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Growth and Chemical Composition of Pistachio Seedling Rootstock in Response to Exogenous Polyamines under Salinity Stress

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Abstract: In order to evaluate responses of a pistachio seedling rootstock (*Pistacia vera* L. cv. Ghazvini) to NaCl induced salinity stress and potential protective role of exogenous spermine and spermidine on NaCl induced salinity stress, a greenhouse experiment was conducted during growing season of 2009. The NaCl treatments, involving 800, 1600, and 3200 mg NaCl per Kg of soil for 90 days, suppressed growth of the seedlings and induced accumulation of Na^+ and Cl^- in roots and shoots. Accumulation of Na^+ and Cl^- in shoots was higher than in roots. Our data also showed more accumulation of K^+ in the shoot than in the roots under salinity stress. The ratio of K^+/Na^+ in compare with control was highly significant in the shoots of stressed plants. Exogenous polyamines (PAs) prevented the growth reduction induced by salinity stress and reduced transport of Na^+ and Cl^- from the root to shoot and increased translocation of K^+ from the root to the shoot of pistachio seedlings. We concluded that 'Ghazvini' rootstock appear to be a valuable seedling rootstock with a level of salt tolerance about 1600 mg NaCl Kg^{-1} Soil. It also concluded that application of exogenous PAs may protect pistachio seedlings from salinity stress effects.

Keywords: Pistachio, *Pistacia vera* L. cv. Ghazvin, Salinity stress, Spermine, Spermidine, Salt tolerance, Exogenous polyamines

INTRODUCTION

Pistachio (*Pistcai vera* L.) is an important nut crop in Iran. Since most of the pistachio orchards are in dry and semi-dry regions, poor quality of irrigation water in association with sodic soils has reduced yield of pistachio over recent years. Saline soil may exert different effects on pistachio rootstocks. Salinity stress can cause decreased growth, alter photosynthesis rates and caused morphological changes in the leaves of pistachio [3,15]. NaCl affects the permeability of the plasma membrane and increases influx of external ions and efflux of cytosolic solutes in plant cells [7, 2]. However such effects can be alleviated by the addition of Ca^{++} to the medium [17]. It has been reported 'Ghazvini' rootstock is more tolerant to salinity than the other common seedling rootstocks used in Iran [11]. The accumulation of Na^+ in leaves and roots indicates a possible mechanism whereby pistachio 'Ghazvini' copes with salinity in the rooting medium and/or may indicate the existence of an inhibition mechanism of Na^+ transport to leaves.

Information on the interaction of salinity and polyamines (PAs) on pistachio seedling growth and performance is still scarce. The presence of PAs has been detected in appoplast, plasma membrane, vacuole, cytosol, chloroplast and nuclei [16]. However, their specific mode of action during salinity is not clearly known. Salt-tolerant rice plant accumulates higher PAs such as spermine (Spm) and spermidine (Spd) in response to salinity stress [6]. Most of the studies have demonstrated that

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exogenous PAs could in varying degree, reverse growth or minimize growth ignition caused by stress, indicating that PAs, are effective at mitigating stress derived cell injury [8]. The purpose of this study was to evaluate the effects of exogenously application of higher PAs on growth characteristics, dry weight, uptake and distribution of Na^+, K^+, and Cl^- in pistachio 'Ghazvini' seedling rootstock, under NaCl induced salinity stress condition.

MATERIALS AND METHODS

Seeds of *Pistacia vera* L. cv. Ghazvini obtained from Pistachio Research Institute, Rafsanjan, Iran. Seeds sown directly in black plastic bags filled with 4.5 Kg sandy loam soil. The soil characteristics are shown in Table 1. Based on the soil analysis, N, P, Fe, Zn, Mn, and Cu elements applied to the soil as chemical salts (Sigma®) (Table 2).

Table 1. Analysis of soil used in the experiment

Soil Texture	pH (Paste)	Organic Carbon (%)	Electrical Conductivity (dS m^{-1})	N (%)	P	K	Fe	Zn	Mn	Cu
					(mg Kg^{-1} Soil)					
Sandy Loam	7.71	0.64	0.77	0.094	0.8	150	12.7	0.29	4.2	4.2

Table 2. Mineral elements were added to the soil

Source of fertilizer	Mineral element	Rate of application (mg Kg^{-1} Soil)
NH_4NO_3	N	100
KH_2PO_4	P	50
FeEDDHA	Fe	5
$ZnSO_4$, H_2O	Zn	5
$MnSO_4$, H_2O	Mn	5
$CuSO_4$, $5H_2O$	Cu	2.5

The seedlings grown in a greenhouse under 23 ºC and 17ºC day-and-night temperature, respectively. Sodium chloride (0, 800, 1600, and 3200 mg Kg^{-1} soil) added to the soil when the seedlings were reached to the six leaves stage. The level of salinity was gradually increased in three steps to prevent shock to the seedlings. After each irrigation (26% soil dry weight), the soil moisture was reached to field capacity without any drainage from plastic bags.

Twenty-four hours after irrigations the plants separately sprayed to run off with 0, 1, and 2 mM of spermine (Spm) and spermidine (Spd). Spray of seedlings with PAs was repeated after irrigations. Ninety days after application of salinity, the seedlings cut at the soil surface and roots washed free of soil. Stem and root heights, and number of leaves were recorded. Leaf area was measured with a portable area meter AM200 – ADC Bioscience. Leaves, stems and roots were dried to constant weight in an oven at 80 ºC and dry weights of leaves, stems, and roots were recorded. Samples of leaves, stems, and roots were dry ashed and Na^+ and K^+ content were determined by flame-photometery (model PFP7, Jenway Ltd, UK). The chloride content of shoot (leaves and stems) and root were determined following the method of chapman and Pratt (1961) [5].

Factorial experiment was arranged in a completely randomized design with four replications and four plants per each replication. All data presented are the mean values and were subjected to analysis of variance using SPSS v. 16 (SPSS) Inc. computer software and means were compared by Duncan's

Multiple Range Test. Results discussed in the next section were significant at the 5% level.

RESULTS

Seedling height of 'Ghazvini' rootstock decreased with increasing salinity (Table 3). Application of PAs significantly increased stem height of seedling grown under salinity stress. Interaction of PAs and salinity prevent reduction of plant height of seedling rootstock (Table3).

Table 3. Effect of interaction of salinity and PAs on seedling height of Ghazvini rootstock (cm)

NaCl		Spermidine (mM)		Spermine (mM)		Mean
(mg kg^{-1} soil)	Control	1	2	1	2	
0	34.7 a-e[†]	38.2 ab	38.2 abc	41.7 a	39.6 ab	38.3 A
800	30.7 b-f	34.4 a-e	33.4 a-e	36.9 a-d	35.0 a-e	34.1 B
1600	21.0 gh	29.1 c-f	28.0 d-f	27.5 ef	29.1 c-f	26.9 C
3200	18.0 h	22.7 gh	21.8 gh	21.5 gh	20.8 f	21.0 D
Mean	26.1 A	31.1A	30.1 A	31.9 A	31.1 A	

[†] Means with the same letter are not significantly different from each other (Duncan's multiple range test, P<0.05).

The effects of Spm and Spd on root length are shown in table 4. Salinity significantly reduced root growth of seedling rootstock. Application of Spm and Spd at both concentrations in compare with control significantly increased root length. Interaction of PAs and salinity reduced the effect of salinity stress on root growth (Table 4).

By increasing the NaCl concentrations in the soil, seedlings' leaves decreased (Table 5). PAs and their interaction with salinity in compare with control increased number of leaves per 'Ghazvini' seedlings, significantly.

Table 4. Effect of interaction of salinity and PAs on seedling root length of Ghazvini rootstock (cm)

NaCl		Spermidine (mM)		Spermine (mM)		
(mg kg^{-1} soil)	Control	1	2	1	2	Mean
0	32.5 abc[†]	37.0 a	34.2 abc	31.5 bcd	32.7 abc	33.8 A
800	30.5 b-e	34.2 ab	32.5 abc	28.7 cde	30.5 b-e	31.7 B
1600	26.0 e	30.5 b-e	32.0 bcd	30.7 b-e	30.5 b-e	29.9 BC
3200	17.2 f	28.7 cde	30.2 b-e	27.2de	28.2 cde	26.0 C
Mean	26.5B	32.7 A	31.9 A	29.9 A	30.4 A	

[†] Means with the same letter are not significantly different from each other (Duncan's multiple range test, P<0.05).

Table 5. Effect of interaction of salinity and PAs on seedling leaf number of Ghazvini rootstock

NaCl		Spermidine (mM)		Spermine (mM)		
(mg kg^{-1} soil)	Control	1	2	1	2	Mean
0	10.1 bcd[†]	12.1 ab	11.8 abc	12.8 a	11.8 abc	11.7 A
800	9.3 de	11.7 abc	11.6 abc	12.2 ab	12.0 ab	11.3 A
1600	7.2 ef	9.0 de	9.2 de	9.8 cd	9.3 de	8.9 B
3200	6.1 f	7.6 ef	7.4 ef	8.5 de	8.4 de	7.6 C
Mean	8.2 B	10.1 A	10.0 A	10.8 A	10.4 A	

[†] Means with the same letter are not significantly different from each other (Duncan's multiple range test, P<0.05).

Increasing concentrations of NaCl in the soil in compare with control decreased stem dry weight of seedling rootstock significantly (Table 6). Application of PAs and their interaction with salinity had no significant effect on stem dry weight (Table 6).

Effects of PAs and salinity on leaf dry weight are shown in Table 7. Salinity stress reduced leaf dry weight, but application of PAs in compare with control significantly increased leaf dry weight (Table 7).

By increasing the salinity level in the soil, root dry weight reduced significantly (Table 8). Application of PAs increased root dry weight, but their effects were not significant.

Application of PAs significantly increased leaf area of seedling rootstock grown under salinity stress (Table 9). NaCl at 1600 and 3200 mg Kg^{-1} soil significantly reduced leaf area (Table 9).

Table 6. Effect of interaction of salinity and PAs on seedling stem dry weight of Ghazvini rootstock (g $Plant^{-1}$)

NaCl		Spermidine (mM)		Spermine (mM)		
(mg kg^{-1} soil)	Control	1	2	1	2	Mean
0	0.54 ab	0.65 a	0.58 ab	0.65 a	0.64 ab	0.61 A
800	0.50 bc	0.56 ab	0.56 ab	0.57 ab	0.58 ab	0.55 B
1600	0.41 cd	0.54 ab	0.51 bc	0.51 bc	0.49 bc	0.50 C
3200	0.28 e	0.36 de	0.33 de	0.31 de	0.31 de	0.32 D
Mean	0.43 B	0.52 A	0.50 A	0.51 A	0.50 A	

† Means with the same letter are not significantly different from each other (Duncan's multiple range test, *P*<0.05).

Table 7. Effect of interaction of salinity and PAs on seedling leaf dry weight of Ghazvini rootstock (g $Plant^{-1}$)

NaCl		Spermidine (mM)		Spermine (mM)		
(mg kg^{-1} soil)	Control	1	2	1	2	Mean
0	0.27 cde †	0.34 a	0.33 ab	0.35 a	0.33 ab	0.32 A
800	0.26 cde	0.32 ab	0.31 abc	0.34 a	0.32 ab	0.31 A
1600	0.20 fg	0.26 de	0.25 def	0.27 cde	0.27 cde	0.25 B
3200	0.19 g	0.24 def	0.23 efg	0.27 cde	0.26 de	0.24 B
Mean	0.23 B	0.29 A	0.28 A	0.31 A	0.29 A	

† Means with the same letter are not significantly different from each other (Duncan's multiple range test, *P*<0.05).

Table 8. Effect of interaction of salinity and PAs on seedling root dry weight of Ghazvini rootstock (g $Plant^{-1}$)

NaCl		Spermidine (mM)		Spermine (mM)		
(mg kg^{-1} soil)	Control	1	2	1	2	Mean
0	0.35 abc †	0.48 a	0.48 a	0.41 ab	0.38 ab	0.42 A
800	0.27 bcd	0.36 abc	0.34 abc	0.29 bcd	0.28 bcd	0.31 B
1600	0.21 cd	0.30 bc	0.29 bc	0.30 bc	0.30 bc	0.28 B
3200	0.14 d	0.20 cd	0.20 cd	0.20 cd	0.19 cd	0.19 D
Mean	0.24 A	0.33 A	0.33 A	0.30 A	0.29 A	

† Means with the same letter are not significantly different from each other (Duncan's multiple range test, *P*<0.05).

Table 9. Effect of interaction of salinity and PAs on seedling leaf area of Ghazvini rootstock (mm^2 $Plant^{-1}$)

NaCl		Spermidine (mM)		Spermine (mM)		
($mg\ kg^{-1}$ soil)	Control	1	2	1	2	Mean
0	2876 def †	3515 ab	3445 ab	3632 a	3515 ab	3397 A
800	2787 ef	3421 ab	3043 b-e	3546 a	3358 abc	3288 A
1600	2246 gh	2756 ef	2659 efg	3043 b-f	2923 c-f	2725 B
3200	2122 h	2610 efg	2456 fgh	2875 ef	2779 ef	2570 B
Mean	2489 B	3052 A	2950 A	3256 A	3130 A	

† Means with the same letter are not significantly different from each other (Duncan's multiple range test, $P<0.05$).

The interaction between salinity stress and PAs (Table 10) revealed that Spm and Spd reduced Na^+ content in the shoot at higher concentrations of salinity, significantly. By increasing salinity level in the soil Na^+ content in the shoot and the root of seedlings increased significantly (Tables 10 and 11). The interaction between salinity level and PAs reveal that Spm and Spd at both concentrations reduced Na^+ content in the root (Table 11).

Table 10. Effect of interaction of salinity and PAs on Na^+ content of seedling shoot of Ghazvini rootstock (%).

NaCl		Spermidine (mM)		Spermine (mM)		
($mg\ kg^{-1}$ soil)	Control	1	2	1	2	Mean
0	0.066 h	0.068 h	0.065 h	0.075 h	0.064 h	0.067 C
800	0.098 g	0.076 gh	0.070 h	0.075 gh	0.073 h	0.078 C
1600	0.239 e	0.186 f	0.181 f	0.194 f	0.177 f	0.196 B
3200	0.397 a	0.323 c	0.289 d	0.349 d	0.303 cd	0.332 A
Mean	0.2 A	0.163 A	0.151 A	0.174 A	0.155 A	

† Means with the same letter are not significantly different from each other (Duncan's multiple range test, $P<0.05$).

Table 11. Effect of interaction of salinity and PAs on Na^+ content of seedling root of Ghazvini rootstock (%)

NaCl		Spermidine (mM)		Spermine (mM)		
($mg\ kg^{-1}$ soil)	Control	1	2	1	2	Mean
0	0.155 ij †	0.156 ij	0.148 j	0.159 hij	0.159 hij	0.155 D
800	0.303 f	0.293 gh	0.286 ghi	0.216 g	0.210 g	0.222 C
1600	0.489 d	0.326 ef	0.317 f	0.359 e	0.327 ef	0.364 B
3200	0.804 a	0.632 c	0.623 c	0. 679 b	0.656 bc	0.679 A
Mean	0.437 A	0.327 A	0.319 A	0.353 A	0.388 A	

† Means with the same letter are not significantly different from each other (Duncan's multiple range test, $P<0.05$).

Application of the PAs increased K^+ concentration in the shoot, but their effects were not significant. By increasing the salinity level in the soil, the K^+ content in the shoot significantly increased (Table 12). The interaction between PAs and salinity level in the soil (Table 12) reveal that Spd at both concentrations significantly reduced accumulation of K^+ in the root. In contrast to the shoot, K^+ concentration in the root was decreased by increasing salinity level in the soil (Table 13).

Table 12. Effect of interaction of salinity and PAs on K^+ content of seedling shoot of Ghazvini rootstock (%)

NaCl		Spermidine (mM)		Spermine (mM)		
(mg kg^{-1} soil)	Control	1	2	1	2	Mean
0	0.84 i †	0.87 hi	0.85 i	0.87 hi	0.86 i	0.86 D
800	0.93gh	1.04 efg	1.02 efg	0.99 fg	0.97 fgh	0.99 C
1600	1.07 cde	1.12 cde	1.07 cde	1.20 bc	1.11 cde	1.10 B
3200	1.20 bc	1.23 bc	1.19 bc	1.31 a	1.28 ab	1.23 A
Mean	1.01 A	1.04 A	1.03 A	1.09 A	1.05 A	

† Means with the same letter are not significantly different from each other (Duncan's multiple range test, P<0.05).

Table 13. Effect of interaction of salinity and PAs on K^+ content of seedling roots of Ghazvini rootstock (%)

NaCl		Spermidine (mM)		Spermine (mM)		
(mg kg^{-1} soil)	Control	1	2	1	2	Mean
0	0.80 a †	0.70 ef	0.65 gh	0.79 ab	0.77 abc	0.74 A
800	0.75 bcd	0.64 gh	0.64 gh	0.72 def	0.74 cde	0.70 B
1600	0.74 cde	0.65 gh	0.62 h	0.71 def	0.73 def	0.69 B
3200	0.72 def	0.62 h	0.64 gh	0.68 fg	0.72 def	0.68 B
Mean	0.75 A	0.65 B	0.64 B	0.72 A	0.74 A	

† Means with the same letter are not significantly different from each other (Duncan's multiple range test, P<0.05).

The K^+/Na^+ ratio in the shoot was decreased by increasing the NaCl level in the soil (Table 14). Application of the PAs increased K^+/Na^+ ratio in the shoot, but their effects were not significant (Table 14). The interactions between salinity levels in the soil and application of PAs were effective on K^+/Na^+ ratio in this experiment (Table 14).
The Cl^- content of the shoot in compare with control significantly was increased by increasing the NaCl concentration in the soil (Table 15). Interaction between the PAs and salinity levels reveal that PAs had a significant effect on reduction of Cl^- content in the shoot under salinity stress (Table 15). Spm at 2 mM significantly reduced Cl^- content in the shoot. By increasing the concentration of NaCl in the soil, the Cl^- content in the root increased significantly (Table 16). Interaction between PAs and salinity stress (Table 16) showed that Spd increased Cl^- content in the root, significantly.

Table 14. Effect of interaction of salinity and PAs on K^+:Na^+ of seedling shoots of Ghazvini rootstock.

NaCl		Spermidine (mM)		Spermine (mM)		
(mg kg^{-1} soil)	Control	1	2	1	2	Mean
0	12.6 cd †	12.7 abc	13.0 a-d	11.6 d	12.7 abc	12.7 A
800	9.5 e	14.2 ab	14.4 a	12.6 abc	13.4 abc	12.7 A
1600	4.4 gh	5.7 fg	5.9 fg	6.2 f	6.3 f	5.7 B
3200	3.0 h	3.6 h	4.1 h	3.6 h	4.2 h	3.7 C
Mean	7.4 A	9.1 A	9.4 A	8.5 A	9.1 A	

† Means with the same letter are not significantly different from each other (Duncan's multiple range test, P<0.05).

Table 15. Effect of interaction of salinity and PAs on Cl^- content of seedling shoot of Ghazvini rootstock (mg g^{-1} Dry weight).

NaCl (mg kg^{-1} soil)	Control	Spermidine (mM) 1	Spermidine (mM) 2	Spermine (mM) 1	Spermine (mM) 2	Mean
0	1.13 fgh †	1.02 ij	1.00 j	0.94 j	0.91 j	1.00 A
800	1.24 e	1.13 fgh	1.09 g-j	1.03 h-j	1.06 ij	1.09 B
1600	1.34 d	1.22 ef	1.18 efg	1.12 ghi	1.06 h-k	1.18 C
3200	1.93 a	1.75 b	1.66 b	1.61 bc	1.53 c	1.70 D
Mean	1.41 A	1.28 AB	1.24 AB	1.17 AB	1.11 B	

† Means with the same letter are not significantly different from each other (Duncan's multiple range test, P<0.05).

Table 16. Effect of interaction of salinity and PAs on Cl^- content of seedling root of Ghazvini rootstock (mg g^{-1} Dry weight).

NaCl (mg kg^{-1} soil)	Control	Spermidine (mM) 1	Spermidine (mM) 2	Spermine (mM) 1	Spermine (mM) 2	Mean
0	0.91 g †	0.81 h	0.86 gh	0.88 gh	0.91 g	0.87 B
800	1.02 e	0.91 g	0.94 fg	0.97 ef	1.02 e	0.97 AB
1600	1.15 cd	0.93 fg	1.00 ef	1.09 d	1.15 cd	1.00 AB
3200	1.30 a	1.09 d	1.19 bc	1.24 ab	1.31 a	1.22 A
Mean	1.09 A	0.93 B	1.00 AB	1.05 AB	1.09A	

† Means with the same letter are not significantly different from each other (Duncan's multiple range test, P<0.05).

DISCUSSION

High NaCl concentrations caused a serious reduction in growth parameters such as seedling shoot and root length, and number of leaves of pistachio seedling rootstock. Treatments consisting of 800 to 3200 mg NaCl Kg^{-1} soil caused growth reduction and leaf abscission in this study (Tables 3, 4, and 5). The reduction in growth can be explained by low osmotic potential of soil solution, which leads to decrease water uptake, transpiration and closure of stomata, which is associated with the reduced photosynthesis [4]. It was reported that salinity damaged root tips of *P. atlantica*, *P trebinthus* and PG II at 175 mM NaCl with 12.5 to 17.5 mM Ca. Cell injury increased linearly with salinity (R^2 = 0.81) and was highest in root tips of *P. trebinthus* [14]. Salt treated seedling had fewer numbers of leaves than control plants (Table 5). Decrease in the number of leaves was not only connected with the growth inhibiting effects of salt, but also to the injurious effects of salt due to defoliation of the leaves [18].

Most researches have demonstrated that exogenous PAs could in various degree reverse growth or minimize growth inhibition caused by salt stress. In this study, exogenous application of Spm and Spd on pistachio rootstocks seedlings was shown to be effective for reversing the inhibitory effects of salt stress (Table 3). Higher concentrations of Spm and Spd were more effective in mitigating salinity injury on pistachio seedlings. The same results were reported on mulberry [8], which foliar spray of Spm (1 mM) reduced the detrimental effects of saline stress. Salinity reduced fresh and dry weight of stems, leaves, and roots of pistachio seedling rootstock (Tables 6, 7, and 8). The reduction in dry weight was attributed to lower leaf number and limitation of leaf development with increased salinity of the soil [12]. Interaction between Spm and Spd and salinity stress revealed that PAs by increasing leaf area of seedlings (by preventing leaf injuries and leaf abscission) under the saline condition, increased leaves' dry weight of seedlings (Table 9).

Our study showed that root system of 'Ghazvini' rootstock retains higher quantity of Na^+ and limits Na^+ transport to leaves (Tables 10 and 11). Similar results have shown that root system of other members of this genus, *P. atlantica* and *P trebinthus*, retain larger quantities of Na^+ and limit Na^+ transport to leaves [9,19]. There was a higher K^+ concentration in the shoot than in the roots (Tables 12 and 13); from our results (Tables 10 and 11) it is clear that PAs prevent the uptake of Na^+ and loss of K^+ from the plant tissue. The accumulation of Na^+ and loss of K^+ ions due to NaCl treatments were most prominent in the 'Ghazvini, pistachio rootstock. PAs actually increased uptake of K^+ and reduced accumulation of K^+ in the root (Tables 12 and 13). In the case of salinity stress, a beneficial effect of an exogenous PA may be related to the improvement of the ion balance in salt treated cells due to its cationic nature as reported by Ndayiragije and Luttus (2006), who showed the exogenous Put at 1 mM clearly decreased both Na^+ and Cl^- accumulation of rice calli exposed to salt [13]. The same result was reported by Ali (2000), application of Put reduced the net accumulation of Na^+ and Cl^- ions in different organs of *Atropa belladonna* subjected to salinity stress [1]. PA treated seedlings under saline conditions showed a higher K^+/Na^+ ratio in the shoots, suggesting an improved discrimination among movement of cations at the root level, especially at the sites of xylem loading [10].

'Ghazvini' pistachio rootstock seedlings grown under salinity stress (800-3200 mg Kg^{-1} soil) showed an accumulation of Cl^- in the shoots after 12 weeks. Walker et al. (1987) reported that the shoots of *P. vera* and *P. atlantica* treated with 30 mM NaCl for 9 weeks showed no marked change in Cl^- concentrations during the period of salt treatment [19]. They found that the rates of uptake and root to shoot transport of Cl^- were identical with the two species, but shoot Cl^- concentrations were less in the species with a higher relative growth rate. Exogenously applied Spm and Spd in compare with control significantly reduced accumulation of Cl^- in the shoot and could prevent damage to the shoot tissues (Table 17).

The research exhibited the relative effect of PAs on reduction of accumulation of Na^+ and Cl^-, and increase of K^+ concentration and K^+/Na^+ ratio in the shoot tissue. The 'Ghazvini, pistachio rootstock also appears to be a voluble rootstock with a sufficient level of salt tolerance to be grown in areas where poor-quality soil and irrigation water are problematic.

REFERENCES

1. Ali, R.M., 2000. Role of putrescine in salt tolerance of *Atropa belladonna* plant. Plant Sci., 152, 173-179.
2. Allen, G.J., Jones, R.G.W. and Leigh, R.A., 1995. Sodium transport measured in plasma membrane vesicles isolated from wheat genotypes with differing K^+/Na^+ discrimination traits. Plant Cell Environ., 18, 105-115.
3. Behboudian, M.H., Walker, R.R. and Torokfalvy, E., 1986. Effect of water stress and salinity on photosynthesis of pistachio. Sci. Hortic., 29, 251-261.
4. Ben-Asher, J., Tsuyuki, I., Bravdo, B.A. and Sagih, M., 2006. Irrigation of grapevines with saline water, I. leaf area index, stomatal conductance, transpiration and photosynthesis. Agric. Water Manag., 83, 13–2
5. Chapman, H.D. and Pratt, D.F., 1961. Methods of analysis for soil, plant and water. Uni. Cal. Div. Agric. Sci., 60-62.
6. Chattopadhayay, M.K., Tiwari, B.S., Chattopadhayay, G., Bose, A., Sengupta, S. and Ghosh, B., 2002. Protective role of exogenous polyamines on salinity-stressed rice (*Oryza sativa*) plants., Physiol. Plant. 116, 192–199.
7. Cramer, G.R., 2002. Sodium-calcium interactions under salinity stress. In: Lauchli, A., Luttge, U. (Eds) Salinity. Environment-

Plants-Molecules, Kluwer Academic Publishers, Dordrecht, The Netherlands, pp 205-227.

8. Das, C., Sengupta, T., Chattopadhay, S., Setua, M., Das, N.K. and Saratchandra, B., 2002. Involvment of kinetin and spermidine in controlling salinity stress in mulberry (*Morus alba* L. cv. S1). Acta Physiol. Plant., 24(1), 53-57.
9. Figueroa, V.U., 1989. Comportamiento de cultivares y portainjertos de pistache (*Pistacia* spp) en condiciones de salinidad., maestria, colegio de postgraduados.
10. Gill, S.S. and Tuteja, N., 2010. Polyamines and abiotic stress tolerance in plants. Plant Sign. Behav., 5, 26-33.
11. Karimi, S., Rahemi, M., Maftoun M., Eshghi, S. and Tavallali, V., 2009. Effect of long-term salinity on growth and performance of two pistachio (*Pistacia vera* L.) rootstocks. Aust. J. Bas. App. Sci., 3(3), 1630-1639.
12. Musyimi, D.M., Netondo, G.W. and Ouma, G., 2007. Effects of salinity on growth and photosynthesis of avocado seedlings. Internat. J. Bot., 3, 78-84.
13. Ndayiragije, A. and Lutts, S., 2006. Exogenous putrescine reduces sodium and chloride accumulation in NaCl-treated calli of the salt-sensitive rice cultivar I Kong Pao. Plant Growth Regul., 48, 51-53.
14. Picchioni, G.A. and Miyamoto, S., 1991. Rapid testing of salinity effects on pistachio seedling rootstock. J. Amer. Soc. Hort. Sci., 116, 555-559.
15. Picchioni, G.A. and Miyamoto, S., 1990. Salt effects on growth and ion uptake of pistachio rootstock seedlings. J. Amer. Soc. Hort. Sci., 115, 647-653.
16. Pistocchi, R., Antognoni, F., Bagni, N. and Zannoni, D., 1990. Spermidine uptake by mitochondria of Helianthus tuberosus. Plant Physiol., 92, 690-695.
17. Tavallali, V. and Rahemi, M., 2008. Calcium induces salinity tolerance in pistachio rootstocks. Fruits, 63, 201-211.
18. Turhan, E. and Eriş, A., 2007. Growth and stomatal behavious of two strawberry cultivars under. long-term salinity stress. Turk. J. Agric. For., 31, 55-61.
19. Walker, R.B., Torokfalvy, E. and Behboudian, M.H., 1987. Uptake and distribution of chloride, sodium and potassium ions and growth of salt-treated pistachio plants. Aust. J. Agri. Res., 38, 383-394.