

Effects of Long-term Salinity on Growth and Performance of Two Pistachio (*Pistacia L.*) Rootstocks

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Abstract: Salinization is one of the most important problems that restrict cultivation of crops in arid and semi-arid regions; Pistachio (*Pistacia vera* L.) is one of the most important trees that grown in these restricts. In this greenhouse study, the effects of salinity on growth of 2 pistachio rootstocks 'Badami' and 'Ghazvini' evaluated. Seedlings of these cultivars were grown in 25×30cm plastic bags containing 4.5kg soil. Salinity was imposed, by adding salt (NaCl) to the pots at 6 leaf stage (about 1 month after planting) to obtain concentration of 0, 800, 1600, and 3200 mg NaCl kg⁻¹ soil. Plants irrigated with 7 days intervals. Ninety days after salt treatment, pistachio seedlings were harvested and length of shoots and roots, number of leaves, relative water content, plant biomass, chlorophyll content, photosynthesis rate, reducing sugar concentration, and proline content of leaves were measured. Salinity decreased shoots and roots growth, number of leaves per plant, plant biomass, net photosynthesis rate, and chlorophyll content in comparison with the control. These parameters had higher value in the 'Ghazvini' rootstock than in the 'Badami' rootstock. The concentrations of reducing sugars in the leaves of the both rootstock improved with increasing salinity concentration up to 3200. Free proline content in the leaves of pistachio cultivars also increased with the increased salinity level. Proline content and reducing sugars in 'Ghazvini' rootstock was much higher than 'Badami'. Data obtained in present study emphasised that 'Ghazvini' rootstock is more tolerant to salinity than 'Badami'.

Key words: photosynthesis, pistachio, proline, reducing sugars, salinity stress, salt tolerance.

INTRODUCTION

Soil salinity is a major constraint limiting agricultural productivity on nearly 20% of the cultivated area and half of the irrigated area worldwide (Zhu, 2001). Increasing salinization of arable lands is a problem of paramount importance to crop production in many parts of the world and especially in irrigated fields of arid and semi-arid regions (Grattan and Grieve, 1999), where soil salt content is high and precipitation is insufficient for their leaching. Saline soils contain sufficient soluble salts to suppress plant growth through a series of interacting factors such as osmotic potential effect, ion toxicity and antagonism, which induce nutrient imbalances (Sepaskhah and Maftoun, 1988; Neumann, 1997). According to Zohary (1973), Iran is a country with a lot of saline soils. The areas with saline and alkaline soils are expanding especially in arid and semiarid regions of Iran. Approximately 12.5% of agricultural lands in Iran are affected by increased or natural salinity (Alkhani and Ghorbani, 1992).

Salt stress has been reported to cause an inhibition of growth and development, reduction in photosynthesis, respiration and protein synthesis in sensitive species (Boyer, 1982; Pal *et al.*, 2004). Salinity and its effects on biomass production have been considered by numerous authors (McKell, 1994; Ungar, 1996; Khan *et al.*, 2000 a, b; Mehari *et al.*, 2005). Accumulation of metabolites that act as compatible solutes is one of the probable universal responses of plants to changes in the external osmotic potential. Metabolites with osmolyte function like sugar alcohols, complex sugars and charged metabolites are frequently observed in plants under unfavorable conditions (Hasegawa *et al.*, 2000; Satiropoulos, 2007). Proline known to serve as compatible osmolytes, protection of macromolecules and also as scavengers of reactive oxygen species under stressful conditions (Hellman *et al.*, 2000; Ashraf and Foolad, 2007). Proline accumulation in the plant tissue due to salinity stress reported in many studies, e.g. in rape (Kundu and Paul, 1997), durum wheat (Bajji *et al.*, 2001), and alfalfa (Irrigoyen *et al.*, 1992) in pistachio (Hokmabadi *et al.*, 2005). Soluble sugars are also believed to

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accumulate in plant tissues and cells due to salinity stress. This may act as an osmotic adjustment or osmotic conservation factor (Bohnert *et al.*, 1995; Ingram and Bartels, 1996). In the first case, accumulation of soluble sugars act as an osmotic adjustment factor to maintain turgor; in the second case, it is related to stabilizing the cell membranes and proteins (Sanchez *et al.*, 1998). Soluble sugar accumulation may be due to further transformation of starch to sugars or less consumption of carbohydrates by the tissues (Irrigoyen *et al.*, 1992).

Pistachio (*Pistacia vera* L.) is one of the most important commercial trees grown in Iran, Turkey, and recently in the USA. Pistachio is considered a potential crop for many arid and semi-arid regions. Pistachio plants are known to be tolerant to salts (Sepaskhah and Maftoun, 1981; Behboudian *et al.*, 1986a; Picchioni and Miyamota, 1990; Ferguson *et al.*, 2002). Najmabadi (1969) also stated pistachio can grow on land too saline for other crops, however Parsa and Karimian (1975) have shown that salt adversely affects the aerial and root growth of *P. vera*. Adverse effects of salinity on growth, photosynthetic rates, and morphological changes in the leaves of pistachio have been shown (Behboudian *et al.*, 1986a; Picchioni and Miyamota, 1990; Munns *et al.*, 2002; Ranjbar *et al.*, 2002). Nevertheless, pistachio plantations are on sodic soils and irrigated with low quality, saline water in Iran. These conditions result in reduction of yields of pistachio over recent years.

This study was carried out to assess and compare two pistachio varieties for their salt tolerance, organic composition and biomass production in salinity conditions.

MATERIALS AND METHODS

Growth Condition and Plant Material:

The experiment was conducted during the spring and summer seasons of 2008 at the research greenhouse of the Department of Horticultural Science of Agricultural College of Shiraz University.

Seeds of two pistachio rootstocks (*Pistacia vera* L. 'Badami' and 'Ghazvini') were obtained from Pistachio Research Center, Rafsanjan, Iran. The seeds were soaked for 10 min and 4 hours in 0.1% sodium hypochlorite and 0.3% benomil solution respectively and rinsing repeatedly with distilled water. After sterilization, seeds were planted in pots (25×30cm plastic bags) containing 4.5kg sterile sandy-loam soil with pH 7.71, EC 2.5 mmhos/cm, and 0.64% organic mater. Adequate amount of fertilizers (NH₄NO₃, KH₂PO₄, MnSO₄, NH₄NO₃, CuSO₄.5H₂O, KH₂PO₄, ZnSO₄.7H₂O, and FEDDHA) have been added to soil, based on soil analysis (Table 1). Seedlings were grown in the greenhouse at day/night temperatures of 30/25°C (±4°C), day/night relative humidity of 40/50%, and a 16-h photoperiod. Seedlings were irrigated with distilled water. After 30 days, salinity treatments of 0 (control), 800, 1600, and 3200mg NaCl/kg soil were applied to the pots at 7-day intervals using irrigation distilled water (FC level).

Data Recorded:

Net photosynthesis rate, and Chlorophyll content: $PN[Nmol(CO_2) m^{-2} s^{-1}]$ measurements were done on fully expanded leaves of seedlings of both varieties using a gas exchange apparatus. The fourth fully expanded leaves were harvested at the end of experiment. The chlorophyll concentration was determined in 80% acetone extract on a spectrophotometer (UV-120-20. Japan). Absorbency was measured against an 80% acetone blank at 645 nm and 663 nm. Chlorophyll concentrations were calculated using the equation proposed by Strain and Svec (1966).

$$\text{Chl. } a \text{ (mg g}^{-1}\text{)} = 11.64 \times (A_{663}) - 2.16 \times (A_{645})$$

$$\text{Chl. } b \text{ (mg g}^{-1}\text{)} = 20.97 \times (A_{645}) - 3.94 \times (A_{663})$$

Where (A₆₆₃) and (A₆₄₅) represent absorbance values read at 663 and 645nm wave length, respectively. The total chlorophyll content (mg g⁻¹) was obtained by summation of the calculated values of chl *a* and *b*.

Relative Water Content (RWC) of Leaves:

Relative water content (RWC) was determined on fully expanded leaves of similar age. Leaves were excised before dawn, weighed fresh (FW) and placed in distilled water in the dark for 24 hours to re-hydrate (Cameron *et al.* 1999). The following morning, leaf turgid weight (TW) was measured and then leaves were dried at 80°C for 48 hours and dry weight (DW) was determined. The RWC was calculated as:

$$\text{RWC} = [(FW - DW) / (TW - DW)] \times 100$$

Destructive Analyses:

90 days after salt treatments, seedlings were harvested, and the following factors were traced.

Shoot Height, Root Length, and Biomass of Shoots and Roots:

After 90 days of treatments, pistachio seedlings were harvested by washing roots from the soil and plants divided into root and shoot. Shoot and root length in each sample was measured using a ruler. Fresh weight of shoot and root were also recorded. Plant material was washed thoroughly with tap water and then twice with distilled water, before being oven-dried at 75°C to a constant weight to estimate dry weight.

Chemical Analyses:

Reducing Sugars Analysis:

The samples were ground into a fine powder and reducing sugars content was measured in 1g of dry leaves. After extraction with 80% (v/v) ethanol, concentration of reducing sugars was measured by the methods described by Buysee and Merckx (1993) and Dubois *et al.* (1956).

Proline Analysis:

Proline content was extracted from the leaf tissues by the method described by Bates *et al.* (1973). 500 mg of fresh leaf material was homogenized in 10 ml of 3% aqueous sulfosalicylic acid and filtered through Whatman's No.1 filter paper. Two milliliter of the filtrate was mixed with 2 ml of acid-ninhydrin and 2 ml of glacial acetic acid in a test tube. The reaction mixture was extracted with 4 ml toluene and the chromophore containing toluene was aspirated, cooled to room temperature, and the absorbance was measured at 520 nm with a UV-120-20 (Japan). L-proline was used as standard.

Statistical Design and Data Analyses:

Treatments were set in a factorial experiment (NaCl treatments×rootstock) based on a complete randomized design (CRD) with 4 replications per treatment. Data were analyzed using SPSS 16.0 software for windows. Means were separated with Tukey's HSD test – at *P* 0.05.

RESULTS AND DISCUSSION

Vegetative Growth and Allocation of Rootstocks:

There were significant differences in height of shoot and length of root between salinity treatments. Increasing in salt concentration decreased growth of shoot and root of both pistachio varieties. However, rate of reduction in growth of the rootstocks was not analogous, and the rate of reduction in growth of 'Badami' was more evident (Table 2). Generally ratio of shoot:root length increased with salt treatments, however the differences was not significant.

Salt treated seedlings had significantly fewer number of leaves than respective control plants (Table 3). Dry weight decreased with increasing salinity concentration for both rootstocks (Table 3). Reduction of biomass by increasing salinity varied among rootstocks and 'Badami' rootstock proved much sensitivity in biomass reduction. Ratio of shoot:root biomass increased with salt treatments, however the differences was not significant.

Relative Water Content (%RWC) of Leaves:

Water content of leaves decreased with increasing salinity slightly; but there found no significant differences in water content between salinity treatments and rootstocks (data not shown). These results are along with Behboudian *et al.* (1986a) and Hokmabadi *et al.* (2005).

Chlorophyll Content:

Salinity had a diverse effect on chlorophyll content of the both varieties. Total chlorophyll content (Chl. *a* + Chl. *b*) of the two stocks decreased with increasing salinity (Table 4). The chlorophyll content of 'Ghazvini' was significantly higher than the 'Badami'. The highest chlorophyll content detected in control plants of var 'Ghazvini', and the minimum values spotted in 3200 of 'Badami' plants. Chlorophyll *a* (Chl. *a*) and Chlorophyll *b* (Chl. *b*) content also decreased with salinity significantly, the differences were significant for both stocks (Table 4). Chl. *a* and Chl. *b* quantity were higher in 'Ghazvini' than in 'Badami'. Rate of reduction in Chl. *b* was higher than Chl. *a* and average value of chlorophyll *a:b* was significantly increased by raising salinity in soil.

Net Photosynthetic Rate:

The effect of salinity on photosynthesis is shown in figure 1 and table 4. Photosynthetic rate of the two pistachio rootstocks measured at different salt concentrations (800, 1600 and 3200 mg NaCl kg⁻¹ soil) varied significantly after 90 days of treatment (Table 4). Photosynthetic rates decreased with increasing salinity in both pistachio rootstocks (Fig. 1); Addition of salt to the growth media caused a reduction in photosynthesis even at the lowest NaCl concentration. However, salt concentration up to 800-1600 mg NaCl kg⁻¹ soil caused much reduction in photosynthesis rate of the rootstocks (Fig. 1).

Sugar Concentration:

Salt treatments induced the accumulation of soluble sugars in leaves of the two rootstocks (Figure 2). Moreover, the soluble sugar concentration was significantly differed in the rootstocks. Accumulation of sugars in cv. 'Ghazvini' was much more than 'Badami'. The highest soluble sugar increase in 'Ghazvini' (143.2%) was obtained in plants exposed to 3200 mg NaCl kg⁻¹ soil, followed by (115.6%) increase at 1600 mg NaCl kg⁻¹ soil. The maximum soluble sugar in 'Badami' (132.1%) also was found in the highest salt concentration, followed by (112.8%) increase at 1600 mg NaCl kg⁻¹ soil. However, there is no significant difference in reducing sugar concentration between salinity treatments.

Proline Content:

The Proline content of the two pistachio cultivars was enhanced at different salt concentrations (Figure 3). The maximum amount of proline was observed at the highest salinity concentration (3200) for the both cultivars. Proline accumulation in 'Ghazvini' leaves was more than 'Badami' (48.62 vs. 14.33 Nmol g⁻¹). Interestingly, 'Ghazvini' accumulated more than three times more proline than 'Badami' in leaves at the highest NaCl concentration in soil (Figure 1).

Discussion:

The effects of salinity on shoots and roots length, dry mass accumulation, chlorophyll content, photosynthetic rate (PN), reducing sugars, and proline content in two pistachio cultivars were investigated.

Exposure to salt may affect plant metabolism by an osmotic effect, causing a water deficit, or by a specific ion effect (depends on the types of salt and species), causing excessive ion accumulation. The reduction in tissue masses when salinity level increased from 800 to 3200 mg NaCl kg⁻¹ soil, as well as visible-injury observations, suggests that the severe saline environment caused not only growth reduction but also chlorosis, defoliation and other toxicity symptoms. The reduction in shoot dry weight was attributed to lower leaf number and development of smaller leaves with increasing salinity of the growth medium. Ion toxic effects of salts are attributed to excess accumulation of certain ions in plant tissues and to nutritional imbalances caused by such ions. It is shown that damage to pistachio plants has been mainly attributed to excessive accumulation of Cland Na⁺ in the leaves (Sepaskhah and Maftoun, 1981, 1988; Tvallali *et al.* 2008).

Total chlorophyll (Chl. *a* + Chl. *b*) content was markedly reduced by the salt treatment (Table 4). Reduction of this characteristic was greater in 'Badami' rootstock than in 'Ghazvini' and it was attributed to *Cb* reduction. Chlorophyll *a* content was higher in the leaves than *b* (Table 4). An increase in *a:b* ratio occurred in plants receiving salt (Figure 4). The results indicated that *a* was higher than *b* showing that salinity induced a marked decreased in *b*. Reduction of *b* may suggest structural damage of photosystem II reaction centers.

The reduction in chlorophyll concentration of salinized plants could be also attributed to the increased activity of chlorophyll degrading enzyme chlorophyllase (Rao and Rao, 1981). However, reduction in *b* in the two pistachio varieties was not same. Chl. *b* reduction in 'Badami' rootstock showed more sensitivity by increasing salinity (Figure 4). Whereas 'Ghazvini' showed a significant increase in *a:b* ratios only at concentration of 3200 mg NaCl kg⁻¹ soil compared to the respective controls.

These results are in agreement with findings by Das *et al.* (2002) on *Morus*, Ranjbar *et al.*, (2002) and Tavallali *et al.*, (2008) on *Pistacia*, and Anjum (2008) on *Citrus*.

The results in the present study salt treatment decreased the photosynthetic rate (Figure 1), and subsequently the whole plant biomass (Table 3). These suggest that the impairment of plant growth by salt stress mainly results from the suppression of photosynthetic activity. Photosynthetic rate of the two pistachio measured at different salt concentrations (800, 1600 and 3200 mg NaCl kg⁻¹ soil) varied significantly after 90 days of treatment (Figure 1). Current data showing that leaves and stem growth depressed more than root growth by salt stress (Table 2 and 3) suggests that sink activity in leaves and stems is inhibited more strongly by salt stress compared to that in roots. These results emphasized that salt stress depresses photosynthetic activity, which may suppress plant growth.

Salinity normally decreases plant photosynthetic rates. Photosynthetic activity can be interfered within two ways: by modifying either, stomatal conductance or the mesophyll capacity to assimilation (Farquhar and Sharkey, 1982). It has been demonstrated that both Na⁺ and Cl⁻ can reduce the mesophyll capacity to assimilate (Behboudian *et al.*, 1986 a,b). Although photosynthetic rates decreased with increasing salinity in both pistachio cultivars, 'Ghazvini' showed a significant decrease in photosynthetic rates only at concentrations of 1600 to 3200 mg NaCl kg⁻¹ soil compared with the respective controls. A progressive decrease in photosynthesis, stomatal conductance and net assimilation rate in salinity stress condition has already been reported by Behboudian *et al.* (1986a) on pistachio (*P. vera* L. 'kerman'), Banuls and Primo-Millo (1992) on sweet orange, Janvanshir and Ewell (1992) on bald cypress (*Taxodium distichum*), Lakshmi *et al.* (1996) on mulberry (*Morus alba* cvs S30 and K2), and Ranjbar *et al.* (2002) on pistachio species. The relatively high salt tolerance of 'Ghazvini' rootstock was evident from a smaller reduction in PN rates than 'Badami'. Based on Chlorophyll data, we also that salinity stress might affect the biochemistry of photosynthesis by causing disorientation of the lamellar system of chloroplasts and loss of chloroplast integrity leading to a decrease in the activities of photosystems.

Plants accumulate compatible osmolytes such as proline and sugars when they are subjected to salinity stress and they appear to protect plants from such stresses (Zhu, 2001). Pistachio responds to elevated salt concentration by increasing leaf reducing sugars accumulation (Figure 2). The role of reducing sugars (glucose and fructose) in the adaptive mechanism is controversial, and even their accumulation can be detrimental from several points of view. Reducing sugars act as osmolytes and can increase the osmotic pressure of the cell (Yancey *et al.*, 1982). In addition, the maintenance of soluble sugar level in leaves could be associated with decreasing growth under salinity. Azcon-Bieto (1983) reported that lower rates of carbon assimilation and decreased in yield were associated with carbohydrate accumulation in many plant species. Carbohydrates accumulation might influence by reduction in carbohydrate utilization due to decline in growth and overall energy demand by stressed plants.

Feedback inhibition of photosynthesis as a result of decreased sink demand is a well-known phenomenon (Roitsch, 1999). Different experimental approaches have shown that sugars play a key role in this regulatory mechanism by repressing the expression of the photosynthetic genes (Koch, 1996). The specific inhibitory effect of sugars on photosynthesis or on the expression of photosynthetic genes is further supported by current studies (Morcuende *et al.*, 1997; Felitti *et al.*, 1998; Winder *et al.*, 1998). These results suggest that photosynthetic activity is possibly depressed by sugar accumulation in leaves.

Proline is a dominant organic molecule that acts as a mediator of osmotic adjustment under salinity stress, a stabilizer of sub-cellular structures, a sink for energy and even a stress-related signal. It is also involved in cell osmoregulation, protection of proteins during dehydration and can act as an enzymatic regulator during stress conditions (Rontein *et al.*, 2002). The quantitative estimation of proline in the two pistachio is shown in figure 3.

Numerous researches indicated that proline accumulation is a consistent response of plants under stress, including salt stress (Delauney and Verma, 1993; Taylor, 1996). In the present study, free proline concentration in the leaves of both rootstocks increased with increase in NaCl concentration in soil (Figure 3). Accumulation of proline was greater in leaves of 'Ghazvini' in compare with the other rootstock (Figure 3). It is shown that there is a positive correlation between salt tolerance and concentration of proline tissues (Kumar *et al.*, 2003; Hokmabadi *et al.*, 2005). Accumulation of high concentration of proline may due to both higher rates of proline synthesis and lower magnitude of proline oxidation in salt tolerant genotypes. Compatible solutes, such as proline, are known to accumulate under conditions of salt stress to play a role in the process of osmotic adjustment in many crops. Recent studies also suggested that protective role of proline is by protecting the protein turnover machinery against stress damage and up-regulating stress-protective proteins (Khedr *et al.*, 2003).

Although the two pistachio cultivars accumulated more proline with increasing salinity stress, 'Ghazvini' possessed comparatively higher amounts of proline, providing evidence for an efficient role of this metabolite as osmoprotectant under salinity stress.

In conclusion, the findings of this study showed that salt stress negatively impact pistachio growth and photosynthesis. However, this negative influence was significant at only concentrations exceeding 800 mg NaCl kg⁻¹ soil. The data also demonstrated that plants of 'Ghazvini' exhibited higher adaptive potential under salinity stress as judged by growth and biomass accumulation, photosynthetic carbon assimilation, and accumulation of osmoprotectants when compared to 'Badami'.

Table 1: Soil chemical and physical characteristics.

Physical characteristics		Nutrient Concentrations		Nutrients Applied to kg of Soil	
Sand%	50	N%	0.094	N	100mg
Silt%	30	P (ppm)	8	P	50mg
Clay%	20	K (ppm)	150		
Texture	Sandy loam	Fe (ppm)	2.7	Fe	5mg
pH	7.71	Zn (ppm)	0.29	Zn	5mg
SP%	31	Mn (ppm)	4.2	Mn	5mg
OC%	0.64	Cu (ppm)	0.42	Cu	2.5m
EC	0.77				

Table 2: Effects of salinity on leaf number, and stem and root growth of pistachio.

NaCl	Cultivar	Shoot Height (cm)	Root Length (cm)	Leaf Number	Shoot:Root Ratio
0	Ghazvini	34.75a	32.50a	10.13a	1.10a
	Badami	29.00ab	30.50ab	9.29ab	0.96a
800	Ghazvini	30.75ab	30.50ab	9.38ab	1.00a
	Badami	24.50bc	27.75ab	8.42abc	0.89a
1600	Ghazvini	21.03bc	26.00abc	7.25abc	0.88a
	Badami	18.75c	22.75bcd	6.44bc	0.83a
3200	Ghazvini	18.00c	18.50cd	6.13bc	1.05a
	Badami	16.50c	17.25d	6.00c	0.90a

Values not associated with the same letter are significantly different (Tukey's HSD, *P* 0.05).

Raising salinity concentration in soil, impact a diverse effect on leaf number, stem and root growth of both rootstocks.

Table 3: Effects of salinity on stem, root, and leaf dry weights (g) of pistachio rootstock seedlings.

NaCl	Cultivar	Stem (g Plant ⁻¹)	Root (g Plant ⁻¹)	Leaf (g Plant ⁻¹)	Shoot:Root Ratio
0	Ghazvini	0.542a	0.357a	0.273a	1.888a
	Badami	0.395abc	0.238ab	0.217ab	1.684a
800	Ghazvini	0.500ab	0.275ab	0.263a	1.828a
	Badami	0.305bcd	0.1 80ab	0.167bcd	1.669a
1600	Ghazvini	0.410abc	0.212ab	0.208abc	2.1 69a
	Badami	0.263cd	0.1 33ab	0. 146cd	1.988a
3200	Ghazvini	0.283cd	0.143ab	0.195bc	2.040a
	Badami	0.173c	0.100b	0.117d	1.758a

Values not associated with the same letter are significantly different (Tukey's HSD, *P* 0.05).

Salinity had an adverse effect on biomass accumulation of pistachio seedling. Biomass of stem, root, and leaves of pistachio plants decreased significantly with rising salt concentration in media. biomass ratio increased with salt, however, the differences was not significant

Table 4: Effects of salinity treatments on chlorophyll content of pistachio cultivars.

Na	Cultivar	Chl.a	Chl.b	Total Chl.	Ca:Cb Ratio	PN
0	Ghazvini	0.921a	0.587a	1.508a	1.569a	11.437a
	Badami	0.888ab	0.566ab	1.453ab	1.569a	11.131ab
800	Ghazvini	0.955a	0.609a	1.564a	1.569a	10.991abc
	Badami	0.504bc	0.320bc	0.824bc	1.571a	10.640abc
1600	Ghazvini	0.835ab	0.532ab	1.368ab	1.569a	8.014bcd
	Badami	0.403c	0.256c	0.659c	1.573a	7.919cd
3200	Ghazvini	0.445c	0.283c	0.728c	1.572a	7.071d
	Badami	0.391c	0.248c	0.639c	1.573a	6.655d

Values not associated with the same letter are significantly different (Tukey's HSD, *PU*0.05).

Salinity reduced chlorophyll a (Chl. a), chlorophyll (Chl. b), and total chlorophyll contents of both rootstocks significantly. However, Chl. a :Chl. b ratio increased with mounting salt concentration in soil, but the differences was not significant. Raising salt concentration in soil also, lead to depress photosynthesis in both rootstocks.

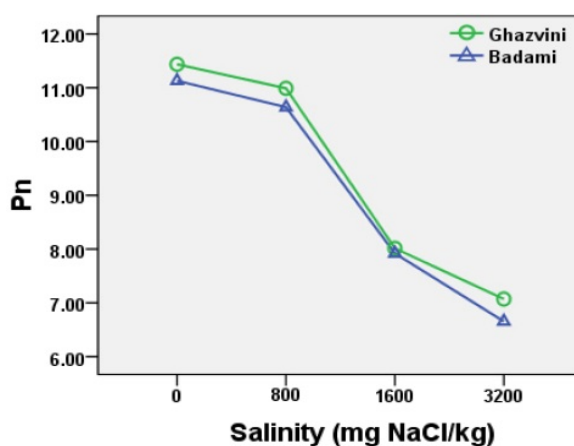


Fig. 1: Effect of salinity on photosynthesis (PN) of pistachio seedlings.

Photosynthesis of the two rootstocks was inhibited by increasing NaCl concentration in soil. Badami rootstock shows much reduction in photosynthesis rate by salt treatments.

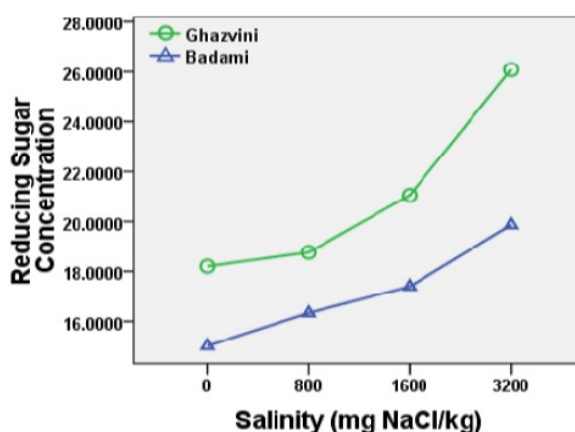


Fig. 2: Effect of salinity on reducing sugars concentration of the leaves of pistachio rootstocks.

Concentration of reducing sugars in leaves of pistachio seedlings increased by salt treatments. Accumulation of reducing sugars in leaves of cv. higher than.

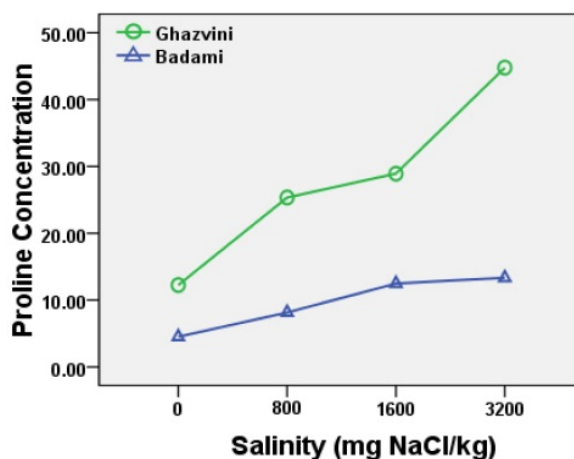


Fig. 3: Effect of salinity on proline accumulation in pistachio leaves.

Accumulation of proline was enhanced by salt treatments in both pistachio cultivars. More proline concentration found in the leaves of cv. Ghazvini.

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