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Chlorophyll fluorescence response of 'Yusef Khani' and 'Malas-e-Yazdi' pomegranate varieties under salinity stress

Seyyedeh Atefeh Hosseini[1*] and Mehdi Khayyat[2]

1, *Department of Plant Protection, University of Birjand, Iran*

2, *Department of Horticultural Science, University of Birjand, Iran*

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***Corresponding author:**
Department of Plant Protection, University of Birjand, Iran.
Email: ahosseini@birjand.ac.ir

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ABSTRACT

Purpose: The present research was done to evaluate the responses of 'Yusef Khani' (Y) and 'Malas-e-Yazdi' (M) Iranian pomegranates to salt stress under field conditions. **Research method:** Treatments included different salinized water (EC=1.05 as control, 4.61 and 7.46 dS m^{-1}) and two commercially Iranian pomegranate varieties. **Main findings:** Interaction of salinity × variety showed the lowest chlorophyll (chl) and potassium (K) level, and the highest chloride (Cl) and sodium (Na) in M variety, under high level of salinity. Although the lowest non-photochemical quenching, and effective quantum yield of photochemical energy conversion in PSII observed in this variety under 7.46 dS m^{-1}, however, basal quantum yield of non-photochemical processes in PSII increased. Accumulation of Na and Cl in leaf tissue increased with increasing salinity in both varieties. Moreover, lower accumulation of calcium (Ca), magnesium (Mg) and iron (Fe) observed in both varieties. More Na and Cl was obtained within leaves of M variety, compared with other one. We found that there were some differences between these varieties and 'Yousef Khani' was more tolerant to salinity compared with 'Malas-e-Yazdi'. **Limitations:** It might be better to evaluate several varieties for salinity resistance, however, it was impossible to us. **Originality/Value:** Iran is the main source of genetic variability for pomegranate. There is a huge diversity within pomegranate germplasm that should be studied for salinity and drought resistance. Thus, here we conducted a research to find a salt resistant pomegranate.

INTRODUCTION

Pomegranate (*Punica granatum* L.), is a fruit tree planted in arid and semi–arid parts of subtropical regions of Iran, where it faces with salinity stress (Khoshgoftarmanesh & Siadat, 2002). The latest statistics shows that 25-30% of irrigated lands are ranked as salt affected (Zaman et al., 2018). Salts influence on plants via water and/ or ionic stresses (Marschner, 1995; Ashraf & Harris, 2004; Silva–Ortega et al., 2008). It stated that increase in solute concentrations around the root medium led to water stress, ionic stress also occurs in relation to Na/K or Na/Ca ratio or high levels of Na^+ and Cl^- (Apse & Blumwald, 2007). Tester and Davenport (2003) stated that nutrient selectivity and uptake alters under high Na^+ and Cl^- concentrations around roots, which leads K^+ and/or Ca^{2+} deficiency. Paranychianakis and Angelakis (2008) and Rahneshan et al. (2018) suggested that difference between salt–tolerant and sensitive genotypes is connected to ion uptake and accumulation patterns into different organs. Osmotic stress tolerance, Na^+ and Cl^- exclusion from leaf, and tissue tolerance to Na^+ and Cl^- accumulation are three ways that are used for sodium and chlorine tolerance by plants (Munns et al., 2006; Ashraf & Foolad, 2007; Molinari et al., 2007; Martinez–Rodriguez et al., 2008; Munns & Tester, 2008). Alteration of chlorophyll fluorescence parameters for plants subjected to drought (Khaleghi et al., 2012) and salinity (Ranjbarfordoei et al., 2006; Kalaji et al., 2011; Mastrogiannidou et al., 2016) are cited many times. Ranjbarfordoei et al. (2006) found that salinity increases the Φ_{N0}, and lead to reduction of q_p (The fraction of open PSII reaction centers) and Φ_2 (Effective quantum yield of photochemical energy conversion in PSII), however, no significant changes observed in q_N and NPQ (Non-photochemical quenching) for almond. Jain and Dass (1988) and Patil and Waghmare (1982) recommended soil electrical conductivity (EC) less than 10 dS m^{-1} for pomegranate. Doring and Ludders (1986; 1987) and Naeini et al. (2006) observed that under salinity high levels of Na^+ and Cl^- accumulates in roots and leaves, respectively. Bhantana and Lazarovitch (2010) ranked pomegranate trees as moderately sensitive to salinity, based on some studies. Holland et al. (2009) achieved normal yield with pomegranates irrigated with saline water (between 2.5 to 4.0 dS.m^{-1}). Resistance of 10 commercial Iranian cultivars to salt stress in pots reported by Tabatabaei and Sarkhosh (2006) and Okhovatian–Ardakani et al. (2010). Recycled water also supplied to pomegranate by Levin (2006) in Turkmenistan. 'Malas–e–Yazdi' and 'Yusef Khani' are categorized as commercially Iranian pomegranate varieties that are used for export markets. They are ranked as late ripening, medium to large size with red skin and arils, and different in shape (Personal communication). Salt effected lands are increasing and we need to introduce new varieties for cultivation and sustainable horticulture. Although, there are some reports about pomegranate responses to NaCl, but, we do not have enough information about the mechanisms and level of resistance of these varieties to salinity.

MATERIALS AND METHODS

Plant material, growth conditions and treatments

The present research was carried out using one–year–old bare rooted plants of pomegranates 'Malas–e–Yazdi' and 'Yusef Khani', under field conditions (Table 1) located in Salinity Research Station of University of Birjand (32° 52′ N and 52° 12′ E), South Khorassan, Iran, during 2017 and 2018. Planting conducted in soil (Table 2) with the space of 2×3 m in rectangular pattern. Different sources of water used as salinity treatments (Table 3). Irrigation was done based on calibration among data collected from evaporation pan (class A), oven method (Black, 1965) and pressure plates (Rhoades, 1982), to inhibit water stress on plants.

Table 1. Some climatic characteristics of filed station (based on 50 years data)

The lowest temperature	The highest temperature	Annual precipitation	Relative humidity
°C		mm	%
–5	+40	171	15-46

Table 2. Soil chemical characteristics

Variable	ECe ($dS.m^{-1}$)	pH	Total N	P	K	Mg	Ca
					($meq.L^{-1}$)		
Rate	0.93	7.12	0.570	0.680	2.310	3.140	2.600
Variable	Zn	Cu	Mn	Fe	Na	Cl	HCO^{-}_{3}
				($meq.L^{-1}$)			
Rate	0.030	0.003	0.040	0.040	4.000	0.500	0.300

Table 3. Chemical characteristics of water used in experiment

EC	pH	Ca	Mg	K	Na	Cl	HCO_3^{-}
($dS.m^{-1}$)				($meq.L^{-1}$)			
1.05	7.54	2.10	5.80	0.20	8.50	13.00	3.90
4.61	7.41	7.00	18.40	0.70	23.80	14.00	2.30
7.46	7.26	12.70	25.00	1.10	77.30	63.00	0.90

Table 4. Soil saturated paste (SSP) characteristics at the end of experiment

Treatment	EC of SSP	pH	K	Na	Cl
($dS.m^{-1}$)				($meq.L^{-1}$)	
1.05	23.35	8.20	4.45	69.80	1.52
4.61	28.93	8.05	4.45	87.29	1.75
7.46	29.66	8.04	4.19	166.58	2.01

At the end of the experiment, some chemical properties of soil saturated paste (SSP) were evaluated (Table 4).

Determination of total chlorophyll content (Chl)

This variable were evaluated 3 times and Chl content ($mg.g^{-1}$ FM) was determined using 80% acetone and also hand–held SPAD 502 meter (Minolta, Osaka, Japan). Absorbance of the extract was read in 645 and 663 nm with a spectrophotometer (Shimadzo AA–670, Japan). For blank, 80% acetone was used.

Then, total chlorophyll content was calculated according to the following equation (1) by method of Saini et al. (2001):

$$\text{Total chlorophyll} = \frac{[(20.2(A645) + 8.02(A663)] \times V}{W} \times 1000 \quad (1)$$

Where V=volume of final extraction (50 mL); W=weight of leaf disk (0.25 g); A= absorbance.

Determination of chlorophyll fluorescence parameters

Chl fluorescence was assessed on the top attached and dark–adapted leaf using a Mini Pam Fluorometer (Walz, Effeltrich, Germany) with regarding to the protocol described by Genty et al. (1989), Roháček (2002) and Zhang and Xu (2003). NPQ (Bilger & Björkman, 1990), q_P (Bilger & Schreiber, 1986), Φ2 (Genty et al., 1989), ΦN0 (Roháček, 2002) and q_N (Bilger & Schreiber, 1986) were calculated as followed (2-5):

$$NPQ \text{ (Non − photochemical quenching)} = \frac{Fm - F\prime m}{F\prime m} \quad (2)$$

$$qp \text{ (The fraction of open PSII reaction centers)} = \frac{F'm - F0}{F\prime v} \quad (3)$$

$$\Phi 2 \text{ (Effective quantum yield of photochemical energy conversion in PSII)} = 1 - \frac{F0}{F\prime m} \quad (4)$$

$$\Phi N0 \text{ (Basal quantum yield of non − photochemical processes in PSII)} = \frac{F0}{Fm} \quad (5)$$

Where F_0 is the minimal fluorescence in the dark – adapted state, F_m is the maximal fluorescence in the dark – adapted state; F_v – the variable fluorescence; F_v/F_m – The maximum quantum yield of PSII or maximum PSII photochemical efficiency; F'_m – maximum Chl fluorescence in the light – adapted state.

Nutrient analysis in leaf

Oven–dried leaf tissues (4 times for sodium and chloride during growing season and 1 time for nitrogen (N), calcium (Ca), magnesium (Mg), iron (Fe) and zinc (Zn)) separately ground and ashed at 550°C in a porcelain crucible for 90 min. The ash was taken up in 2 M hot HCl, filtered and made up to 50 ml with distilled water and used for sodium (Na^+) and potassium (K^+) analysis with a flame photometer (Corning 405, Cambridge, UK). Cl^- was assessed by the titration method (Chapman & Pratt, 1982). Nitrogen evaluated via Kjeldahl method. Other ions were evaluated using atomic absorption spectrophotometry (Shimadzo AA-6300; Shimadzu Corp., Tokyo, Japan).

Statistical analysis

The experiment was designed in a completely randomized block (CRBD). A split-split plot (three salinity levels × two varieties × different evaluation times) or split plot (three salinity levels × two varieties) with three replications was set. Statistical analysis of data was carried out using ANOVA procedure on GENSTAT (GENSTAT Release 12.1). The means were compared using least significant differences (LSD) at $P < 0.05$.

RESULTS AND DISCUSSION

Water and soil quality assessment

With increase in salinity of water, Ca, Mg, K, Na and Cl concentrations of soil increased (Table 3), which made increase to the final ECe for SSP, Na and Cl (Table 4).

Total chlorophyll content (Chl)

The lowest Chl was observed in 7.46 $dS.m^{-1}$ salinity treatments at first year. Interaction of salinity and sampling time indicated the lowest amount of this variable in 7.46 $dS.m^{-1}$ at days 60 and 90, which accompanied with higher temperatures during growing season (Table 5). Decreasing Chl by salt treatments was in agreement with Kaya et al. (2002) and Khayyat et al. (2009) on strawberry, Tiwari et al. (2010) on cucumber and Mastrogiannidou et al. (2016) on pomegranate. Munns and Tester (2008) found that salts accumulated within the chloroplast and negatively affects photosynthesis. In addition, salinity influenced absorption of Mg^{2+} and Fe^{2+}, which are very important to the chlorophyll building (Hanafy et al., 2002). Mastrogiannidou et al. (2016) found that Mg concentration in stem increases with salinity increment.

Chlorophyll fluorescence parameters

NPQ

Data showed a raise in this variable in treatments from 1.05 to 4.61 dS.m^{-1}, which then significantly decreased from 4.61 to 7.46 dS.m^{-1} (data not shown) that was in agreement with Acosta-Motos et al. (2015a) and Acosta-Motos et al. (2015b)., For the second year, this variable significantly decreased with salinity increase (data not shown). The highest NPQ was resulted in 'Yusef Khani' that significantly decreased with time (data not shown). Interactive effect of salinity and variety showed the highest NPQ in 4.61 dS.m^{-1} for both varieties, and for the next year, high level achieved in 1.05 dS.m^{-1} (Table 6). Interactive effect of salinity × sampling time showed the highest NPQ in 4.61 dS.m^{-1} for the first and in 4.61 and 7.46 dS.m^{-1} for the next year, which both of them obtained in day 120 (Table 7). Interaction of salinity × variety × sampling time indicated the highest NPQ in 'Yusef Khani', for 4.61 and 7.46 dS.m^{-1} at day 120 (data not shown).

Quantification of this variable needs measurements on dark–adapted leaves, in particular determination of Fm. NPQ is linearly related to thermal dissipation and its changes reflect changes in heat dissipation under dark condition.

Table 5. Interactive effects of salinity × sampling time on chlorophyll content (mg.g^{-1} FM)

Year	2017								
Sampling time	30			60			90		
Treatment (dS.m^{-1})	1.05	4.61	7.46	1.05	4.61	7.46	1.05	4.61	7.46
Total Chlorophyll (mg.g^{-1} FM)	5.002b	4.504a	3.763c	4.011b	3.777c	1.764e	3.553c	2.426d	1.895e
Year	2018								
Total Chlorophyll (mg.g^{-1} FM)	5.442a	3.281c	3.679b	4.968a	2.754d	2.842d	3.674b	1.532e	2.704d

Mean values in each row followed by the same letter are not significantly different by the LSD ($P < 0.05$).

Table 6. Interactive effects of salinity × variety on NPQ

Year	2017					
Variety	'Yusef Khani'			'Malas–e–Yazdi'		
Treatment (dS.m^{-1})	1.05	4.61	7.46	1.05	4.61	7.46
NPQ	-0.347d	0.426a	-0.207c	-0.043b	0.403a	-0.210c
Year	2018					
NPQ	0.587a	0.371b	0.274b	0.514a	0.086c	0.094c

NPQ=Non-photochemical quenching.
Mean values in each row followed by the same letter are not significantly different by the LSD ($P < 0.05$).

Table 7. Interactive effects of salinity × sampling time on NPQ

Year	2017			
Sampling time	30	60	90	120
Treatment (dS.m^{-1})				
1.05	-0.1675e	-0.1735e	-0.1673e	-0.1646e
4.61	0.1936c	0.1476c	0.0375d	0.7537a
7.46	-0.5745g	-0.3005f	-0.1487e	0.3503b
Year	2018			
1.05	0.5639b	0.5373b	0.5366b	0.5467b
4.61	0.0444c	0.0787c	0.0587c	0.8036a
7.46	0.0661c	0.0632c	0.0476c	0.7645a

NPQ=Non-photochemical quenching.
Mean values (shown in each year) followed by the same letter are not significantly different by the LSD (P <0.05).

qP

Salinity increment significantly reduced qP (data not shown) that was in agreement with Ranjbarfordoei et al. (2006). In both years, the lowest rate of this variable was obtained in 'Malas–e–Yazdi' and in final sampling (Table 8).

qP indicates the photochemical capacity of PSII in light adapted-state and quantifies the actual fraction of PSII reaction centers that are in open state, *i.e*. with re–oxidised QA (Krause & Weis, 1984). As defined by Juneau et al. (2005), qP is proportional to the photon energy captured by open PSII reaction centers and dissipated *via* photosynthetic electron transport. Optimal use of photochemical energy in carbon assimilation (including photorespiration) is characterized by high qP values, while qP declines when light absorption exceeds requirements of carbon assimilation. Thus among other factors, qP serves as a valuable indicator of "light stress" (Medrano et al., 2002).

$\Phi 2\ (\frac{\Delta F}{F\prime m})$

Salinity × variety assessment showed the lowest rate of Φ2 in 4.61 and 7.46 $dS.m^{-1}$ and for 'Malas–e–Yazdi' (Table 9). Reduction of that under salinity was in agreement with Ranjbarfordoei et al. (2006) on almond trees. This variable reflects electron transport rate and indicates the plant's capacity to convert photon energy into chemical source once steady–state electron transport has been achieved (Genty et al., 1989). According to Roháček (2002), ΔF/F'm is related to the actual fraction of photochemistry active reaction centers in PSII under light adapted–state. In contrast to the dark–adapted state, the fluorescence obtained in the light–adapted state (Fs and F'm) is sensitive to any alteration of the overall PSII–PSI electron transport and to biochemical reactions linked to photosynthesis (Lazár, 1999).

$\Phi_{N0}\ (\frac{F0}{Fm})$

Regarding to both years, data showed the lowest rate of Φ_{N0} in control (data not shown) and was in agreement with Ranjbarfordoei et al. (2006) on almond trees. Effects of salinity × variety showed the lowest rate of that in 1.05 $dS\ m^{-1}$, for both years (Table 10). This variable covers the both Chl fluorescence and non–radioactive energy dissipation in dark adapted–state when all centers of PSII are open (Roháček, 2002). Based on the definition of Fv/Fm and F0/Fm and the values of F0/Fm quoted above, F0/Fm for undamaged plants is $0.222 \leq F0/Fm \leq 0.810$. Bilger et al. (1987) and others suggested that F0/Fm is markedly raised for damaged plants, which is also observed here. The increase in F0/Fm can be attributed to a loss of excitation energy, and to an increase of energy loss through non–photochemical quenching processes (Roháček, 2002).

Nutrient analysis of leaf tissue

Chloride

Salinity increased chloride accumulation in both years (data not shown). Interaction between salinity × varieties showed the highest chloride accumulation in 7.46 $dS.m^{-1}$ for both varieties in 2017, however, in the next year, the highest level was observed in 7.46 $dS.m^{-1}$ for 'Yusef Khani' (Table 11).

Acumulation of chlorine in leaf tissue under salinity was in agreement with findings of Chartzoulakis et al. (2002) on olive, Doring and Ludders (1987), Asrey and Shukla (2003) on pomegranate and Neocleous and Vasilakakis (2007) in raspberry. Under the highest salinity level, higher level of Cl^- was accumulated in 'Yusef Khani' compared to 'Malas–s–Yazdi', which may be related to cell osmotic adjustment by this anion in that variety and/ or inactivity of any mechanism by which its influx into leaf tissue can be reduced. Moya et al. (2003)

stated that lower Cl^- accumulation in leaf tissue may be related to higher water use efficiency, which can be seen in 'Malas–s–Yazdi'.

Sodium

Salinity × variety interaction indicated the huge accumulated rate of sodium in 'Malas–s–Yazdi' under the highest salt treatment, in both years (Table 12), which showed a low resistance for Na^+ absorption from the soil. These findings were in agreement with of Chartzoulakis et al. (2002) on olive, Doring and Ludders (1987), Asrey and Shukla (2003) and Mastrogiannidou et al. (2016) on pomegranate. Regarding to data presented here, it may be found that 'Malas–s–Yazdi' does not have any mechanism to restrict Na entrance into photosynthetic organ.

Potassium

Data presented for both years showed that with salinity increment accumulation of this cation increased in leaf tissue (data not shown). Evaluation of salinity × sampling time indicated the highest potassium concentration in treatment 7.46 $dS.m^{-1}$ and at the final sampling (Table 13). Salinity × variety indicated high potassium uptake by 'Yusef Khani' under salt stress that was disagreement with Asrey and Shukla (2003) and Mastrogiannidou et al. (2016) on pomegranate and in agreement with Storey and Walker (1999) in citrus, however, in another one lower K^+ uptake observed under salinity increase (data not shown).

Table 8. Interactive effects of variety × sampling time on qP

Year	2017			
Sampling time	30	60	90	120
'Yusef Khani'	2.02a	1.57a	1.66a	-0.08a
'Malas–e–Yazdi'	2.18a	1.96a	2.37a	-6.82b
Year	2018			
'Yusef Khani'	1.51a	1.07a	1.12a	1.97a
'Malas–e–Yazdi'	2.36a	1.88a	1.96a	-7.58b

qP=The fraction of open PSII reaction center.
Mean values (shown in each year) followed by the same letter are not significantly different by the *LSD* ($P < 0.05$).

Table 9. Interactive effects of salinity × variety on Φ_2

Year	2017					
Variety	'Yusef Khani'			'Malas–e–Yazdi'		
Treatment ($dS.m^{-1}$)	1.05	4.61	7.46	1.05	4.61	7.46
Φ_2	0.202b	-0.053c	-0.048c	0.483a	-0.254e	-0.106d
Year	2018					
Φ_2	1.154a	0.665b	0.472c	1.430a	0.325d	0.369d

Φ_2=Effective quantum yield of photochemical energy conversion of PSII.
Mean values in each row followed by the same letter are not significantly different by the *LSD* ($P < 0.05$).

Table 10. Interactive effects of salinity × variety on Φ_{N0}

Year	2017					
Variety	'Yusef Khani'			'Malas–e–Yazdi'		
Treatment ($dS.m^{-1}$)	1.05	4.61	7.46	1.05	4.61	7.46
Φ_{N0}	0.944c	1.295b	1.342b	0.515d	2.336a	2.334a
Year	2018					
Φ_{N0}	0.254d	0.700c	0.955b	0.303d	1.353a	1.456a

Φ_{N0}=Basal quantum yield of non-photochemical processes in PSII.
Mean values in each row followed by the same letter are not significantly different by the *LSD* ($P < 0.05$).

Table 11. Interactive effects of salinity × variety on leaf chlorine (mg.g^{-1} D.W.)

Year	2017					
Variety	'Yusef Khani'			'Malas–e–Yazdi'		
Treatment (dS.m^{-1})	1.05	4.61	7.46	1.05	4.61	7.46
Chlorine	0.647d	4.004b	7.442a	4.807c	5.993b	5.337a
Year	2018					
Chlorine	3.173d	6.004b	12.336a	5.806c	8.110b	8.972c

Mean values in each row followed by the same letter are not significantly different by the *LSD* ($P < 0.05$).

Table 12. Interactive effects of salinity × variety on leaf sodium (mg g^{-1} D.W.)

Year	2017					
Variety	'Yusef Khani'			'Malas–e–Yazdi'		
Treatment (dS.m^{-1})	1.05	4.61	7.46	1.05	4.61	7.46
Sodium	2.219c	9.785c	14.057b	4.387c	17.930b	28.242a
Year	2018					
Sodium	2.058c	8.763c	11.584b	5.364c	15.537b	28.361a

Mean values in each row followed by the same letter are not significantly different by the *LSD* ($P < 0.05$).

Table 13. Interactive effects of salinity × sampling time on leaf potassium (mg.g^{-1} D.W.)

Year	2017			
Sampling time	30	60	90	120
Treatment (dS.m^{-1})				
1.05	4.003e	5.554e	6.687e	9.543d
4.61	5.423e	16.551c	18.555c	22.187b
7.46	9.317d	17.346c	21.004b	29.253a
Year	2018			
1.05	5.026e	5.765e	5.602d	8.652d
4.61	7.654d	17.254c	21.607b	26.332a
7.46	6.875d	15.336c	19.837b	26.444a

Mean values followed by the same letter are not significantly different by the *LSD* ($P < 0.05$).

Nitrogen

Interaction of salinity × variety showed the highest total nitrogen in control for both varieties in both years, however, with salinity increase, 'Yusef Khani' tried to uptake more N compared with the other variety. Increased salinity from 4.61 to 7.46 dS.m^{-1} significantly decreased N accumulation in 'Malas–e–Yazdi' (Table 14). Mastrogiannidou et al. (2016) stated that salinity unaffected N content in stem of pomegranate.

Calcium

The lowest calcium concentration was observed in 'Malas–e–Yazdi', for both years and other variety held the constant Ca level in different salinity levels (Table 14). The highest Ca^{2+} observed in control treatment that was in agreement with Loupassaki et al. (2002) on olive and Asrey and Shukla (2003) on pomegranate. White and Davenport (2002) stated that Ca^{2+} may be replaced by Na^{+} under salt stress and uptake into plant organs.

Magnesium

'Malas–e–Yazdi' showed the highest Mg accumulation in leaves under 7.46 dS.m^{-1} (Table 14) that was in agreement with Loupassaki et al. (2002) on olive and Asrey and Shukla (2003) on pomegranate. It seems that just Mg^{2+} has played a significant role in protection of chlorophyll structure under salt stress, because iron reduced.

Table 14. Interactive effects of salinity × variety on leaf calcium, magnesium, iron and zinc concentration

	Treatment ($dS.m^{-1}$)	Nitrogen (%)	Calcium	Magnesium	Iron	Zinc
					($mg.kg^{-1}$ D.W.)	
Year				2017		
Variety						
'Yusef Khani'	1.05	2.132a	3.265a	0.556b	542.18a	613.84a
	4.61	1.637b	3.723a	0.583b	502.16a	551.43a
	7.46	1.205b	3.881a	0.627b	418.20b	487.36b
'Malas–e–Yazdi'	1.05	1.984a	3.204a	0.568b	527.73a	576.37a
	4.61	1.638b	1.826b	0.738b	339.15c	446.28b
	7.46	0.813c	1.784b	2.115a	343.27c	387.48c
Year				2018		
Variety						
'Yusef Khani'	1.05	2.417a	3.031a	0.863c	580.60a	536.16a
	4.61	2.163a	3.887a	0.958b	485.53b	572.17a
	7.46	1.426b	3.185a	1.114b	472.18b	434.73b
'Malas–e–Yazdi'	1.05	2.012a	2.878a	0.651c	497.12b	521.17a
	4.61	1.445b	2.707c	1.372b	330.16c	486.25b
	7.46	0.861c	1.054d	2.765a	215.28d	286.31c

Mean values in each column followed by the same letter are not significantly different by the *LSD* ($P < 0.05$).

Iron

The highest leaf iron concentration observed in 'Yusef Khani' under control treatment for both years. Although increment of salinity significantly decreased its level in leaves for both varieties, but, 'Malas–e–Yazdi' showed more declining of this variable (Table 14).

Zinc

Regarding to results, 'Malas–e–Yazdi' showed less accumulation of zinc under salinity (Table 14). Tester and Davenport (2003) stated that salinity decreases iron and zinc uptake from the soil solution via reducing root growth and development.

CONCLUSIONS

It might be concluded that both varieties tested here showed osmotic and ionic effects of salt stress. Na^+ and Cl^- uptake and transport into leaf tissue was not similar. Accumulation of nitrogen, potassium, calcium, magnesium, iron, and zinc significantly affected by salinity, however, 'Yusef Khani' showed better status about ion uptake and accumulations. Chlorophyll fluorescence consisted of some parameters also confirmed significant differences between varieties evaluated in our research. Finally, it could be stated that 'Yusef Khani' tolerates salinity stress better than 'Malas–e–Yazdi'.

Conflict of interest

The authors declare no conflict of interest to report.

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