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The salinity tolerance of pomegranate cultivars: Effects of salt stress on root and leaf mineral content

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Abstract: In this study, the effect of irrigation water salinity on rooted cuttings of eight pomegranate cultivars namely 'Malase Saveh' ('M-Saveh'), 'Malase Isfahan' ('M-Isfahan'), 'Robabe Ghermeze Shiraz' ('Robab'), 'Gabrie Yazd' ('G-Yazd'), Gabrie Torshe Yazd' ('GT-Yazd'), 'Zaghe Sefide Yazd' ('ZS-Yazd'), 'Zaghe Torshe Yazd' ('ZT-Yazd') and 'Malase Torshe Pishva' ('M-Pishva') was studied. Sodium chloride was added to irrigation water to get final concentrations of 3, 6, 9 and 12 dS/m. Leaf and root mineral content, leaf abscission and root characteristics were determined at the end of the experiment. The results showed that the salinity reduced significantly fresh and dry weight of root in all pomegranate cultivars. Water salinity up to 3 dS/m increased slightly roots fresh and dry weight of all cultivars and thereafter decreased. With increasing water salinity to 12 dS/m, accumulation of sodium and chloride both in roots and leaves increased, but nitrogen, phosphorus, magnesium and calcium contents decreased. The change of leaf potassium content was dependent to pomegranate cultivar. The lowest sodium and chloride accumulation in root was observed in 'ZT-Yazd', but 'M-Pishva' translocated the lowest sodium and chloride to leaf. The low ability of nitrogen absorption was found in 'M-Saveh', whereas 'M-Pishva' maintained the highest leaf nitrogen under salt stress conditions. The most potassium content of root was observed in GT-Yazd', while 'ZS-Yazd' and 'G-Yazd' translocated the highest potassium to leaves. Generally, the responses of pomegranate to absorption and translocation of elements to leaves under salinity conditions were completely dependent to cultivar. 'M-Pishva' and Yazd cultivars showed higher tolerance to salinity stress.

1. Introduction

High salt concentration in the soil is responsible for decreasing productivity in a wide range of agricultural crops in the world (FAO, 2008). Soil salinity also is one of the serious environmental stress that limits growth and productivity of horticultural crops. Different factors include the excessive application of chemical fertilizers, the use of saline water for irrigation and the high water levels led to soil salinity (Mastrogiannidou *et al*., 2016).

Irrigation with saline water affects the absorption of nutrient elements. The adverse effects depend on the salinity level, the type of salt, the plant species and the presence of other stress (Grattan and Grieve, 1999). Therefore, differences in adaptability potential in plant species to prevailing abiotic stress conditions can be attributed to their varied ability for nutrient uptake and consequently different content of macro and micronutrients in plant organs and tissues (Jamali *et al*., 2016).

Soil salinity indirectly decreases the absorption of nutrients in the plant by reducing root growth (Kiani and Abbasi, 2010). Karimi and Nasrollahpour-Moghaddam (2016) also found that salinity affected the accumulation of potassium content in the root and the transfer rate of sodium and calcium to shoot in Pistachio plants. In other research, it was found that pistachio rootstocks under salinity stress have restriction mechanisms for absorbing and transferring of sodium and chloride ions (Karimi and Maleki Kuhbanani, 2015). In olive, Rossi *et al*. (2015) found that roots distinctly play an important role in the regulation of apoplast to reduce permeation and ion transfer to shoot, which depends on plant genotype and sodium concentration.

Pomegranate is one of important commercial fruit in tropical and subtropical regions of the world and also in mediterranean climate, which is enriched of nutritional and antioxidant compounds (Parvizi and Sepaskhah, 2015). Other studies indicated that there is different levels of tolerance to abiotic stress conditions such as drought and salinity among different pomegranate cultivars (Tabatabaei and Sarkhosh, 2006; Okhovatian-Ardakani *et al*., 2010; Ibrahim, 2016). In general, tolerance to abiotic stress is complex and depends on both genetic and physiological properties. Karimi and Hasanpour (2014) showed that with increasing salinity level, the sodium, chlorine and potassium contents in roots and shoots of 'Robab' and 'Shishe Gap' pomegranate cultivars increased. 'Shishe Gap' cultivar showed good growth by restricting the absorption and transfer of chlorine under salt stress conditions (Karimi and Hasanpour, 2014).

It was also reported that the use of saline water reduced stem length, length and number of internode, leaf area and root development in pomegranate cultivars (Amiri *et al*., 2011). In contrast, Bhantana and Lazarovitch (2010) observed that there were no differences between 'Vanderfol' and 'SP-2' pomegranate cultivars in response to salt water stress. Some results showed a significant change in the anatomical structure of roots and leaves of the pomegranate, when exposed to salt levels of 800 to 4000 dS/m. These changes included an increase in the thickness of the cuticle layer, the formation of parenchymal cells, and an increase in the number and density of crystals in the parenchymal cells of the leaves and roots in pomegranates (Zarinkamar and Esfah, 2005).

Therefore, the aim of this study was the evaluation of the effect of irrigation water salinity on some root growth characteristics and absorption and transfer of root nutrient elements to shoot in eight pomegranate commercial cultivars.

2. Materials and Methods

Plant material and cultivation

This study was carried out during 2016-2017 in Isfahan Agricultural and Natural Resources Research and Education Center, Iran. Uniform rooted cuttings of eight pomegranate commercial cultivars including 'Malase Saveh' ('M-Saveh'), 'Malase Isfahan' ('M-Isfahan'), 'Robabe Ghermeze Shiraz' ('Robab'), 'Gabrie Yazd' ('G-Yazd'), Gabrie Torshe Yazd' ('GT-Yazd'), 'Zaghe Sefide Yazd' ('ZS-Yazd'), 'Zaghe Torshe Yazd' ('ZT-Yazd') and 'Malase Torshe Pishva' ('M-Pishva') were used as plant materials. Rooted cuttings were planted in 20-liter plastic pots (35×30cm). The soil mixture was clay loam and cow manure with 1:1 ratio (v/v). Physical and chemical properties of the soil mixture were analyzed at the beginning of the experiment (Table 1).

Salinity treatments

Four levels of water salinity (control, 3, 6, 9 and 12 dS/m) were used for irrigation of different pomegranate cultivars (Table 2). The source of sodium chloride used in this experiment was from the lake salt that was analyzed before application (Table 3). The salinity treatments were carried out from two months after planting in the pots for four months.

Table 1 - Some physical and chemical properties of soil mixture

Property	unit	value
pH	-	7.75
Saturation percentage	%	17
Field capacity	%	30
Permanent wilting point	%	7.25
Organic carbon	%	10.14
Nitrogen	%	0.096
Total neutralizing value	%	32.5
Silt	%	35
Clay	%	35
Sand	%	30
Tissue	-	Clay Loam
K	mg/kg	709
P	mg/kg	2.26
Zn	mg/kg	0.64
Mg	mg/kg	10.23
Fe	mg/kg	5.01
Cu	mg/kg	1.23
B	mg/kg	2.66
Na	Meq/L	4.53
Cl	Meq/L	7.19
Salinity	dS/m	3.24

In order to avoid salt stress shocks, initially, pomegranate plants were irrigated with water of 3ds/m electrical conductivity (EC). According to the climatic conditions of the region, the irrigation interval was applied in a Three-day interval which reduced to two days at very hot months. The ratio of electrical conductivity of the irrigation water and leach off were measured and the mean value was recorded as the leaching fraction (LF). The leaching coefficient was dependence to salinity level.

The amount of the consumed water by each pot during the growing season was measured. In order to determine the irrigation intervals and net irrigation requirement (In), the irrigation depth parameter (dn) was calculated. The depth of stored water in the soil and readily available water (RAW) were determined using the depth of root development and bulk density (Pb). In this way, soil moisture content at field capacity (FC) and wilting point (PWP) levels was measured. The obtained gross water requirement (Ig) depends on irrigation system efficiency. In order to prevent of the salt accumulation, over-irrigation was implemented to the pots (in the amount of 15% of the field capacity), so that the water was drained from the bottom of the pots.

Evaluated traits

At the end of the experiment, the plants were removed from the pot and the roots weighed after washing (root fresh weight). To determine root dry weight, samples were dried for 48 hours at 75°C and thereafter weighed using a digital scale (Smit *et al*., 2000). In the end, the percentage of the root dry matter was obtained from the following formula:

Root dry matter = [(Fresh weight - dry weight)/Dry weight] x 100

The leaf abscission was counted at the end of the experiment (late September). The necrotic percentage of leaves at the end of the stress was visibly evaluated and recorded using the scoring method from 0

Table 2 - The chemical analysis of used water for salt stress treatment

EC dS/m	pH	K mg /L	Mg (mg /L)	Ca (mg /L)	Cl (mg /L)	Na (mg /L)
Control (0.38)	6.90	3.80	1.2	2.80	3	2.8
3	7.45	5.09	66	1.98	1320	770
6	7.84	12.49	162	4.86	3240	1890
9	7.90	19.66	255	7.65	5100	2975
12	8.20	25.45	330	9.9	6600	3850

Table 3 - Some chemical properties of used lake salt for salinity treatments

Co (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Fe (mg/kg)	Cl (%)	Na (%)	Mg (%)	Ca (%)	K (%)	P (%)
3	2	0	8	15	0	60	35	3	0.09	0.23	0

to 9. Zero means non-necrosis leaves, one for very low necrosis (between 0 to 10%), three for low necrosis (between 10 to 30%), five for moderate necrosis (between 30 to 50%), and seven for sever (between 50-70%), and nine means very severs necrosis (between 70-90%).

The content of mineral elements such as nitrogen, phosphorus, potassium, calcium, magnesium, chloride and sodium in leaf and root of pomegranate cultivars was determined just in control (without salt additions) and 12 dS/m salinity stress treatment at the end of the experiment.

The Kjeldahl method is used to determine the nitrogen content in leaf and root samples (Jones, 2001). Briefly, 0.3g of fine dry powder was digested in concentrated H_2SO_4 and distilled with NaOH (40%), and ammonium nitrogen was fixed in H_3BO_3 (2%) and titrated with 0.1N H_2SO_4.

The P content of samples was determined by the vanadate-molybdate colorimetric method (Chapman and Pratt, 1982). The absorbance of samples was measured at 470 nm in a UV/visible spectrophotometer (model PG Instrument+80, Leicester, UK).

Potassium (K) and sodium (Na) content was determined by the flame photometric method as described by Jones (2001). The digested extract was diluted by calcium chloride ($CaCl_2$) at 1:9 ratios (v/v) and the absorbance was measured at 766.5 nm (Jones, 2001).

Calcium (Ca) and magnesium (Mg) were measured using atomic absorption spectroscopy. Briefly, digested extracts were diluted with distilled water (1:9 v/v), then 4.75 mL of lanthanum nitrate [La (NO3)3] was added to 250 ml of the diluted extract. Finally, the absorbance was measured at 422.7 nm for Ca and 285.2 nm for Mg by atomic absorption (Jones, 2001). Chloride ion content was determined by titration.

Statistical analysis

This experiment was conducted as the factorial experiment based on a randomized complete block design with two factors. To evaluate each trait, three replications and five observations in each replication were considered. The first factor was eight pomegranate cultivars and the second factor was salinity treatment at five levels. Analysis of data was performed by ANOVA method using statistical software SAS (version 9.1) and means comparison using Tukey test.

3. Results

Fresh and dry weight of root

The results showed that with increasing salinity levels from 3 dS/m to 12 dS/m in irrigation water, both fresh and dry weight of roots in all pomegranate cultivars significantly decreased (Fig. 1). The lowest fresh and dry weight was found when plants irrigated with 12 dS/m, however, there was no significant difference between 12 and 9 dS/m. Overall, fresh weight of root in pomegranate cultivars in 6, 9 and 12 dS/m treatments decreased by 46.3, 57.4 and 66%, respectively, compared with control treatment (Fig. 1A), as well, root dry weight decreased by 45.4, 52.5 and 59 %, respectively (Fig. 1B).

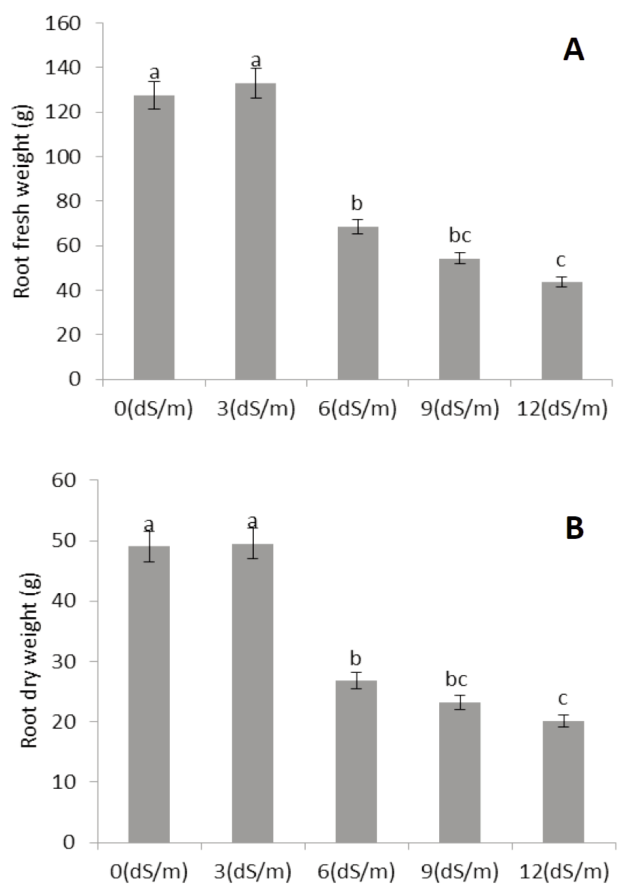

Fig. 1 - Effects of different levels of water salinity on fresh (A) and dry (B) weight of root in pomegranate cultivars.

The decreasing rate of fresh weight in the studied cultivars was completely dependent on the cultivar. The highest fresh weight of root was found in 'GT-Yazd', 'Robab' and 'M-Saveh' cultivars, respectively. The lowest fresh weight of root was observed in 'ZS-

Yazd' (Fig. 2).

Root dry matter also significantly decreased when pomegranate cultivars irrigated with 9 and 12 dS/m water (26.69 and 46.17%, respectively). In contrast, this trait slightly increased when plants irrigated with 3 dS/m saline water (Fig. 3).

Leaf abscission

Leaf abscission was significantly affected by water salinity levels and pomegranate cultivars. Overall, with increasing salinity level, leaf abscission was increased in all studied pomegranate cultivars (Fig. 4). The highest leaf abscission was recorded when plants irrigated with 9 and 12 dS/m water. In 3 dS/m, 'ZT-Yazd' and 'M-Pishva' had the lowest percentage of leaf abscission. The lowest percentage of leaf abscission in salinity of 6 ds/m was observed in 'M-Isfahan' and 'M-Pishva'. In 9 dS/m, 'G-Yazd' and 'Robab' showed the lowest leaf abscission. The lowest percentage of leaf abscission in salinity of 12 dS/m was observed in 'G-Yazd' and 'ZT-Yazd'. In this salinity level, leaf abscission was 100% in 'M-Saveh'.

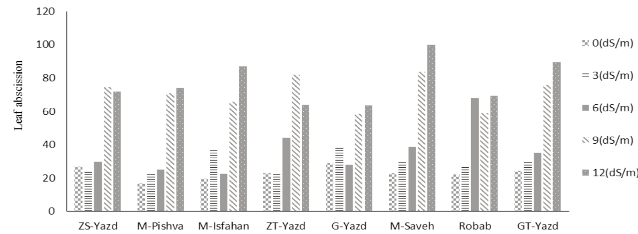

Fig. 4 - The interaction effects of salinity levels and cultivars on leaf abscission.

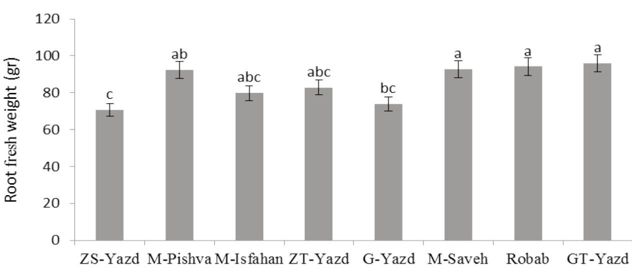

Fig. 2 - Effect of different pomegranate cultivars on root fresh weight.

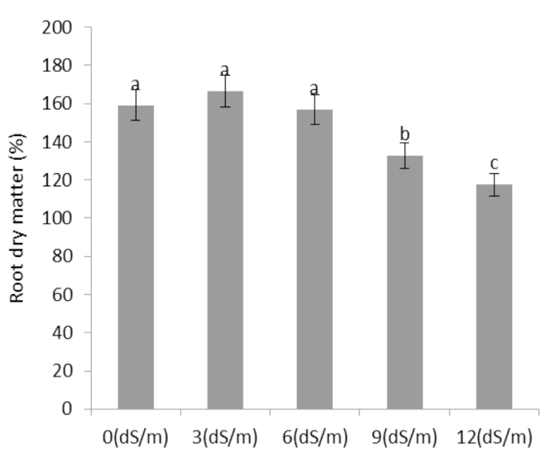

Fig. 3 - Effects of water salinity on root dry matter percentage of pomegranate cultivar.

Leaf necrosis

The leaf necrosis also affected by salinity level and pomegranate cultivars (Fig. 5). There was no difference in leaf necrosis between 3 dS/m and control treatments in 'ZT-Yazd' and 'M-Isfahan' cultivars. In 6 dS/m, the lowest leaf necrosis were observed in 'M-Pishva' and 'ZT-Yazd' with 1.6 and 1.8%, respectively. 'ZT-Yazd' and 'M-Pishva' had the least leaf necrosis in 12 dS/m with the average of 2.3% (Fig. 5).

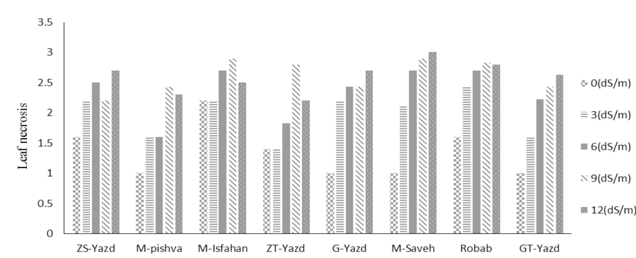

Fig. 5 - The interaction effects of salinity levels and cultivars on leaf necrosis.

Root and leaf Cl and Na content

Chloride and sodium contents of the root increased significantly when irrigated with 12ds/m saline water in compared with the control (Table 4).

The lowest root chloride content was found in 'ZT-

Table 4 - Effects of water salinity (12 ds/m) on root mineral elements of pomegranate

Salinity (dS/m)	Cl (mg/kg)	Na (mg/kg)	Mg (%)	Ca (%)	P (%)	N (%)
Control	16.325 b	24.798 b	0.228 a	1.071 a	0.173 a	1.213 a
12	51.430 a	90.434 a	0.198 b	0.721 b	0.140 b	0.962 b

Similar letters in each column indicate no significant difference at the 5% level of Tukey test.

Yazd' with 22.752 mg/kg. There was no significant difference among other pomegranate cultivars (Table 5).

In this study, pomegranate cultivars showed different levels of root sodium accumulation. The least sodium content was observed in 'ZT-Yazd' with 39.308 mg/kg. 'M-Saveh' and 'ZS-Yazd' showed the highest sodium accumulation of roots (74.118 and 62.947 mg/kg, respectively).

The interaction effect of saline water treatment and pomegranate cultivars on leaf sodium and chloride contents was significant. The highest leaf chloride content was found in 'M-Saveh' with 12 dS/m saline water (112.8 mg/kg) and the lowest ones was observed in 'M-Pishva' with an average of 46.72 mg/kg (Fig. 6).

The highest leaf sodium content was observed in 'M-Saveh' and 'GT-Yazd' with averages of 427 and 383.5 mg/kg, respectively (Fig. 7). In contrast, 'M-Pishva' showed the lowest leaf sodium content (141.5 mg/kg).

Root and leaf N content

The results showed that when pomegranate cultivars irrigated with 12 dS/m water, the nitrogen content of the roots reduced significantly to 20.69% compared with the control (Table 4). The response of pomegranate cultivars was different, when exposed to salinity stress (Table 5). The lowest roots nitrogen content was found in 'M-Saveh' (1%) but, no any significant difference was found among others cultivars (Table 5).

The leaf nitrogen content in pomegranate cultivars also decreased when irrigated with 12 dS/m saline water. The highest and the lowest leaf nitrogen content was found in 'M-Pishva' and 'M-Saveh' (in 12ds/m), respectively (Fig. 8).

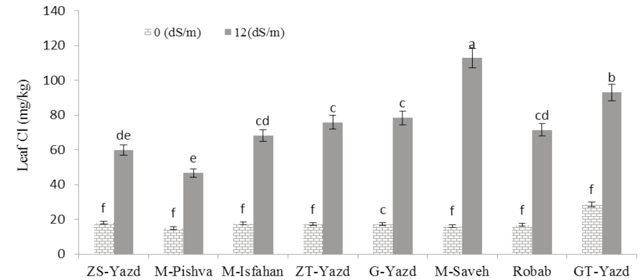

Fig. 6 - The interaction effects of water salinity and pomegranate cultivars on leaf chloride accumulation.

accumulation

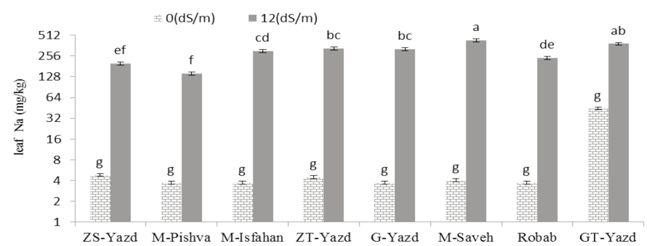

Fig. 7 - The interaction effects of water salinity and pomegranate cultivars on leaf sodium accumulation.

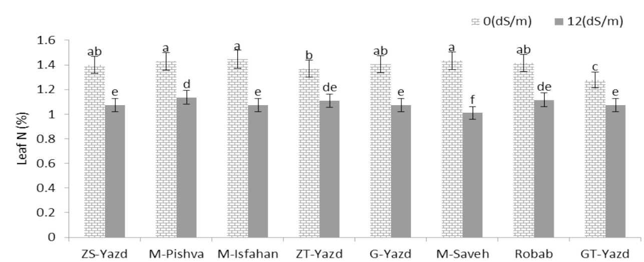

Fig. 8 - The interaction effects of water salinity and pomegranate cultivars on leaf nitrogen content.

Table 5 - The comparison of root mineral elements in eight pomegranate cultivars

Cultivars	Cl (mg/kg)	Na (mg/kg)	Mg (%)	Ca (%)	P (%)	N (%)
'ZS-Yazd'	36.178 a	62.947 ab	0.230 ab	0.883 ab	0.153 a	1.108 a
'M-Pishva''	38.848 a	58.632 b	0.213 b	0.910 ab	0.155 a	1.105 a
'M-Isfahan'	33.678 a	55.745 b	0.196 b	0.861 ab	0.163 a	1.111 a
'ZT-Yazd'	22.752 b	39.308 c	0.205 b	0.865 ab	0.151 a	1.106 a
'G-Yazd'	31.427 a	55.317 b	0.201 b	0.843 b	0.166 a	1.088 a
'M-Saveh'	39.583 a	74.118 a	0.256 a	0.906 ab	0.151 a	1.00 b
'Robab'	32.610 a	53.788 b	0.198 b	0.960 a	0.158 a	1.063 ab
'GT-Yazd'	35.943 a	61.072 b	0.205 b	0.940 a	0.156 a	1.123 a

Similar letters in each column indicate no significant difference at the 5% level of Tukey test.

Root and Leaf P content

The root phosphorus content significantly decreased in 12 dS/m salinity (19.07%) compared to control treatment. However, there was no significant difference among pomegranate cultivars in root phosphorus (Tables 4 and 5).

In the salinity of 12 dS/m, the leaf P content decreased compared with the control treatment. However, no significant difference was found among pomegranate cultivars for leaf phosphorus in the control treatment (Fig. 9).

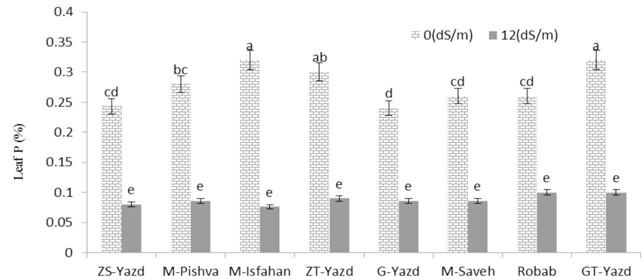

Fig. 9 - The interaction effects of water salinity and pomegranate cultivars on leaf phosphor content.

Root and leaf K content

The response of pomegranate cultivars to potassium accumulation of root was significantly different when irrigated with 12 dS/m water. 'ZS-Yazd', 'G-Yazd', 'M-Pishva' and 'GT-'Yazd showed increase potassium content of root while, potassium contents of 'Robab', 'M-Isfahan', 'M-Saveh' and 'ZT-Yazd' was decreased compared with the control. The lowest and the most potassium content of root were found in 'GT-Yazd' and 'M-Isfahan', respectively in salinity of 12ds/m (Fig. 10).

In contrast, leaf potassium content of all pomegranate cultivars decreased significantly when irrigated with 12 dS/m saline water (Fig. 11). The lowest content of leaf potassium was observed in 'M-Saveh', 'GT-Yazd' and 'ZT-Yazd' with 12 dS/m saline water treatment. The highest leaf potassium content in salinity conditions was found in 'ZS-Yazd' and 'G-Yazd'.

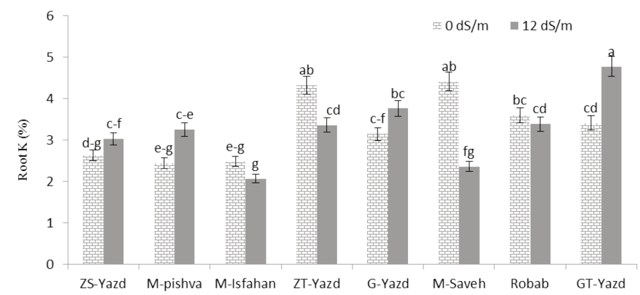

Fig. 10 - The interaction effects of water salinity and pomegranate cultivars on root potassium content.

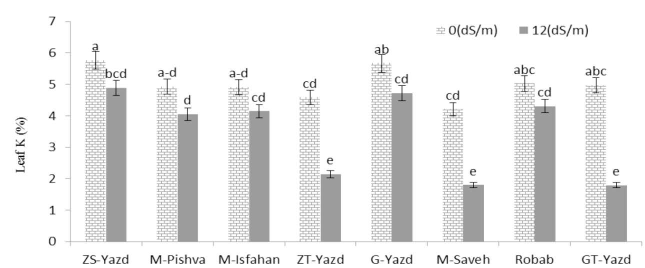

Fig. 11 - The interaction effects of water salinity and pomegranate cultivars on leaf potassium content.

Root and leaf Ca content

Root calcium content showed a significant reduction of 32.67% compared with the control when treated with saline water (Table 4). The lowest root calcium content was observed in 'G-Yazd' with an average of 0.84% (Table 5). In contrast, 'Robab' and 'GT-Yazd' cultivars showed the highest root calcium with averages of 0.96 and 0.94 %, respectively.

The leaf calcium content also decreased under salinity conditions (Fig. 12). The lowest leaf calcium content was recorded in 'G-Yazd' cultivar with an average of 0.843% and the highest ones were found in 'Robab' with 0.96% (Table 6).

Root and Leaf Mg content

The magnesium content of root also decreased when pomegranate plants irrigated with 12 dS/m saline water (13.15% compared with the control). The lowest of root magnesium content was found in 'M-Isfahan' and 'Robab' with averages of 0.196 and 0.198 %, respectively (Table 4 and 5). In contrast, 'M-Saveh' was able to absorb the most magnesium under salt stress condition compared with other cultivars.

Leaf magnesium content also decreased when treated with 12 dS/m irrigation water (Fig. 12). The least leaf magnesium content was found in 'M-Isfahan' with 0.196% (Table 6).

4. Discussion and Conclusions

Salinity reduces the ability of plants to water absorption and reduces the plant growth rate. The salt will eventually rise to a toxic level via transpiration of leaves, causing leaf senescence and abscission (Munns, 2002). Previous studies also showed that salinity changed growth parameters in pomegranate (Karimi *et al*., 2011; Mastrogiannidou *et al*., 2016), and pistachio (Picchioni *et al*., 1990; Naieni *et al*., 2004; Saadatmand *et al*., 2007).

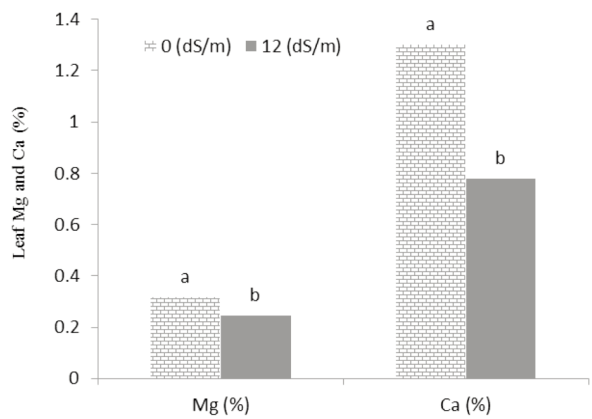

Fig. 12 - Effect of 12ds/m saline water treatment on leaf Mg and Ca content.

Table 6 - The comparison of root mineral elements in eight pomegranate cultivars

Cultivars	Leaf Mg (%)	Leaf Ca (%)
'ZS-Yazd'	0.230 ab	0.883 ab
M-Pishva'	0.213 b	0.910 ab
'M-Isfahan'	0.196 b	0.861 ab
'ZT-Yazd'	0.205 b	0.865 ab
'G-Yazd'	0.201 b	0.843 b
'M-Saveh'	0.256 a	0.906 ab
'Robab'	0.198 b	0.960 a
'GT-Yazd'	0.205 b	0.940 ab

Similar letters in each column indicate no significant difference at the 5% level of Tukey test.

The results of the current study showed that salinity affected the growth characteristics in pomegranate cultivars. Fresh and dry weight of roots as well as dry matter of root was decreased with increasing salinity levels. Reduction of fresh weight of root was completely dependent on pomegranate cultivar. For example 'GT-Yazd', 'Robab' and 'M-Saveh' cultivars maintained their growth characteristics more than other cultivars. Munns and Tester (2008) reported that in 'Malase Shirin' that was the salt tolerant cultivar, the growth rate increased after an increase in the salinity up to 40 mM, and the more. But in salt sensitive cultivars, increase in salinity decreased the plant growth characteristics (Munns and Tester, 2008). According to the previous studies, salinity tolerant plants, especially permanent species, have more potential to survive and maintain growth rate under salt stress conditions (Ferreira-Silva *et al*., 2008).

The results showed that fresh and dry weight of roots as well as dry matter percentage in mild salinity (3 dS/m) slightly increased but thereafter decreased. High levels of salinity reduced the rate of these traits. Amiri *et al*. (2011) showed that salinity levels of 40, 80 and 120 mM of sodium chloride in irrigation water of 'Robab' cultivar significantly reduced root fresh and dry weight. Also, Khoshbahkt *et al*. (2014) found that sodium chloride with 20, 40 and 60 Mm concentration in irrigation water caused a reduction in root fresh weight, and root dry weight in citrus. We also found that fresh weight of root was significantly affected by pomegranate cultivars.

Momenpour *et al*. (2015) also found a significant increase in almond leaf abscission when irrigated with saline water. Khoshbahkt *et al*. (2014) reported that with increasing sodium chloride in irrigation water, a significant increase was observed in the leaf abscission percentage of two citrus rootstocks. These results are consistent with the findings of other researchers, which the increase in salinity levels of irrigation water, led to an increase in necrotic leaflet growth (Momenpour *et al*., 2015). The result of the current study also showed that by applying salinity stress and increasing its concentration, in all studied cultivars, the percentage of leaf abscission increased. The least leaf abscission was observed in 'G-Yazd' and 'ZS-Yazd'. Reducing the number of leaves in the cultivars significantly reduces the plant photosynthesis level, which could be another reason for reducing plant growth characteristics in sensitive salinity cultivars.

According to the results, with increasing concentration of sodium chloride in irrigation water, leaf necrosis increased in the middle and the end of the stress period that are consistent with the findings of other researchers (Momenpour *et al*., 2015). In the concentrations of 6, 9 and 12 dS/m, 'M-Pishva', 'ZS-Yazd' and 'ZT-Yazd' showed the lowest percentage of leaf necrosis, respectively.

Previous studies showed that with increasing salinity level in irrigation water, accumulation of chloride and sodium ions increased in the pomegranate root and leaf (Karimi and Hasanpour, 2014; Mastrogiannidou *et al*., 2016). Zarei *et al*. (2016) reported that salinity stress, increased the amount of root and leaf chlorine and sodium in fig cultivars. Khayyat *et al*. (2014) also reported that with increasing salinity level from 4.61 to 7.46 dS/m, shoot Cl content in pomegranate cv. 'Malas Mommtaz' increased, but it decreased in 'Shishe Kab'. In fact, 'Shishe Kab' could manage sodium transport into leaves better than 'Malas Mommtaz' cultivar. Salinity-tolerant plants transfer less sodium and chlorine to shoot than sensitive plants (Fernandez, 2014; Munns, 2002). We also find the significant difference in pomegranate cultivars for absorption of sodium and chloride ions and translocation to shoot. 'ZT-Yazd' showed the lowest content of root chloride and sodium in 12 dS/m. At the same concentration of salinity, the lowest leaf sodium and chloride content was observed in 'M-Pishva'.

The results showed that by increasing sodium chloride in irrigation water, nitrogen content of root and leaf reduced, which is in agreement with finding of Naeini *et al*. (2004) on 'Alak Torsh', 'Malas Torsh' and 'Malas Shirin' pomegranate cultivars.

Karimi and Hassanpour (2014) reported that under salinity stress, the root and leaf phosphorus content in 'Shisheh Gap' cultivar decreased. In the present study, there was a decrease in the content of root phosphorus under salinity. Momenpour *et al*. (2015) no significant difference was observed among almond pomegranate cultivars in the root and leaf phosphorus under salt stress conditions that were similar to the results of this study.

Mastrogiannidou *et al*. (2016) showed that increasing of sodium chloride concentration in irrigation water decreased root and leaf potassium content in 'Wonderful' pomegranate cultivar. However, Karimi and Hasanpour (2014) reported that with increasing sodium chloride in irrigation water, root and leaf potassium content in pomegranate increased. In our study, salinity reduced leaf potassium, but potassium changes of root were affected by pomegranate cultivar. GT-Yazd' and 'ZS-Yazd' showed the highest root and leaf potassium, respectively.

Salinity stress led to the reduction of leaf and root magnesium. Naeini *et al*. (2004) also reported that with increasing sodium chloride concentration in irrigation water, content of root and leaf magnesium decreased in 'Alake Torsh', 'Malase Torsh' and 'Malase Shirin' cultivars. In the current study, M-Isfahan showed the lowest root and leaf magnesium. The highest leaf and root magnesium was observed in 'M-Saveh'.

Increasing salinity was associated with a decrease in leaf and root calcium. Aboutalebi *et al*. (2008) reported that by increasing sodium chloride, the root calcium in four citrus species decreased and in one of them increased. In the present study, 'Robab' had the highest leaf and root calcium in salinity conditions. Sarafi *et al*. (2017) indicated that 'Wonderful' and 'Ermioni' cultivars had the different abilities for P, K, Ca and Mg uptake under salt stress conditions. Differences in the absorption of elements were reported between 'Robab' and 'Shishe Kab' by Hasanpour *et al*. (2015).

'ZT-Yazd' showed the lowest leaf abscission and necrosis. 'M-Pishva' showed less leaf necrosis than other cultivars in salinity conditions. 'ZT-Yazd' and 'M-Pishva' showed the least amount of chlorine and sodium accumulation in root and leaf, respectively. It seems that the mechanism of these two cultivars is different to salinity tolerance, so 'ZT-Yazd' transmits excess chlorine and sodium to the leaves, but 'M-Pishva' transmits less chlorine and sodium to the leaves and shows the accumulation of these elements in the root. Perhaps for this reason, the amount of leaf nitrogen in 'M-Pishva' was higher than other cultivars in salinity conditions. However, in severe salinity conditions, in some cultivars, the potassium content of root decreased, but the potassium content of root in these two cultivars, along with 'G-Yazd' and 'GT-Yazd' increased. It seems that there is a wide variation among the studied cultivars that leads to different reactions to salinity. In general, 'M-Pishva' and Yazd cultivars showed higher tolerance to salinity stress.

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