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Evaluation of Potassium Silicate Applying to Reduce Adverse Effects of Salinity on Marigold Plant (*Tagetes erecta* L. 'Nana')

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Abstract

In order to evaluation of mitigation effect on salinity stress on the morphological and biochemical properties of marigold (*Tagetes erecta* L. Nana), an experimental was carried out in factorial arrangement base on randomized complete block design in three replications at Khorasan Razavi Agriculture Research and Education Center in 2018. The first factor was four salinities (0, 4, 8 and 12 dS m^{-1}) and the second factor was potassium silicate (PS) at three levels (0, 100 and 150 ppm). The results showed that the highest plant height was obtained at zero salinity with application 100 ppm PS. The highest shoot dry weight was recorded at salinity of 8 dS m^{-1} with 150 ppm PS. The highest amount of leaf potassium was observed at salinity of 12 dS m^{-1} with using of 100 ppm PS and the highest amount of root potassium was obtained at 4 dS m^{-1} salinity treatment with 100 ppm PS. The results was also showed that in marigold at high salinity (more than 8 dS m^{-1}), potassium silicate composition could not have a favorable effect on plant growth. The use of PS in salinity of 12 dS m^{-1} was able to reduce the concentration of sodium in leaf tissues and increase the amount of potassium, although the amount of potassium increase was higher in low salinities. In general, the use of potassium silicate can be considered as a supplement in plant nutrition at low salinities.

Keywords: Plant height, Potassium, Shoot dry weight, Sodium.

INTRODUCTION

Salinity is one of the most important stressors that limiting the productivity of crops and orchards. Significant sections from the lands in the world are under the influence of salinity and it is estimated that speed spread salt is about 1.5 million hectares per year. The World Food Organization (WHO) states that approximately 20% of the land irrigated by the pressurized irrigation system is estimated at 227 million hectares, so that they are also part of saline soils. Most of these saline soils are located in 100 countries that located in arid and semi-arid region of the world (Munns *et al*., 2002). About 90% of Iran's area is located in arid and semi-arid climate (Qureshi *et al*., 2007). The area of saline soils in Iran is about 24 million hectares, which is equivalent to 15% of the agriculture land in country. Therefore, salinity stress has always been raised in Iranian agriculture and it is necessary to find solutions to face it. Due to the lack of proper irrigation management, the agriculture land seriously affected by the processes of salinization and chemical degradation of soil (Jafari, 1994). Salinity affects plants in two ways: 1) The effect of osmosis, which reduces the osmotic potential of the soil solution, impairs the absorption of water by the plant, and 2) The effect of ion, which causes ion toxicity (due to the high concentration of toxic ions, such as chlorine and sodium) cause damage and changes physiological and morphological morphology in the plant (Munns and Termaat, 1986). In salinity stress caused by Na^+, the damage to the leaves is always much greater than the roots, and the reason of it, is the accumulation of more Na^+ and Cl^- in the leaves than the roots. When Na^+ stress occurs, there is a marked deficiency of other nutrients as well, because an increase in Na^+ interferes with the absorption of other nutrients. One of the solutions to reduce the harmful effects of salinity is to use the methods of minerals nutrition, including silicon. Silicon is the second most abundant element (27.6%) in the earth's crust and in most biological and non-biological stresses, its positive effects have been proven (Liang *et al*., 2007). In the soil solution, the form of silicon is monosilicic acid (H_2SiO_4) is dissolved in silica and is absorbed by plants in the same form (Marschner, 1995). Numerous studies have shown that this element (silicon) has a positive effect on growth and plant yield (Ma and Takahashi, 2002). Peyvast *et al*. (2008) reported that potassium silicate improved salinity stress tolerance in lettuce. Similar results have been reported that application of silicon compound was alleviated the salinity stress (Liang *et al*., 2007). Potassium silicate is involved in inducing, reducing transpiration and inhibiting transpiration bypasses.

Marigold (*Tagetes erecta* L.) belongs to the genus Asteraceae, from Mexico and is now cultivated all over the world and is one of the spring and summer flowers. This plant is annual and its flowers appear in colors of lemon yellow, cream yellow, golden and orange, brown (Ghasemi Ghahsareh and Mohammadi, 2008). This plant used both as a garden flower and as a cut and potted flower. It is used commercially for the extraction of carotene and especially xanthophyll. Extracted carotenoids of this plant are used to intensify the coloration of eggs, that added to food of chickens. The leaves of this plant contain special aromatic oils, which are used in the treatment of insects. Due to climate change, increased evapotranspiration and the use of unconventional water in agriculture has increased the concentration of mineral ions in the plant, which lead to decreased in morphological, physiological and biochemical traits in plants, therefore, this study was conducted to evaluated effect of potassium silicate on salinity stress in marigold plant.

MATERIALS AND METHODS

In order to study the effect of potassium silicate on the alleviated salinity stress on marigold flower (*Tagetes patula* L. 'Nana') an experimental was carried out in factorial arrangement base on randomized complete blocks design with three replications in Khorasan Razavi Agriculture Research and Education Center in Mashhad in summer 2018. The first factor was salinity at four levels (0, 4, 8 and 12 dS m^{-1}) and the second factor was three levels of potassium silicate (0, 100 and 150 ppm). At first, the seeds were planted in a seedling tray containing coco peat on 6th May, after reaching the 6-leaf stage, they were transferred to the pots (volume of pot was 7 kg), and 4 plants was sowing in each pot. The results of potting soil analysis was showed in table 1. Before applying the stress, the pots were irrigated with ordinary water for 25 days. For application treatment we used of NaCl salt (Merck Germany) and potassium silicate (with the trade name of SILICOCARB). For preparation EC water was used equation 1 and 2:

$$\text{Equation 1: } EC<7 \quad TDS = EC \times 640$$
$$\text{Equation 2: } EC>7 \quad TDS = EC \times 800$$

Total dissolved solids (TDS) was the amount of salt used in terms g L^{-1}.

The plants were irrigated with prepare solution treatment after adapting plants to the new conditions in the 10-leaf stage, and in each irrigation, the EC of solution was measured before irrigation with NALFLEET EC meter apparatus. To ensure equal of EC input and output at the bottom of each pot is placed a holes, and measured the EC of drains. In the next irrigation, which took about 24 to 48 hours, irrigation was performed with water containing potassium silicate. The control plants were irrigated with ordinary water (without salinity and silica). This process was carried out up to 5 stages irrigation with salinity water and water containing silica alternately and the irrigated was stopped when the plants reached the stage of 50% flowering. At the end of this stage, morphological traits (plant height, number of branches, fresh and dry weight of shoot and root and root volume) were measured. To measure the amount of potassium and sodium in leaves and roots, dry digestion method was used and sodium and potassium were measured with a flame photometer apparatus.

Data were analyze variance by Minitab-16 and MSTATC software's. The means were compared with Duncan test at 5% probability level and the graphs were drawn with Excel software.

Table 1. Physical and chemical properties of soil.

Texture	K (ppm)	P (ppm)	N (%)	OM (%)	OC (%)	pH	EC (dS m^{-1})
Loam	284	8.19	0.21	1.87	2.59	7.8	1.51

RESULTS AND DISCUSSION

Plant height

The results of analysis of variance showed that the effect of salinity and potassium silicate (PS) and interaction of salinity and PS was significant different on plant height ($P<0.01$) (Table 2). By increasing salinity, the amount of plant height was reduced, and higher levels of salinity further reduced plant height. The highest plant height (56.6 cm) was recorded from zero salinity with 100 ppm PS and the lowest of it was obtain at salinity solution (12 dS m^{-1}) with no application of PS. The results showed that the application of PS at high levels of salinity did not have much effect and only affected up to salinity of 4 dS m^{-1}, so that at the salinity level of 4 dS m^{-1} with consumption of zero and 150 ppm PS and plant height were placed in 51.66 and 50.66 cm, respectively (Fig 1, A). Bayat *et al*. (2013) stated that salinity stress was reduced number of flowers and diameter of flowers, and height of plants in compared of control in Gerbera plant. In another research application silica in non-saline condition was reduce plant height in marigold plant in compare of control, but in salinity condition, application of silica was increased the plant height in two marigold plant (Orange and Yellow Boy) (Iyyakkannu *et al*., 2010). It seems that increase of concentration of potassium in the root zone and also increase its concentration gradient in soil solution and surfaces of clay minerals have caused improved the absorption of water and other nutrients (Lasof and Bernstein, 1998).

Shoot dry weight

The results of table 2 showed that shoot dry weight was affected by salinity and PS and their interaction. The highest amount of shoot dry weight was in 4 dS m^{-1} with application 100 and 150 ppm PS, that both of which were statistically in one group. The lowest this trait (8 g $plant^{-1}$) was at 12 dS m^{-1} salinity with zero ppm PS (Fig 1, b). Gorgi *et al.* (2009) reported that shoot dry weight of safflower decreased under saline conditions. Research has shown that the silica has efficacy on increase plant resistance to salinity and plant growth. Valdez-Aguilar *et al*. (2009) and Rezaei *et al*. (2010) observed that salinity reduced the branch dry weight of marigold flower. Under salinity stress, sodium can replace calcium in plasma membranes, which alters the permeability of the it, thus, causing potassium leakage from the cell membrane. Tarzi (1995) reported that increasing salinity strongly inhibits organelle formation in cumin, which in turn leads to a decrease in biomass. Results in barley (Penuelas *et al*., 1997) and barley and wheat (Pessarakli *et al*., 1991) showed that salinity stress was decrease stem length and shoot dry weight. The results of this study showed that the use of 100 and 150 ppm potassium silicate has significantly increased the amount of shoot dry weight. It seems that in salinity stress potassium silicate had positive effect of plant growth that lead to increased shoot dry weight.

Table. 2. Results of analysis of variation some morphological traits in marigold.

S.o.V	df	Plant height	Biomass	Root dry weight	Number of branch	Root length	Root volume
Block	2	1.17^{ns}	0.636^{ns}	0.066^{*}	2.98^{**}	0.091^{ns}	0.007^{ns}
Salinity	3	290^{**}	20.1^{**}	0.062^{*}	5.33^{**}	3.42^{**}	0.394^{**}
Potassium silicate (PS)	2	17.4^{**}	7.01^{**}	0.684^{**}	0.471^{ns}	0.432^{**}	0.036^{**}
Salinity × PS	6	34.9^{**}	26.2^{**}	0.220^{**}	1.59^{**}	0.602^{**}	0.051^{**}
Error	22	1.36	0.485	0.015	0.219	0.037	0.009
CV (%)		12.1	7.51	8.16	12.1	10.6	9.11

^{ns}, * and **: Non-significant , significant at $P < 0.05$ and $P < 0.01$, respectively.

Root dry weight

The effect of potassium silicate (PS) in salinity stress on root dry weight was significant (table 2). The interaction of salinity in PS showed that the highest root dry weight (1.9 g $plant^{-1}$) was recorded from zero salinity with 100 ppm PS and in the second scale application of 150 ppm of PS in 4 dS m^{-1} had also the maximum root dry weight. The lowest root dry weight was observed at zero level of PS in all three salinity levels (4, 8 and 12 dS m^{-1}). However, the effect of PS was more dominance in salinity levels at 4 and 8 dS m^{-1} (Fig 1, c). Lim *et al*. (2012) stated that consumption PS was induce higher opening stomata plant, that lead to increase the photosynthesis rate.

Ma (2004) suggested that stomata are responsible for gas exchange, evaporation, and plant perspiration, which, if closed, reduce the photosynthesis rate and reduction assimilation substance. In another study, Marshner (1995) reported that a large portion of sodium is absorbed by plants passively and the absorption process is affected by the transpiration rate, as a result reduction of sodium absorption may be due to the effect of silicon on transpiration rate.

Number of branch

The results of analysis of variance showed that salinity and interaction salinity × potassium silicate (PS) had significant different on the number of lateral branches, but the PS was not significant on this trait (Table 2). The highest number branches were obtaining at 100 ppm PS at 4 dS m^{-1} that the number of branches was 22% more than the zero PS at 4 dS m^{-1} salinity stress treatment and the lowest of it was recorded at zero PS at 12 dS m^{-1} salinity (Fig 1, d). The results was showed that reduction number of branches was observed in high salinity level, but the use of PS in this salinity levels was improved the plant growth and prevented for more decline of growth. The results of Rahimi *et al*. (2011) showed that the increase in salinity up to 14 dS m^{-1} did not significant different on number of branches in *Portulaca oleracea* plant, so that the number of branches was 15.1, 14.5, 14.8 at 0, 7 and 14 dS m^{-1} respectively, but there was a significant decrease at 21 dS m^{-1}, so that the number of lateral branches was 9.6 at 21 dS m^{-1} salinity stress.

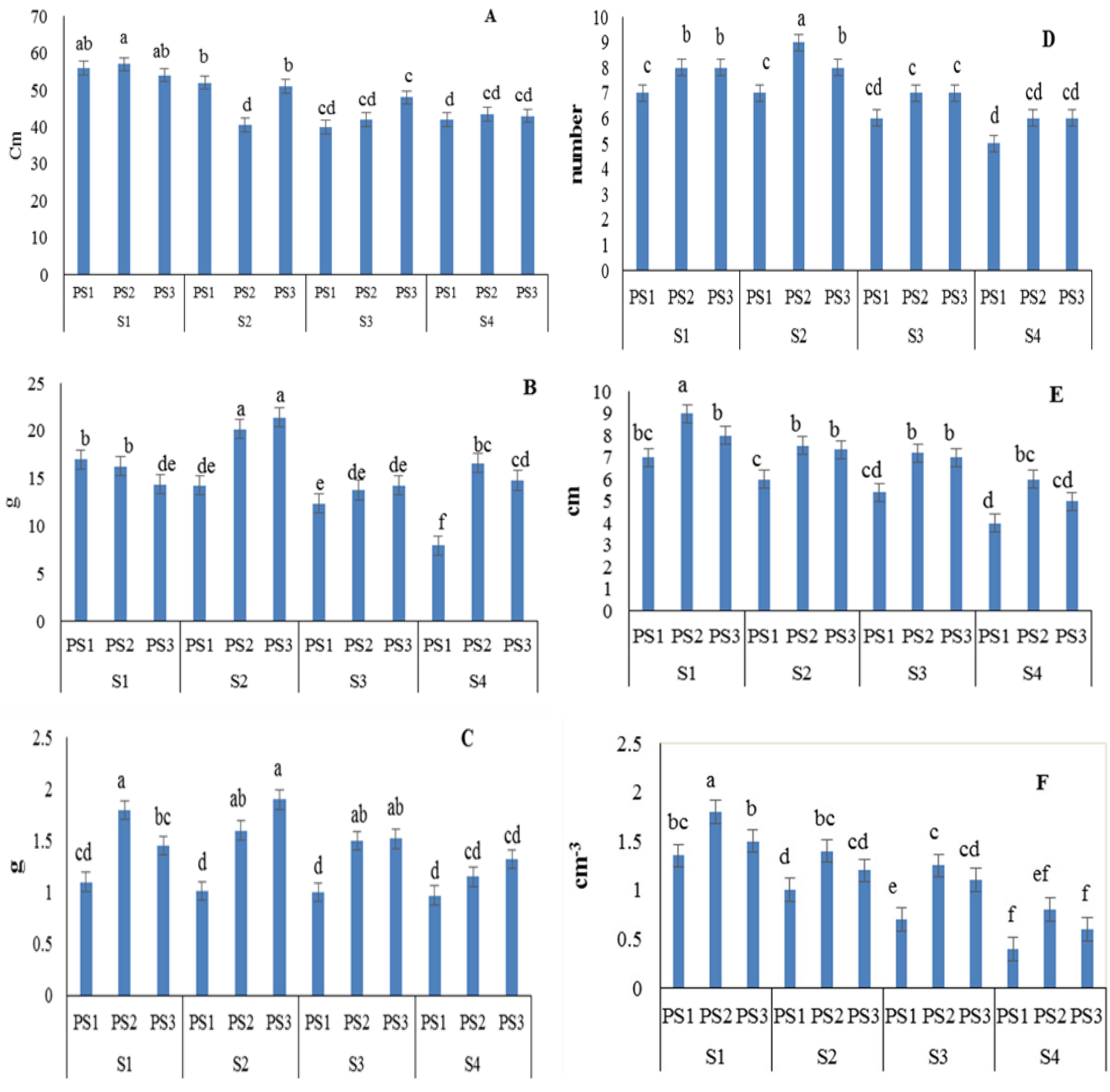

Fig. 1. The effect of potassium silicate treatment on morphological traits of marigold in different salinities treatments. A) Plant height, B) Shoot dry weight, C) Root dry weight, D) Number of lateral branches, E) Root length, and F) Root volume. SP1, SP2 and SP3: Levels of zero, 100 and 150 ppm potassium silicate, respectively. S1, S2, S3 and S4 have zero, 4, 8 and 12 dS m^{-1} salinity levels, respectively.

Root length

The efficacy of salinity, potassium silicate (PS) and their interaction had significant different on root length (Table 2). Although salinity had a inhibitory effect on root length, but the use of PS treatment reduced effect of salinity on root length, so that the zero of PS at all salinity treatments had the lowest amount of root length in compare of the applied of PS. The maximum root length

(9 cm) was at zero salinity with consumption of 100 ppm PS and the lowest root length (4 cm) was recorded at 12 dS m^{-1} and zero ppm PS (Fig 1, e). The increasing root length can be as one way to increase tolerance to abiotic stress. Higher root-to-shoot ratio under stress conditions helps to increase plant tolerance, and stress-tolerant plants have more root-to-shoot ratio and plant access to more water and nutrients. The roots are more exposure to salinity stress than other organs, it controls the passage of ions and provide the relative ion of sodium and potassium for cellular activities.

Any disturbance in the system of adsorption and transfer of selective ions which is caused by the adverse effects of chemical conditions on the soil environment can be effect on the physiological processes and lead to poisoning effects on plant (Munns and Schachtman, 1993). Kauri *et al*. (2011) reported that root dry weight was low reduction by application of silicon in the root environment of sorghum under salinity stress, which was accompanied by an increase in water absorption. The use of silicate reduced the osmotic potential of the root without affecting the water content, this indicates that osmotic regulation has occurred with increasing water absorption.

Root volume

There was significant different effect of salinity, potassium silicate (PS) and their interaction on root volume (Table 2). Results showed that root volume was decreased with increase salinity level, but when applied PS, the root volume was increased in compare of other treatments (Fig 1, f). In saline free medium, root volume had better increased than in saline environments by application PS. In salinity stress, with increase the concentration of salt in the nutrient solution, osmotic potential of the solution was also increases, that lead to decreased the water uptake and consequently the cell turgor pressure was decreased. The cell growth rate was inhibited by outflow water from it, on the other hand, reduction in growth of branches and leaves also reduced the root growth rate. With shrink and or fall of leaves, the assimilate substance was decreased, therefore the amount of materials reaches to root cell was decreased and lead to decreased the root volume. The results in pumpkin plant showed that the biomass of plant was increased by application of silicon in salinity stress (Savvas *et al*., 2009). In another study, plant growth rate was improved in beans by application of silicon under salinity stress (Zuccarini, 2008).

Leaf potassium

The effect of salinity, potassium silicate (PS) and their interaction was significant on leaf potassium content (Table 3). The highest leaf potassium (60.4 mg g^{-1} leaf dry weight (LDW)) was obtained at interaction 100 ppm PS at 12 dS m^{-1} salinity treatment and the lowest of leaf potassium was obtained at 4 dS m^{-1} salinity and application of zero ppm PS (Fig 2, a). The lowest potassium was observed at control in all treatments. Maintaining the optimal amount of potassium in plants is very important in saline environments, because potassium plays an important role in regulating the osmotic potential of plant cells. The ratio of potassium to sodium can be a good indicator of tolerance plant to salinity. High levels of sodium ions in saline environments not only inhibit potassium uptake, but also impair the selective uptake of ions by damaging cell membranes (Marschner, 1995).

Azizi *et al.* (2016) showed that salinity increased the concentration of sodium ions and decreased potassium and calcium ions in the roots and aerial parts of the alfalfa plant (*Medicago scutella* L.). Silicon appears to be concentrated slowly after entering the plant, gently, and precipitated silica in the endoderm and polymerization. Silicate from colloidal silica to silica gel or polysilicic acid throughout the apoplast reduces the uptake of some elements from the outer root cell pathway (Yeo *et al.*, 1999).

Table. 3. Results of analysis of variation (means of squares) K^+ and Na^+ amount of leaf and root of marigold plant.

S.o.V	df	Root Na^+	Root K^+	Leaf Na^+	Leaf K^+
Block	2	0.257^{ns}	0.470^{**}	0.407^{*}	0.570^{ns}
Salinity	3	52.7^{**}	127^{**}	0.287^{**}	538^{**}
Potassium Silicte (PS)	2	81.8^{**}	42.3^{**}	2.09^{**}	15.3^{**}
Salinity×PS	6	72.8^{**}	26.6^{**}	49.5^{**}	38.5^{**}
Error	22	0.124	0.037	0.107	0.220
CV (%)		9.7	6.7	5.7	8.6

^{ns}, * and **: Non-significant , significant at $P < 0.05$ and $P < 0.01$, respectively.

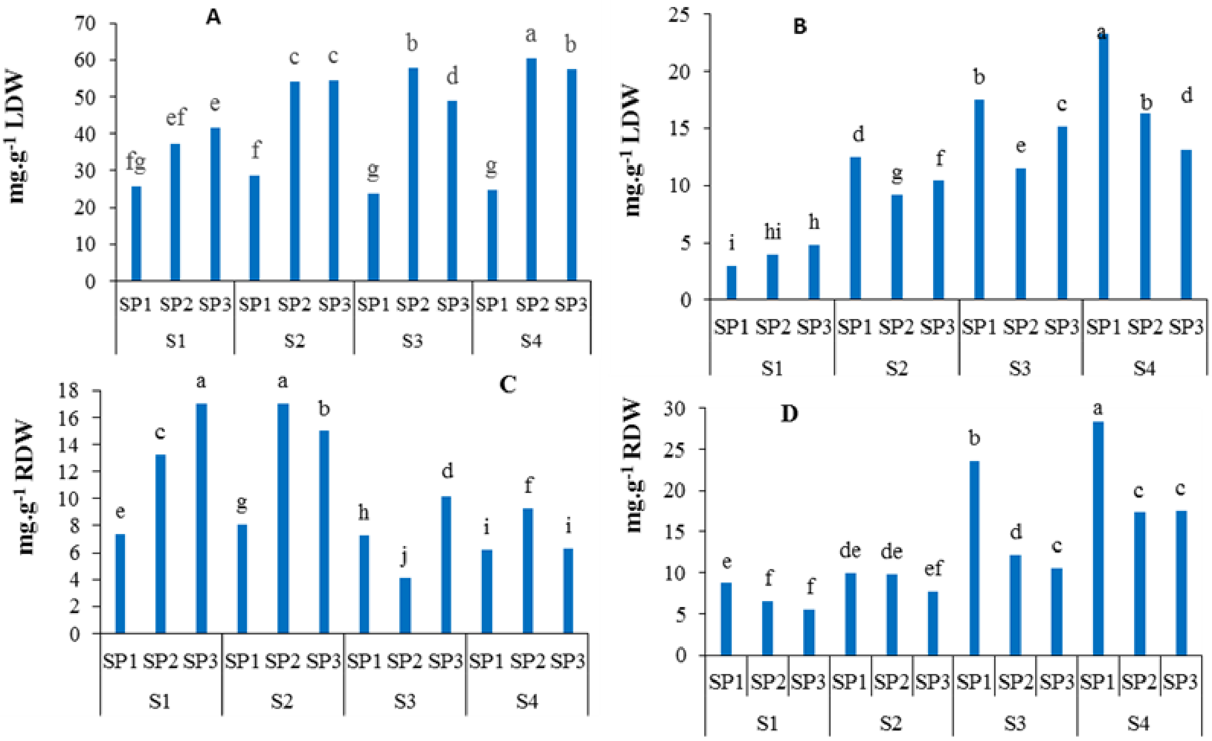

Fig. 2. The effect of potassium silicate treatment onamount of amount of Na^+ and K^+ in leaf and root in marigold plant in different salinities treatments. A) Leaf K^+, B) Leaf Na^+, C) Root K^+ and D) Root Na^+. SP1, SP2 and SP3: Levels of zero, 100 and 150 ppm potassium silicate, respectively. S1, S2, S3 and S4 have zero, 4, 8 and 12 dS m^{-1} salinity levels, respectively.

Leaf sodium

The results of analysis of variance showed that the effect of salinity, potassium silicate (PS) and their interaction had significant effect on leaf sodium (Table 3). The highest leaf sodium (23.2 mg g^{-1} leaf dry weight (LDW)) was at 12 dS m^{-1} salinity without use of PS and the lowest of leaf sodium (3 mg g^{-1} LDW) was observed in zero salinity and zero PS. The amount of leaf sodium at 8 and 4 dS m^{-1} with no application of PS was 17.5 and 12.5 mg g^{-1} LDW, respectively (Fig 2, b). The results of Bandani and Abdolzadeh (2007) showed that salinity caused an increase in sodium ion both aerial and root parts of the plant poxinelia. In this experiment, silicon treatments reduced the sodium ion in the aerial and root part, however, some silicon treatments increased the potassium content of the roots and shoots of Poxinelia plant, but this increase was not significant. Zhao *et al.* (2005) suggested that silicon reduces the permeability of plasma membranes and also preserves peroxidation of plasma membranes and their health under salinity, resulting reduced salinity toxicity and improves plant growth. Zucarini (2008) reported that silicon improved bean growth under salinity stress by reducing the amount of leaf electrolyte leakage.

Root potassium

The root potassium was affected by influence of salinity, potassium silicate (PS) and their interaction (Table 3). The highest amount of root potassium (7 mg g^{-1} root dry weight (RDW)) was at zero salinity with 150 ppm PS. The lowest amount of root potassium (1.4 mg g^{-1} RDW) was recorded at 8 dS m^{-1} and consumption of 100 ppm PS (Fig. 2, c). These results show that in the simple effect of salinity, with increasing salinity level, the amount of root potassium was decreased, because sodium around the roots prevents the absorption of potassium, and by increasing the amount of silicate from zero to 100, and then to 150 ppm, it improves potassium uptake and increases root potassium. A study conducted by Azizi *et al*. (2016) on alfalfa (*Medicago scutellata* L.) showed that salinity increased sodium concentration and decreased potassium and calcium ions in roots and aerial parts of this plant.

Root sodium

The results of analysis of variance in table 3 showed that salinity, potassium silicate (PS) and their interaction had significant different on root sodium. The highest root sodium (28.4 mg g^{-1} root dry weight (RDW)) was at 12 dS m^{-1} with zero ppm PS and the lowest of it was at zero salinity with application of 150 ppm PS (Fig 2, d). Comparison of different levels of PS in salinity treatments showed that when the amount of potassium ions in the environment is high, some of the potassium replaces the sodium ions transferred to the roots and the it reduced the concentration of sodium in the roots. On the other hand, research has shown that silicate deposition in the exoderm and endoderm reduces sodium absorption, which is accomplished by reducing apoplast transmission throughout the root (Munns and Tester, 2008).

CONCLUSION

The results showed that potassium silicate (PS) could not have a favorable effect on plant growth at salinity above 8 dS m^{-1} in marigold plant. The highest plant height was observed in zero salinity with 100 ppm PS and also the highest biomass was obtained at 4 dS m^{-1} with application 100 and 150 ppm PS. Therefore, it seems that substances that reduce the adverse effects of salinity, such as potassium silicate, can to some extent be effective against the adverse effects of salinity accumulation in the plant, and in this case, the plant genetic, is the main factor to induced resistance to salinity stress and the reducing substance, as an auxiliary force, can increase the ability of the plant to withstand against salinity.

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