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Evaluating the effect of superabsorbents on soil moisture and physiological characteristics of *Lolium perenne* L. 'Chadegan' and *Festuca arundinacea*

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Abstract

Creating water-conserving turfgrasses using superabsorbents in soil is a challenge especially in arid environments because their related soil and plant's behavior is still less known. This research investigated soil moisture content and physiological characteristics of *Lolium perenne* L. 'Chadegan' (perennial ryegrass) and *Festuca arundinacea* (tall fescue), in the absence (control treatment) or presence of four superabsorbent types. The superabsorbents were Zeolite (zero and 10% wt), Bentonite (zero and 6%wt), Aquasorb (zero and 6 g/m^2) and Boloorab (zero and 50 g/m2). The experiment was factorial based on a randomized complete block design with four replications. A one-month stop on irrigation occurred after the first five-month full irrigation regime to simulate drought stress conditions. The results showed tall fescue had higher leaf relative water content, lower relative electrolyte leakage and lower relative saturation deficit than that in perennial ryegrass after applying the drought stress. However, tall fescue had higher chlorophyll content than this factor in the ryegrass. Aquasorb and then Bentonite were able to improve the fresh weight and dry weight in roots and shoots under drought stress conditions compared to the control treatment. Using Aquasorb was associated with better physiological characters in the turfgrasses and higher water content in the soil. Overall, under drought stress conditions, planting tall fescue in a soil containing Aquazorb promised a better quality turfgrass for urban green spaces.

Keywords: Drought stress; turfgrass; superabsorbent; soil moisture; landscape

1. Introduction

Todays, lawns have become important elements in urban landscapes for many reasons including the need for creating attractive landscapes, improving environmental conditions, creating recreational and athletic sites (Ignatieva *et al*., 2015), preventing soil erosion and due to their high resistance to traffic and high elasticity (Rabbani Kheir khah and Kazemi, 2015).

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In many urban communities, irrigation of urban landscapes is a considerable fraction of urban water consumption (between 40% and 70%). Therefore, especially in arid cities where a shortage of water is evident, there is a need to find landscape strategies and methods to save water and keep our urban landscapes at the same time (Nazemi Rafi *et al*., 2019). Water consumption in most lawns is 25-75mm/day which represents a high water consumption compared to that in many other plant species. However, in some cases, even lawns may be irrigated more than their needs but still may present symptoms of water stress. One of the reasons may be the lack of permeability of heavy soils or high drainage of water in lightweight soils which causes lack of access to water by plant roots. In arid and semiarid regions, soils often have unfavorable physical properties, and on sandy soils it is impossible to store sufficient water in a plant-available form during irrigation (Banedjschafie and Durner, 2015).

In the most well-known water-conserving method of landscaping, which is called xeriscaping, one of the main recommendations for managing water usage is soil physical amendments such as superabsorbents, which can assist in enhancing Water Holding Capacity (WHC)of the soil (Kazemi and Safari, 2018). Such recommendations can be more important especially for arid regions as it can gradually release water and make it available for the plants (Shooshtarian *et al*., 2001). Superabsorbents are hydrophilic networks that can absorb and retain high amounts of water or aqueous solutions (Khalil Darini *et al.*, 2015, Abobatta, 2018). Superabsorbents are including: a) plant materials such as sawdust, wood chips, leaves, peat (turbine or peat) and mucilage, b) minerals such as Perlite, Kaolin, Bentonite, Diatomite, and Zeolite, C) synthetic materials such as synthetic mulches and polymers, hydro plus and Igta.

Bentonites consist of 2:1 mineral, and those which have a lot of minerals montmorillonite and great adhesion (Tang *et al*., 2014). They have the general formula (Na, Ca) $(Al, Mg)_6$ $(Si_4O_{10})_3$ $(OH)_6$ nH2O (Basma and Dhilal., 2017). Water absorption of Bentonites which have sodium as their major components is more than other types. These minerals have benefits such as ability for proper drainage, high water holding capacity and appropriate cation exchange capacity; and in recent years have been used as a polymer superabsorbent (Abedi Koopayee and Sohrab, 2005).

The most important natural Zeolite which is used in agriculture is Clinoptilolite with chemical formula $(Na, K)_6A_{l6}Si_{30}O_{72}\cdot 20H_2O$(Ambrozova *et al*.,2015). In fact, Zeolite is an aluminosilicate with trellis structure that large ions and water molecules can be mobile in its structure so that the ion exchange reactions and dewatering in it can be reversible (Franz, 1983). Application of Zeolites in the soil can improve soil physical and chemical conditions, increase soil moisture storage (Abedi Koopayee and Sohrab, 2005), improve plant growth by increasing availability of the soil minerals (Polait *et al*., 2004) and increasing fertilizer use efficiency (Campos Bernardi *et al*., 2016).

The results of the effect of using natural Zeolite on physiological characteristics of marigold were reported by Nazari *et al*. (2007). They found that using natural Zeolite increases cation exchange capacity of the soil, increases available Nitrogen, Phosphorus, Potassium, Calcium and Magnesium in the soil and reduces leaching. The use of Zeolite in the substrate in this experiment resulted in an increased rate of photosynthesis, water use efficiency and chlorophyll content in marigold. In a study in early 2000, wider investigations on the impact superabsorbents were performed especially in arid regions of the world such as Africa, South America, Middle East and the Far East regions (Sarafrazi, *et al*., 2012). Polymer superabsorbents are made of hydrocarbons. These polymers consist of three categories including starch acrylate copolymer, polyacrylamide and polyvinyl alcohols (Dar *et al*., 2017). Polyacrylamides are available in forms of soluble and insoluble in water but insoluble forms are used for storing water (Wallace & Wallace, 1994). The amount of water absorbed in polymers depend on formulations, impurities and the number of salts present in water which is about 20 to more than 2000 portions of the total weight of the Polyacrylamides (Dar *et al*., 2017). These materials by keeping water and then the gradual release of it can increase irrigation intervals in drought conditions. Superabsorbent hydrogels with different brand names such as Aquazorb, A-200, Stockosorb are available in the market.

Alami *et al*. (2011) also examined the effect of paclobutrazol and a superabsorbent and as irrigation interval in Mashhad weather conditions on a turfgrass species (*Lolium perenne* 'Barball'). The results showed that quality of color, density and chlorophyll content was obtained to 33, 42 and 48%, respectively when the lawn received superabsorbent compared to the control treatment. Overall, with the application of 6 g/kg superabsorbent along with paclobutrazol a good quality lawn with less water usage was obtained. Shekofteh and Salari (2016) investigated the influence of hydrogel polymers and $NO3^-$: $NH4^+$ ratios on the yield and essential oil composition of the seeds of dill (*Anethum graveolens* L.). The y concluded that high rates of superabsorbents can increase the available water for the plants which is absorbed by the polymers, and such water can be gradually released after irrigations. Such a mechanism can lead to an increase in the yield and efficiency of this plant.

Reviews confirmed the importance of the application of different types of superabsorbents in greenspaces of arid and semi-arid environments. However, in each region and for each plant type, according to the conditions of the soil and climate and available facilities of the region, different types of minerals or organic superabsorbents may bring optimum water use efficiency. This study, therefore, aimed to compare the effects of Zeolite, Bentonite, Aquazorb, and Boloorab (as a relatively new type of superabsorbent) and non-application of these superabsorbents on performances of two cool season turfgrasses.

2. Material and Methods

2.1. Experimental design and site description

This research work was performed at experimental fields of the Department of Horticulture and Landscape in Agricultural College of Ferdowsi University of Mashhad, Mashhad, Iran in an arid and semi-arid climate region (59038′ E and 360 16′ N; elevation 989m; mean annual rainfall 255.2 mm) during 2014. Long term averages of maximum and minimum temperature were 22°C and 8.9°C, respectively. The experiment was factorial based on a randomized complete block design with four replications.

2.2. Plant materials and superabsorbents

Turfgrasses consisted of perennial ryegrass (*Lolium perenne* L. 'Shadegan'), a turfgrass species native to the area of Chadegan in Esfahan province of Iran and tall fescue, *Festuca arundinacea,* native to Isfahan, Iran.

Superabsorbents were including mineral types of Zeolite (10% wt) and Bentonite (6%wt), organic superabsorbents of Aquasorb (6 g/m^2) and Boloorab (50 g/m^2), and the control (without the superabsorbent). All types of the superabsorbents used in this research were mixed with the lowest 8 cm depth of the soil in the pots to ensure deep growth of the roots of the turfgrasses in the pots. The optimum amount of each superabsorbent was selected based on the optimum amount suggested in the previous research work (for example, Abedi Koopayee and Sohrab (2005) or the amount suggested by the producers on the brochures of the products. For the case of Boloorab, there were not any conducted research to use as a benchmark; therefore, the optimum consumption amount of 50gr/m^2 was selected as was recommended on the selling brochure of the product.

Table 1. Characteristics of the seeds of the turfgrasses used in this experiment

Turfgrasses	Seed viability (%)	Seed purity (%)	Weight of one thousand seeds (gr)
Lolium perenne L. 'Chadegan'	80.0	96.0	1.9
Festuca arundinacea	86.0	97.0	2.5

2.3. Planting and maintenance

The seeds were planted in pots with 19cm diameters and 18cm heights with a uniform density. Superabsorbents were mixed with the lowest 7cm of the soil and were toped up with 8cm soil without superabsorbents. Chemical, physical and moisture characteristics of the soil used in this experiment were given in the following tables.

Table 2. Chemical and physical characteristics of the soil used in this experiment

Organic Components (%)	EC (dS/m)	pH	Clay (%)	Silt (%)	Sand (%)	Texture
2.26%	9.67	6.91	8%	20%	72%	Sandy loam

Table 3. Characteristics of the soil moisture in presence of the superabsorbents

Superabsorbents	FC (%)	PWP (%)	Available water (%)
Control	15.00	7.00	8.00
Bentonite	13.65	4.09	9.56
Zeolite	11.50	3.45	8.05
Aquazorb	12.95	3.18	9.77
Boloorab	12.35	3.70	8.65

Irrigation was applied without water restrictions during the first five months of planting and was completely stopped to simulate drought stress conditions on the remaining period of the experiment (one month). The experimental pots were placed in an open field at the beginning of the experiment and were put in a shaded place at the period of applying drought stress to protect the pots from the rain.

2.4. Measured factors

Soil moisture content was measured at different soil depths with specific time intervals by a soil moisture probe (EXTECH MO75, made in the USA). Physiological factors of the turfgrasses were measured after the drought stress was applied. The percentage of Relative Water Content (RWC) was calculated according to Barrs and Weatherley (1962) and based on the following formula:

RWC (%) = (fresh weight – dry weight / turgid weight – dry weight) ×100 (1)

Relative saturation deficit was calculated according to Sammar Raza *et al*. (2012) and based on the following formula:

RSD (%) = Saturated weight – Fresh weight/ Saturated weight× 100 (2)

The chlorophyll concentrations were obtained from the following equations (Dere *et al*., 1998):

Chl a (µg/ ml) = (15/65× A 666) – (7/34× A 653) (3)

Chl b (µg/ ml) = (27/05× A 653) – (11/21× A666) (4)

Chl Total (µg/ ml) = (1000× A 470) – (2/860× Chl a) – (129/2× Chl b) / 245 (5)

To determine the stability of the leaf cell membranes, electrolyte leakage was measured according to Blum and Ebercon (1981). The amount of electrolyte leakage (EL) was calculated by the following equation:

EL = (Ci/Cs) / 100 (6)

Destructive sampling was done at the end of the experiment and the fresh weight of roots and shoots were measured using a balance. The samples were then oven dried in a temperature less than 60 °C until a constant weight was achieved (Kazemi *et al*., 2011).

2.5. Statistical analyses

The collected data were subjected to analysis of variance (ANOVA) using JMP8 software package. Where significant treatment effects ($P<0.01$) were determined by ANOVA tests, comparison of the means was performed using Tukey tests.

a b

Fig. 1. a) Overview of the design before applying drought stress in open space, b) Overview of the design after applying drought stress in a greenhouse without heating

3. Results

The results of the analysis of variance have been provided in Tables 4 and 5.

Table 4. Analysis of variances (mean squares) related to physiological characteristics of the turfgrasses under treatments with superabsorbents one month after drought stress

Sources of variation	df	RWC	RSD	Electrolyte Leakage	Total Chlorophyll	Chlorophyll a	Chlorophyll b	Soil moisture
Replication	3	14.71	4.66	26.48	2.34	0.47	0.67	4.69
Species	1	116.87**	93.83**	1070.40**	8.45**	1.91**	3.08*	0.93
Superabsorbent	4	100.98**	74.41**	1021.71**	21.63**	4.10**	7.38**	42.93**
Superabsorbent × species	4	51.26**	60.04**	201.14	4.33**	0.18	1.44	2.54
Error	27	6.49	8.68	117.79	0.92	0.21	0.64	3.85

**, * significant at 1% and 5% probability levels, n.s. non-significant

Table 5. Analysis of variances (mean squares) related to yield characteristics of the turfgrasses under treatment with superabsorbents one month after drought stress

Sources of Variation	df	Root Fresh Weight	Root Dry Weight	Shoot Fresh Weigh	Shoot Dry Weight	Root/Shoot Ratio
Replication	3	3.74	0.91	9.28	0.21	0.15
Species	1	697.73**	21.40**	318.69**	16.53**	2.29**
Superabsorbent	4	759.18**	45.88**	164.90**	4.87**	1.19**
Superabsorbent × species	4	156.64**	11.61**	21.30*	0.62	1.00**
Error	27	19.60	2.00	6.25	0.34	0.21

**, * significant at 1% and 5% probability levels, n.s. non-significant

Leaf Relative Water Content (RWC): The main effects of species and superabsorbents and also interaction effects of species and superabsorbents were statistically significant at 1% probability level (Table 4). Comparison of the means showed that applying Aquasorb in *Festuca arundinacea* showed the highest amount of RWC. This was followed with RWC values for tall fescue in treatment with Bentonite. The lowest RWC belonged to *Lolium perenne* and *Festuca arundinacea* under treatment with Zeolite and *Festuca arundinacea* when it was treated with Boloorab (Figure2).

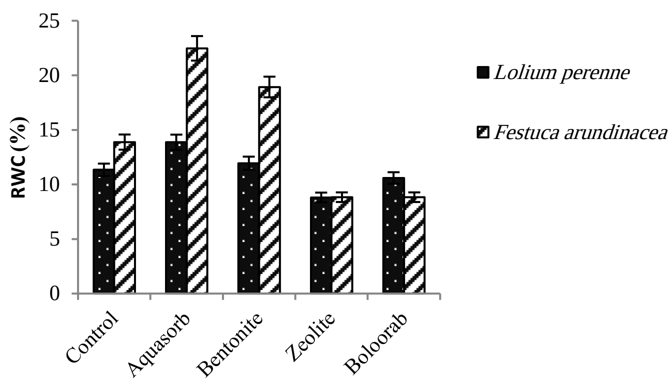

Fig. 2. Interaction effect of different superabsorbents and turfgrass types on RWC

Relative Saturation Deficit (RSD): RSD of the leaves showed significant main effects of species and superabsorbents and also significant interaction effects between these two factors ($p<0.01$) (Table 4). Mean comparisons showed that RSD of tall fescue was the lowest when Aquasorb was applied in the soil. The highest RSD was in *Lolium perenne* in absence of superabsorbent or in presence of Zeolite in its soil (Figure 3).

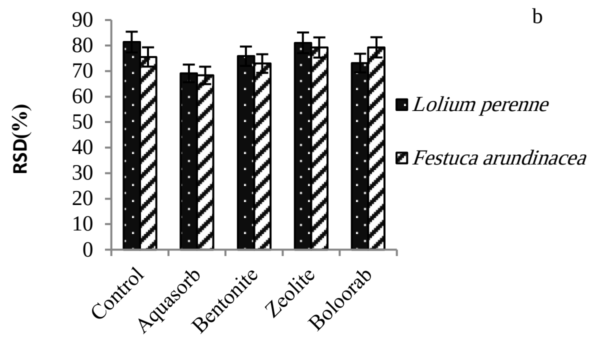

Fig. 3. Interaction effect of different superabsorbents and turfgrass types on RSD

Electrolyte Leakage (EL): The results demonstrated that the main effects of species and superabsorbents became significant at 1% probability level (Table 4). In this experiment, *Lolium perenne* showed more ionic leakage than the tall fescue grass (Table 6). Also two species when they were planted without superabsorbents and also when they were planted in a soil containing Boloorab showed the most ionic leakage while when they were along with Aquasorb in their soil showed smallest ionic leakage (Figure 4).

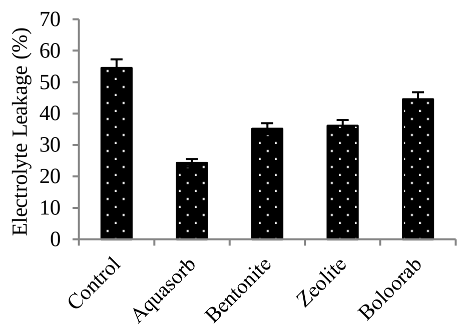

Fig. 4. Simple effects of superabsorbents on Electrolyte Leakage

Chlorophyll content: the analysis of variance on the content of chlorophyll and bas the effect of species and superabsorbents were significant at 1% level (Table 4). However, the effect of the species and the superabsorbents and the interaction of these two factors on total chlorophyll were significant ($p<0.01$) (Table 4). Boloorab appeared to decrease chlorophyll a content most (even more than the control treatment) in both species of the turfgrass. Further, chlorophyll a and b was in its highest rate in the turfgrasses associated with Aquasorb, Bentonite and Zeolite, respectively, compared to that in the control treatment (Figure 5). Finally, tall fescue allocated the highest total chlorophyll content when it was with Aquasorb and possessed the second highest rate for this factor when it was associated with Bentonite. The lowest rates for total chlorophyll were also associated with Boloorab and any of the two turfgrass species which was very similar or even lower than the rates of this factor in the turfgrasses planted in the soils without superabsorbents (Figure 6).

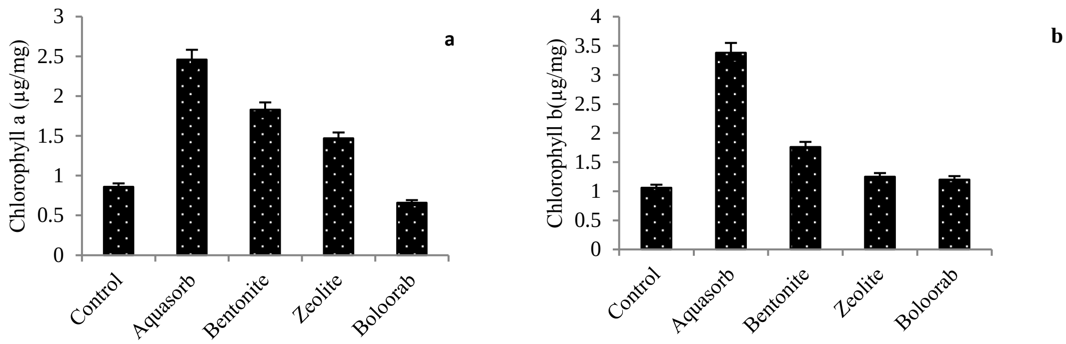

Fig. 5. Simple effects of superabsorbents on chlorophyll a (a) and chlorophyll b (b)

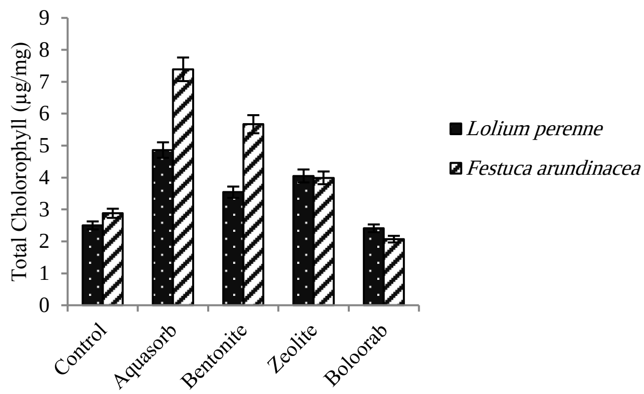

Fig. 6. Interaction effect of different superabsorbents and turfgrass types on total chlorophyll

Soil moisture: in the substrates containing different superabsorbents, moisture content in the 15cm depth of the soil was significantly different ($p<0.01$) (Table 4). Moisture content was the highest when Aquasorb and then Boloorab were used as superabsorbents, respectively.

Further, although the moisture in the soils containing Zeolite and Bentonite was not statistically higher than the soil moisture in the control treatment, it was still observationally higher than that in the control treatment as can be seen in Figure 7.

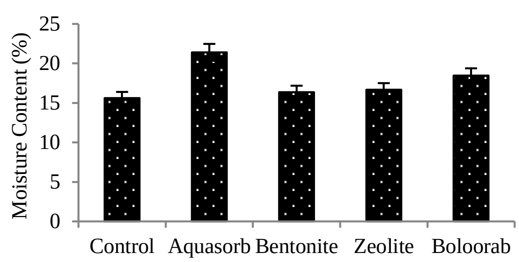

Fig. 7. Simple effects of superabsorbents on Soil moisture

Fresh and dry weight of root: These traits showed significant main effects of species and superabsorbents and also significant interaction effects between these two factors ($p<0.01$) (Table 5)., the highest fresh and dry weight of roots was in *Lolium perenne* when its soil was mixed with Aquasorb and in *Festuca arundinacea* it was obtained when the soil was mixed with Bentonite. The lowest fresh and dry weight of roots belonged to *Lolium perenne* when its soil was mixed with Boloorab or was not mixed with any superabsorbent (Figure 8). The effect of Boloorab on reducing the fresh and dry weight of roots in *Festuca arundinacea* was not as much as that in *Lolium perenne* so that the numbers were significantly higher than the similar numbers in the control treatment.

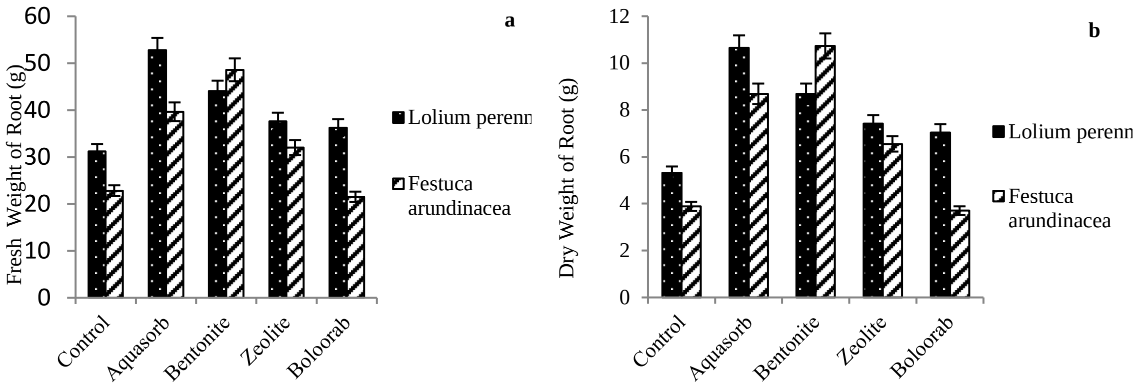

Fig. 8. Interaction effect of different superabsorbents and turfgrass types on fresh weight of root (a) and dry weight of root (b)

Fresh and dry weight of shoot: In these cases effect of species and superabsorbents were significant but the interaction between them was only significant for shoot fresh weight ($p<0.01$) (Table 4). The highest fresh weight of shoots belonged to *Lolium perenne* when its soil was mixed with Aquasorb and the lowest fresh weight of shoots belonged to *Festuca arundinacea* when its soil was mixed with Boloorab (Figure 9). The effect of superabsorbents on the dry weight of shoots was shown as a simple effect so that shoot dry weight was the highest when Bentonite and Aquasorb were used as superabsorbent and were the lowest when Boloorab was used as a superabsorbent (Figure 10).

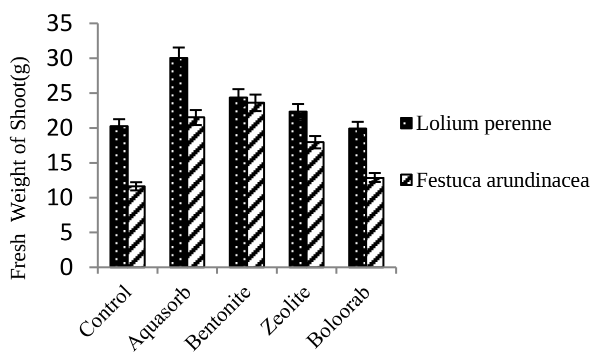

Fig. 9. Interaction effect of different superabsorbents and turfgrass types on Fresh weight of shoot

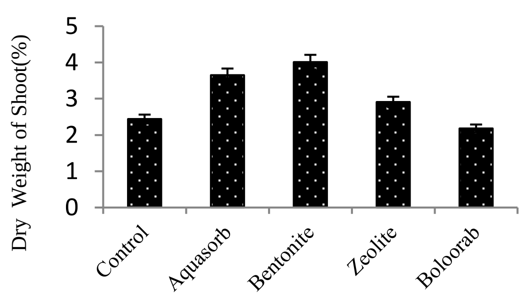

Fig. 10. Simple effects of superabsorbents on Dry weight of shoot

Root/shoot ratio: The main effects of species and superabsorbents and also the interaction effects of species and superabsorbents were significant at 1% level (Table 5). The highest root/shoot ratio was related to using Aquasorb and Bentonite in the substrate of tall fescue (Figure 11).

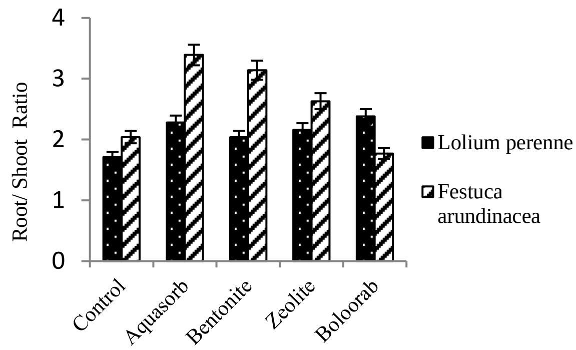

Fig. 11. Interaction effect of different superabsorbents and turfgrass types on root/shoot ratio

4. Discussion

In the current research, the results showed different responses among turfgrasses in presence of superabsorbents. *Festuca arundinacea* showed better physiological and morphological responses than *Lolium perenne*. These results are in agreement with findings of Samar Raza *et al*. (2012) and Fu *et al*. (2004) that drought resistant mechanisms in different species are different. Based on the results of Manuchehri and Salehi (2015), tall fescue could be grown under moderate levels of the combined stresses of water shortage and salinity without considerable damage to the plant at the physiological and/or biochemical levels.

Fu *et al*. (2004) reported reducing the amount of relative water content with increasing water stress in different species of turfgrass. High relative water content and low relative saturation deficit in some of these species showed the higher resistance of the species to water stress Ability of the plants to maintain a favorable water balance until the next rainfall event could greatly minimize the need for supplemental irrigation while producing an acceptable quality turf (Richardson and Karcher, 2009). In this experiment, tall fescue had higher relative water content and less relative saturation deficit compared to *Lolium perenne*, which shows higher drought tolerance ability of this turfgrass species.

This study also indicated that different types of superabsorbents were associated with different physiological characteristics in the turfgrasses. This result confirms the results of Alami *et al*. (2011) where found superabsorbents improve physiological characteristics of turf under drought conditions. In this experiment, Aquasorb was able to keep moisture in the soil and led to retaining more water in the leaves.

Reduction in leaf relative water as a result of drought stress has a direct relation with soil moisture content (Nautiyal *et al*., 1997), because in drought conditions, production and accumulation of reactive oxygen types such as superoxide radicals, hydrogen peroxide and hydroxyl radicals increases (Foyer *et al*., 1994) that damage many cell components such as lipids, proteins, carbohydrates and nucleic acids. By deformation of the membrane as the effect of lipid peroxidation and protein (Liang *et al*., 2003), the permeability of the cell membrane will increase and this leads to electrolyte leakage to outside the membrane (Blum *et al*., 1982) and as a result plant growth is affected.

Also using of Aquasorb was associated with the lowest amount of electrolyte leakage. This can be due to more moisture retention in the soil by the superabsorbent. Inze and Montague (1995) reported higher amounts of electrolyte leakage from leaf cells with lower soil moisture levels.

Plant water availability depends on two soil water parameters, field capacity (FC) and permanent wilting point (PWP). Field capacity occurs when soil water ceases to drain freely. The remaining soil water is held by adhesion to soil particles. A permanent wilting point occurs when plants can no longer extract water from the soil. The remaining soil water is so tightly bound by the soil particles that the plant root is not able to overcome the forces of attraction of water to soil. Plant Available Water (PAW) is the difference between FC and PWP (Hudson and Berman, 1994). When any of the four superabsorbents are mixed with soil, the amount of available water to soil have increased compared to the available water in the control soil (table 2). In 15cm depths of the soil that soil moisture contents were measured, superabsorbents were present. Aquasorb and Boloorab as synthetic superabsorbents had moisture retention capacity more than the mineral superabsorbents of Bentonite and Zeolite. These observations were consistent with the findings by Zeineldin and Aldakheel (2006). Sarfarzi *et al*. (2011) designed and performed a test to examine volume moisture changes of soil and water retention potential of the soil used for turfgrass culture by applying different quantities of Potasium Acryle Amide as a superabsorbent. The result showed that in treatments containing the polymer up to 75% water consumption was saved in comparison with the control. Water stress reduces photosynthesis in plants with two mechanisms: First, closure of the stomata typically limits the supply of carbon dioxide to chloroplasts. Second, the low water potential of the cells may have detrimental effects on the machinery of photosynthesis (Zlatev and Cebola Lidon, 2012).

Drought stress leads to more enzyme activity of Chlorophyllase and also increasing synthesis of some of the growth regulators such as abscisic acid and ethylene which leads to destruction and reduction of chlorophyll of the leaves and observance of pale leaves and loss of their color (Goodfellow and Barkham, 1974). Jiang and Fry (1998) also reported a decrease in the concentration of chlorophyll in drought stress. The reason for this reduction might be membrane destruction under influence of oxidative stresses. The results of this study showed that tall fescue after water stress had more visible chlorophyll content. Further, Aquasorb when was along with any of the two species of turfgrass kept more chlorophyll in the plants under drought stress. According to McCann and Huang (2008) Aquasorb prevents reducing the amount of chlorophyll in plants under drought stress probably by reducing electrolyte leakage and increasing the stability of the cell membranes and chloroplasts. It appears that each of the organic and mineral superabsorbents by different mechanisms reduces the effects of drought stress in the turfgrasses. Aquasorb by keeping more water in the soil led to keeping water content of the leaves, chlorophyll content and freshness of the leaves, while Zeolite and Bentonite as mineral superabsorbent led to wall cell membrane stability and reduction of leaf chlorophyll degradation by having a high cation exchange capacity and absorbing more elements of the soil.

Although the measurement of growth rate either above ground or underground dry weight could be a measure of resistance to drought stress measuring the ratio of the underground section to shoot or shoot to the underground section to find out how plants respond to drought stress is more appropriate criteria (Qian *et al*., 1997). By comparing the control treatments in both species in this experiment we found that the *Lolium perenne* genetically has a better ability to produce roots and shoots compared to tall fescue. This is while Aquasorb and then Bentonite have been able to improve these traitsunder drought stress compared to the control. This indicates that Aquasorb and Bentonite have been able to increase the water use efficiency of these two of turfgrass.

Improving the growth of roots and shoots and biomass of the turfgrasses treated with different superabsorbents have been reported by Agaba *et al*. (2011).

Relatively modern turfgrass management suggests sand turfgrass culture in which a high percentage of the turf medium is sand. This is because sand maintains good aeration properties, drains quickly, resists compaction (Richardson *et al*., 1999) and can provide quality turfgrass. However, it does have limitations such as poor water and nutrient retention and potentially may be a more susceptible substrate for plants in drought stress. Using sandy textured substrates such as the one used in this study for turfgrass culture may be more justified when they are used with superabsorbents which increase water retention potential of the soil.

5. Conclusion

This study showed that *Festuca arundinacea* can keep better quality compared with *Lolium perenne* L. ‘Chadegan’ for measured physiological characteristics under water stress conditions. This species of turfgrass along with Aquasorb as the superabsorbent can promise a reduction in water usage in lawn spaces in arid urban environments.

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