	Silt (%)	Clay (%)	N (ppm)	P (ppm)	K (ppm)
Soil	7.94	2.41	0.86	Loam	47.30	18.70	34	1071	11.62	263
MSW vermicompost	8.62	4.19	19.89	-	-	-	-	9567	4733	10138
Manure vermicompost	7.18	5.33	11.31	-	-	-	-	12483	5429	9780

Table 3. The ingredients of the used zeolite

Chemical compositions	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	L.O.I
Weight percent (%)	68.95	11.14	0.97	4.83	0.79	0.95	0.95	0.068	10.68

Seeds of *Festuca arundinacea* Schreb (Gaz Borkhar ecotype) (purity=98%, viability=85%) which were bought from Pakan Bazr® company, were planted in 81 pots (18 cm in diameter and 17.5 cm in depth) and covered with a thin layer of sand. Levels of irrigation were applied in the pots from the beginning of the experiment. To monitor the amount of moisture for each growing medium, the pots were regularly weighed and they were toped up with water to get to their required irrigation level in the experiment whenever necessary (Alizadeh, 2004). During this period (three months), the environmental conditions of the greenhouse were as follows: light intensity (sum): 280-390 Klux, minimum temperature: 18 °C, maximum temperature: 30 °C, average temperature: 24 °C and average relative humidity: 45%.

At the first stage, emergence percentage and mean emergence time (MET), then plant height and fresh and dry weight of clipping per unit area were measured.

Mean emergence time (MET) = $(A_1D_1+ A_2D_2+ A_3D_3+ A_nD_n)/A_1+ A_2+ A_3+A_n$

Where A is the number of emergent seeds, and D is Day.

At the end of the experiment, morphological characteristics including root length and volume, soil moisture percentage, root and shoot water content were measured by using a ruler, Archimedes method and the following formulas, respectively:

Soil moisture percentage = (wet soil – dry soil)/ dry soil × 100

Root water content = (root fresh weight – root dry weight)/ root fresh weight × 100

Shoot water content = (shoot fresh weight – shoot dry weight)/ shoot fresh weight × 100

For measuring physiological traits, the following methods were used:

Electrolyte leakage (EL) = (E1/E2) × 100 (Lutts *et al.* 1996)

E1= Electrolyte leakage before autoclave

E2= Electrolyte leakage after autoclave

Relative water content (RWC) (%) = (Fresh weight - Dried weight)/ (Turgid weight - Dried weight) × 100 (Barrs and Weaterley, 1962)

Total chlorophyll and carotenoids contents were measured based on the method suggested by Lichtenthaler (1987). Visual and functional characteristics of the turf grasses including color, smoothness, coverage, texture, traffic tolerance, resistance to weeds and total quality were also evaluated. Visual quality was assessed using a visual score based on a 1–9 scale, as used in the National Turf grass Evaluation Program (NTEP)(1 = poorest, 9 = best qualities) (Morris and Shearman, 2000).

The data was analyzed using Minitab Software Package (V.17) and the means were compared using the Least Significant Difference (LSD) test at $p \leq 0.05$.

3. Results

According to Table 4, the interaction between irrigation levels and growing media types was significantly different on the soil moisture percentage, percentage of seed emergence, root volume, root length, electrolyte leakage, total chlorophyll content and carotenoids content. In mean of seed emergence time, the simple effect of irrigation levels and in traits height, root water content, shoot water content and relative water content simple effect of growing media types was significantly different (Table 4). According to Table 5, the effects of color, texture and coverage on the effects of both factors on irrigation levels and growth rate were significant. As for smoothness, the only significant factor was the growing media, and in terms of traffic tolerance and general quality, the effect of irrigation levels was significan only.

3.3. Mean of seed emergence time

A faster seed emergence time was observed under 60% FC (2.52 days) and 80% FC (3.04 days), and these values were significantly different from the corresponding values under 40% FC irrigation treatment (2.45 days) (Table 6).

3.4. Height

As it can be seen in Table 6, the plants in Vr10, Vm10 and Z4 had the greatest height (11.85, 11.83 and 11.82 cm) compared to the plants in Z8 and S1 treatments with the minimum height of 10.61 and 10.4 cm, respectively.

3.5. Root volume

It can be observed in Table 7 that the plants associated with the treatments S1 and S3 had the highest root volume in the three irrigation levels. In general, in all the three levels of irrigation, treatments containing vermicompost as the growing media (Vr5, Vr10, Vm5 and Vm10) were associated with the plants with least amount of roots.

3.6. Root length

Table 7 shows that S1, S3, Z4, Z8 and the control treatments had the longest root length in all irrigation levels (with the exception of S1 in 80% FC), and vermicompost treatments (animal and MSW vermicompost) had the shortest root length.

3.7. Root water content percentage

The plants in the treatments containing municipal waste vermicompost and manure vermicompost had the highest root water content and showed significant differences from the plants in the control treatment. In addition, the plants in Vr5, Vr10 and Vm5 showed significant increases in their root water content compared with the plants in Z8 and S1 treatments (Table 6).

3.8. Shoot water content percentage

Based on Table 6, the growing media containing manure vermicompost and MSW manure had the highest shoot water content. Furthermore, shoot water contents in treatments Vr5 (81.83%), Vm5 (81.28%) and Vm10 (83.15%) were significantly higher than those in other treatments including the control one (73.40%).

3.9. Relative water content (RWC)

The highest RWC was related to the plants associated with Z4 (72.68%) and the lowest value was related to the plants associated with Z8 (55.8%), as can be seen in Table 6. Stockosorb® had a positive effect on RWC in the turf grass, regardless of the amount used. In contrast, the amount of zeolite had an important role, so that leaves from plants grown in Z4 had the highest amount of RWC. However, plants grown in Z8 were not significantly different from the plants grown in the control treatment. In general, all the growing media types increased RWC in *Festuca arundonacea* Schreb compared with the control growing medium (loam soil).

Table 4. Analysis of variance (mean squares) for physiological traits of *Festuca arundinacea* Schreb. under water stress and growing media treatments

Source of variation	d_f	Soil moisture	Seed emergence	MET	Height	Root volume	Root length	Root water content	Shoot water content	RWC	EL	Total chlorophyll content	Carotenoids content
Irrigation levels	2	**386.97	**8224.80	**2.78	0.12^{ns}	**21.34	**13.55	4.45^{ns}	18.47^{ns}	210.33^{ns}	**503.22	**239.26	**21.12
Growing media	8	**71.34	511.90^{ns}	0.16^{ns}	*2.73	**88.47	**37.11	**188.80	**147.23	**337.42	**741.75	**368.51	**6.64
Irrigation levels × Growing media	16	**22.36	**639.20	0.11^{ns}	1.35^{ns}	**4.34	*4.63	16.02^{ns}	25.47^{ns}	114.04^{ns}	*132.50	**174.52	**4.18
Error	54	4.82	267.10	0.80	1.23	0.71	2.31	23.38	23.98	71.59	65.20	12.00	1.34

ns, * and ** show non-significant, significant at 5%and 1% probability levels, respectively

Table 5. Analysis of variance (mean squares) for visual and functional qualities of *Festuca arundinacea* Schreb.

Source of variation	d_f	Texture	Color	Coverage	Smoothness	Traffic tolerance	General quality
Irrigation levels	2	**8.12	**2.94	**7.00	0.08^{ns}	**2.34	**2.19
Growing media	8	**1.19	**1.25	**2.30	*1.26	0.28^{ns}	0.45^{ns}
Irrigation levels ×Growing media	16	0.30^{ns}	0.32^{ns}	0.83^{ns}	0.61^{ns}	0.20^{ns}	0.29^{ns}
Error	54	0.32	0.22	0.73	0.51	0.31	0.22

ns, * and ** show non-significant, significant at 5% and 1% probability levels, respectively

Table 6. Comparison of the means of irrigation treatment and different growing media types

treatment		MED (day)	Height (cm)	Root water content (%)	Shoot water content (%)	RWC (%)	Texture (1-9 scores)	Color (1-9 scores)	Coverage (1-9 scores)	Smoothness (1-9 scores)	Traffic tolerance (1-9 scores)	General quality (1-9 scores)
Irrigation levels	Growing media											
40% FC	-	3.04 a	-	-	-	-	6.29 a	7.07 a	5.63 b	-	5.85 b	6.10 b
60% FC	-	2.52 b	-	-	-	-	5.40 b	6.62 b	6.58 a	-	6.44 a	6.63 a
80% FC	-	2.45 b	-	-	-	-	5.29 b	6.42 b	6.44 a	-	6.09 b	6.56 a
-	C	-	10.88 abc	80.82 bc	73.40 c	54.50 d	4.97 d	6.22 d	6.08 bc	6.63 bc	-	6.30 abc
-	S1	-	10.61 bc	73.00 d	72.45 c	63.23 bc	5.91 ab	6.24 d	5.75 c	6.43 c	-	6.71 a
-	S3	-	11.00 abc	84.54 abc	75.60 bc	69.23 ab	5.33 cd	6.86 ab	6.00 bc	6.67 bc	-	6.22 bc
-	Z4	-	11.82 a	83.17 abc	76.35 bc	72.68 a	5.45 bcd	6.72 bc	5.84 abc	6.90 abc	-	6.03 c
-	Z8	-	10.40 c	80.07 c	74.10 c	55.80 cd	5.80 bcd	6.27 cd	5.86 ab	6.49 c	-	6.44 abc
-	Vr5	-	11.35 abc	87.26 a	81.83 a	62.49 bcd	5.75 bcd	6.94 ab	7.05 a	7.39 a	-	6.58 ab
-	Vr 10	-	11.85 a	87.04 a	80.18 ab	61.77 bcd	5.86 abc	6.80 ab	5.86 ab	7.25 ab	-	6.44 abc
-	Vm 5	-	11.51 ab	86.74 a	81.28 a	61.62 bcd	6.20 a	7.18 a	6.59 a	7.37 a	-	6.72 a
-	Vm10	-	11.83 a	84.88 ab	83.15 a	55.92 bcd	5.69 abc	7.11 ab	6.94 abc	7.08 abc	-	6.44 abc

Means with the same letters are not significantly different. FC (Field capacity), C (control), S1 (Stockosorb® 660 + soil (1: 99% W/W)), S3 (Stockosorb® 660 + soil (3: 97% W/W)), Z4 (Zeolite + soil (4: 96% W/W)), Z8 (Zeolite + soil (8: 92% W/W)), Vr 5 (Municipal solid waste vermicompost + soil (5: 95% W/W)), Vr 10 (Municipal solid waste vermicompost + soil (10: 90% W/W)), Vm 5 (Manure vermicompost + soil (5: 95% W/W)), Vm 10 (Manure vermicompost + soil (10: 90% W/W)

Table 7. Comparison of the means of irrigation treatment with different growing media types

Treatment		Soil moisture (%)	Seed emergence (%)	Root volume (cm^3)	Root length (cm)	Electrolyte leakage (%)	Total chlorophyll content (mg/gr)	Carotenoids content (mg/gr)
Irrigation levels	Growing media							
40% FC	C	10.12 klm	64.67 d-k	6.16 efg	13.00 b-e	62.83 a-d	44.06 a	5.67 abc
40% FC	S1	10.47 klm	74.67 b-h	10.55 b	10.66 efg	55.53 b-f	20.20 n	4.05 c-g
40% FC	S3	8.32 m	53.55 jk	11.01 b	12.06 c-f	35.28 ij	39.95 a-d	5.42 a-d
40% FC	Vm 10	12.67 ijk	62.44 f-k	5.00 g-j	10.66 efg	34.78 ij	24.23 lmn	5.74 abc
40% FC	Vm 5	14.60 g-j	67.17 c-j	4.66 h-k	9.50 ghi	50.57 d-h	40.23 abc	4.94 a-e
40% FC	Vr 10	16.91 d-h	48.00 k	2.66 n	9.66 fghi	35.47 ij	33.30 e-h	5.73 abc
40% FC	Vr 5	13.59 h-k	56.22 ijk	4.50 i-l	9.50 ghi	33.02 j	32.32 e-h	3.59 d-h
40% FC	Z4	12.97 ijk	62.67 e-k	5.66 f-i	14.00 a-d	48.71e-h	37.45 b-e	5.36 a-d
40% FC	Z8	10.76 klm	49.11 k	7.16 cde	13.83 a-d	45.93 f-j	26.27 i-m	4.96 a-e
60% FC	C	15.59 e-i	98.00 a	7.83 cd	15.00 ab	67.07 ab	29.15 g-l	2.14 hij
60% FC	S1	11.66 j-m	78.22 b-g	14.64 a	14.16 a-d	65.97 abc	24.66 k-n	3.91 c-h
60% FC	S3	9.05 lm	84.22 abc	14.44 a	13.66 a-d	66.33 abc	25.54 j-n	3.08 e-i
60% FC	Vm 10	18.76 c-f	72.00 b-i	5.22 g-j	10.50 fg	44.78 f-j	30.26 f-k	4.99 a-d
60% FC	Vm 5	14.62 g-j	88.60 ab	4.25 j-m	11.75 d-g	41.41g-j	28.24 h-l	4.38 b-g
60% FC	Vr 10	22.40 ab	59.33 h-k	3.00 mn	11.00 efg	45.32 f-j	26.01 j-m	3.75 d-h
60% FC	Vr 5	17.25 d-g	80.22 b-f	4.33 i-m	10.16 fgh	40.68 g-j	30.29 f-k	3.66 d-h
60% FC	Z4	14.66 g-j	88.00 ab	6.00 e-h	13.96 a-d	39.73 hij	35.79 c-f	3.03 fi
60% FC	Z8	11.78 j-m	76.22 bh	7.00 def	14.16 a-d	44.78 f-j	21.25 mn	6.51 a
80% FC	C	22.18 abc	61.55 g-k	5.25 g-j	13.66 a-d	71.33 a	31.07 f-j	2.56 g-j
80% FC	S1	19.52 bcd	82.44 a-d	8.50 c	8.00 hi	56.87 b-f	9.02 o	0.87 j
80% FC	S3	15.23 f-j	73.11 b-i	10.22 b	14.50 abc	60.85 a-e	34.43 d-g	4.29 b-g
80% FC	Vm 10	12.30 i-l	79.77 b-f	5.00 g-j	10.50 fg	44.22 f-j	31.82 e-i	4.03 c-h
80% FC	Vm 5	19.10 b-e	80.44 a-e	3.16 lmn	9.66 f-i	46.63 f-i	35.45 c-f	4.88 a-f
80% FC	Vr 10	23.79 a	87.33 ab	3.50 k-n	10.50 fg	45.19 f-j	42.80 ab	6.14 ab
80% FC	Vr 5	23.81 a	85.77 ab	2.83 n	7.50 i	47.09 f-i	39.88 a-d	2.54 g-j
80% FC	Z4	19.39 bcd	85.77 ab	6.33 efg	15.50 a	52.20 d-h	13.94 o	1.51 ij
80% FC	Z8	22.54 ab	78.22 b-g	6.00 e-h	14.00 a-d	53.14 c-g	13.64 o	2.91 ghi

Means with the same letters are not significantly different. FC (Field capacity), C (control), S1 (Stockosorb® 660 + soil (1: 99% W/W)), S3 (Stockosorb® 660 + soil (3: 97% W/W)), Z4 (Zeolite + soil (4: 96% W/W)), Z8 (Zeolite + soil (8: 92% W/W)), Vr 5 (Municipal solid waste vermicompost + soil (5: 95% W/W)), Vr 10 (Municipal solid waste vermicompost + soil (10: 90% W/W)), Vm 5 (Manure vermicompost + soil (5: 95% W/W)), Vm 10 (Manure vermicompost + soil (10: 90% W/W)

3.10. Electrolyte leakage (EL)

In general, the turf grasses grown in S1, S3 and especially in the control treatments had the highest percentage of electrolyte leakage (Table 7). The plant in the control and S1 in 40% FC, and the plants in the control, S3 and S1 in both 80% and 60% FC levels had the highest EL. However, the plants in other treatments under 80% and 60% FC levels were not significantly different from each other in terms of electrolyte leakage (Table 7).

3.11 Total chlorophyll content

On the basis of means comparison (Table 7), in 80% FC, the least amount of total chlorophyll was observed in the plants cultivated in S1 (60.17 mg/gr), Z8 (92.98 mg/gr) and Z4 (90.94 mg/gr), respectively. In 60% and 40% FC treatments, the plants in Z8 (141.69 mg/gr) and S1 (134.66 mg/gr) had the lowest total chlorophyll content, respectively.

3.12. Carotenoid content

Under 80% and 60% FC, the plants cultivated in Vr10 (40.99 mg/gr) and Z8 (43.43 mg/gr) had the highest carotenoid levels, while under 40% FC, the plants in the control (37.86 mg/gr), Vm10 (38.29 mg/gr) and Vr10 (38.24 mg/gr) showed the highest carotenoid contents. In 80% and 60% FC, these values were much higher than the corresponding values in the control treatment (Table 7).

3.13. Visual and functional qualities

3.13.1. Texture

The higher texture scores were associated with irrigation levels of 40% FC, which imply an improved texture in the plants. However, there was not a significant difference between irrigation levels of 60% FC and 80% FC (Table 6). According to Table 6, the finest and coarsest textures were found in turf grasses planted in Vm5 and control treatments, respectively.

3.13.2. Color

Table 6 shows that the turf grass species grown under 40% FC possessed higher color values than the turf grass grown under 60% FC and 80% FC irrigation levels. There were also significant differences among the different growing media treatments in terms of color. It was found that the lowest color values were associated with the control treatment (6.22). The best growing media treatment for color was Vm5 (quality value of the turf grass: 7.18), followed by Vm10 (quality value of the turf grass: 7.11) and Vr5 (quality value of the turf grass: 6.94) (Table 6).

3.13.3. Coverage (%)

The best turf grass coverage was associated with irrigation levels of 60% FC (6.58) with no significant difference from the turf grass coverage in 80% FC (6.44), while the lowest turf grass coverage was seen under 40% FC (5.63) (Table 6). According to Table 6, the turf grass coverage in two treatments Vr5 (7.05) and Vm10 (6.94) were the highest, and the plants planted in S1 (5.75) growing medium had the lowest coverage.

3.13.4. Smoothness

Mean comparisons of the growing media types showed that the highest smoothness scores was obtained in turf grasses planted in manure and MSW vermicomposts. In addition, the turf grasses planted in vermicompost (5% w) had a smoother surface than those planted in vermicompost (10%W) (Table 6).

3.13.5. Traffic tolerance

Table 6 shows that only irrigation levels had significant effect on traffic tolerance of the turf grass. It can be seen in Table 6 that the highest traffic tolerance score was associated with 60% FC (6.44), and, by contrast, the lowest traffic tolerance value was seen in plants grown under 40% FC.

3.13.6. General quality

According to Table 6, general quality of the turf grass was significantly affected by simple effects of irrigation levels and growing media types. Fig. 14 shows that among the different levels of irrigation, the lowest quality values were related to the plants grown under 40% FC (6.1), while the highest quality values were observed in the plants grown under 60% FC (6.63). These did not have significant differences from the plants grown under 80% FC irrigation level (6.56). In relation to the growing media, Table 6 showed that, all the treatments, in particular Vr 5, improved general quality of the turf grass compared to S3 (6.22) and Z4 (6.03) and the control treatments (6.30).

4. Discussion

The aim of this study was to improve the most sensitive growth stage of lawn, which is the emergence and establishment of the seedlings to water stress. This paper investigated how management strategies such as using an appropriate threshold for the irrigation rates and selecting appropriate amendment mixtures with soil can be used as a way to control drought stress as well as to optimize water usage in a native *Festuca arundinacea* Schreb lawn.

Turf grass is an important plant in landscape, especially from an aesthetic point of view. Evaluation of turf grass from this perspective is made using a number of traits such as plant coverage, color, texture, smoothness, traffic tolerance and general quality. One of the most common methods for measuring these traits is developed by Morris and Shearman (2000), in which these traits are evaluated visually by a human assessor with a scoring ranged between 1 to 9. In this research, aesthetic traits were evaluated using this method and it was determined that turf grass can have more aesthetic and smoother appearance in some growing media and water regimes with an aim to save water as much as possible. The findings of the present study showed that an irrigation regime of 40% FC led to better results in texture and color of the turf grass. However, some traits including percentage of turf grass coverage, traffic tolerance and general quality of the turf grass were better in 60% FC irrigation treatment. Nektarios *et al*. (2014) found that higher irrigation regime increased evapotranspiration significantly, and that might be the reason for lower turf grass quality in 80% FC. Therefore, irrigation in 60% FC is recommended. It seems also that vermicompost growing media (Vm5, 10 and Vr5, 10) was the most appropriate growing medium that could guaranty a quality lawn.

In addition to the high importance of aesthetic traits in evaluating the quality of turf grass, studying the morphological and physiological traits of the turf grass in different growing media and levels of drought stress should also be considered. Although these traits may be less visible in appearance of the lawn, they are important in biochemical and metabolic processes of the plants which are considered important in environmental performance and also in terms of the health of plants.

In the seedling emergence stage, it seems that although soil substrates mixed with vermicompost manure (5% and 10%), Stockosorb® (1% and 3%) and zeolite (4%) led to good emergence percentage in the irrigation regime of 80% FC, the soil without amendment (control) especially in 60% FC irrigation regime was associated with the highest percentage of seed emergence. The differences between municipal solid waste vermicompost (10% w) and other treatments in terms of seed emergence in 60% FC, might be due to the higher pH and osmotic potential in Vr10, which may cause the seeds not to absorb water under severe stress conditions. This might be the reason why some of the seeds remained in a dormancy stage. In many species, the best pH for germination is 6.0 to 7.5 (Okay *et al*., 2011), while low and high pH levels limit seed germination (Baskin and Baskin, 2014). In addition, the pH of the embryo in some plant species has been shown to decrease during dormancy-breaking treatments (Footitt and Cohn, 2001), so it seems that lowering pH values in growing media which have a pH higher than the usual can be problematic for an embryo, and that is why an embryo remains in a dormant stage. Given that percentages of seed emergence in 60% FC and 80% FC irrigation treatments were not significantly different, it is recommended to use 60% FC level as the irrigation regime to increase the percentage of emergence and simultaneously get the chance to conserve water compared to the irrigation rate of 80% FC.

In this regard, studying the amount of soil moisture is of great importance. In this experiment, the soil moisture behavior showed that when MSW or manure vermicompost was used as a soil amendment, the soil moisture content was conserved well especially under water stress conditions. These findings correspond with the results reported by Koppad and Rao(2004), who stated that using vermicompost led to an increased growth of young teak trees through nutrient additions, and improved moisture retention of the growing medium. In this regard, Celik *et al*. (2004) also showed that vermicompost increased available water capacity of the soil. Furthermore, according to Puhalla *et al*. (2010), a compost mixture that has been decomposed for at least one year can enhance nutrients, water and buffering capacities of sand. Previous research has also showed that using vermicompost can improve soil chemical parameters (Jack and Thies, 2006; Haghighi, 2011). Moreover, soil moisture content was the highest particularly when MSW vermicompost (10% w) was used to amend the soil. However, given the low percentages of seed emergence in this treatment, MSW vermicompost cannot be considered as a recommended amendment for the soil in turf grass culture. It seems higher pH caused by this growing medium type (10% w), as presented in table 2, was the reason for the reduction in visual attributes of the turf grass.

Generally, two important physiological traits affected by drought stress, are leaf relative water content and electrolyte leakage. It became clear that all treatments, especially Z4 (mixture of zeolite and soil with 4%/86% w/w), were associated with higher RWC in the turf grass compared to the turf grasses in the control treatment. Regarding electrolyte leakage of plants, all the treatments except for the control and the mixture of 1% and 3% stockosorb and soil were associated with the plants with low electrolyte leakages. However, in an irrigation rate of 40% FC, treatments of 5% MSW vermicompost, 10% manure vermicompost and combination of synthetic superabsorbent of Stockosorb ® (3%) were associated with the lowest electrolyte leakages in the turf grasses, respectively. Maintaining higher RWC (Jiang and Huang, 2002) and lower electrolyte leakages shows that plants are physiologically more resistant to drought stress (Huang and Fry, 1998; Jiang and Huang, 2002). These characteristics could be linked to an increase in the activities of antioxidant enzymes and the reduction in membrane lipid peroxidation in plants (Wang and Huang, 2002).

Overall, root characteristics including root volumes and lengths, and root water contents were similar in different treatments and as mentioned earlier, the plants treated in the growing media containing either kind of vermicomposts had the lowest root volumes and lengths and the highest root water contents. Vermicompost can increase water holding capacity of the soil (Parthasarathi *et al*., 2008). It seems that the reduction in the mentioned characteristics is due to the presence of moisture in the vermicompost growing medium. In addition, the treatments containing vermicompost also had great superiority compared to this trait in other growing media treatments. However, S1 and Z4 treatments did not show significant differences from vermicompost-containing treatments in terms of relative water content of the shoots.

In addition to this result, it was shown that treatments S1 (mixture of Stockosorb® superabsorbent and soil with 1%/99% w/w) and Z8 (mixture of zeolite and soil with 8%/82% w/w) in three irrigation levels were associated with the lowest amounts of chlorophyll a and b in the turf grasses. However, it seems that in watering with 60% FC, differences among the treatments were greatly reduced. In this irrigation system, according to the literature, high chlorophyll content, especially under stress conditions, increased the rate of photosynthesis and was considered as an indicator showing plant tolerance to stress conditions. This matter is of high importance even in plant recovery conditions after removing the stress (Jiang and Huang, 2001; Wang and Huang, 2004; Rodriguez Navarro *et al*., 2004; Liu *et al*., 2008; Shi *et al*., 2012). In relation to root length and chlorophyll content, the results of this experiment were similar to the results of Taghizadeh *et al*. (2014), who reported that using a mixture of organic fertilizer of vermicompost and soil could improve some physiological characteristics such as chlorophyll content and reduce root length in sport turf grass.

Generally, by examining all the traits, turf grasses treated by 60% FC and a growing medium containing 5% municipal solid waste vermicompost and 10% manure vermicompost showed high germination rates, high RWC, low electrolyte leakage, high chlorophyll content and high scores in visual traits and more water saving compared with the control at the same time. Although in this irrigation system the plants treated with Stockosorb 3% and zeolite 4% did not have a significant difference from the plants treated with vermicompost with respect to most of the traits, however the selection between these compounds and recommending the best growing medium in agricultural projects, using Stockosorb compared with the other options will not be the first choice due to its chemical nature, disrupting sustainability of the agricultural systems, being an imported product and having a high cost. Regarding the selection between substrates containing zeolite and vermicompost, it seems that vermicompost is preferred because vermicompost is an organic compound and according to references, it can enhance the total amounts of N, P and K in the treated plants more than these elements in the plants treated with the soil as the control. Further, the available amounts of N, P and K in the growing media were enough (Li *et al*., 2011). Using vermicompost in soil composition of the turfgrass can improve physiological characteristics such as length and shoot dry weight, soil organic matter as well as turfgrass quality (Taghi-Zadeh *et al*., 2014). On the other hand, stress increases antioxidant activities. Application of vermicompost and nitrogen in the growing medium reduced activity of antioxidant enzymes compared to the control soil (Kasthuri *et al*., 2011). Unlike vermicompost, zeolite is a mineral with no nutritional properties. Therefore, in selecting the most appropriate growing medium, components containing vermicompost may be recommended as the first choice. However, if this is going to be a growing media recommendation to a specific organization, such as a municipality that is responsible for managing large amounts of municipal waste, use of municipal solid waste vermicompost as an amendment for the growing medium of lawns is preferred.

5. Conclusion

According to the results of this experiment, it seems that during the seed emergence stage and early growth of the plants using irrigation rate of 60% FC compared to 80% FC and 40% FC levels is the optimum irrigation level. Increasing the irrigation level up to 80% FC may increase water consumption with no significant improvement in turf grass quality. Moreover, decreasing the irrigation level to 40% FC can cause a significant reduction in the turf grass quality. In such circumstances, a mixture of municipal solid waste or manure vermicompost with soil can be a good growing media mix because it can maintain moisture in the soil and also improve morphological, physiological and visual quality of *Festuca arundinacea* Schreb.

Acknowledgement

We are grateful to Hadise Poorali and Ali Masoomi for their assistance with this research. We also thank Ferdowsi University of Mashhad for financial support of the project under grant number 33284.

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