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THE ALLEVIATION EFFECT OF SILICON ON SEED GERMINATION AND SEEDLING GROWTH OF TOMATO UNDER SALINITY STRESS

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Summary

This study was conducted to evaluate the effectiveness of silicon (Si) application under salinity levels on seed germination and growth characteristics of tomato seeds. A laboratory experiment was performed on completely randomized design with two levels of salinity (25 and 50 mM NaCl) and 2 concentration of Si (1 and 2 mM) with 4 replications. Germination percentage, germination rate, seedling shoot and root length, fresh and dry weight of seedling and mean germination time was measured. Seed germination of *Lycopersicon esculentum* L. was significantly affected by salinity levels, Si and their interaction. Germination characteristics of tomato seeds decreased drastically by increasing NaCl concentrations. However, 1 mM Si had positive effects on seed germination characteristics and improved germination percentage, germination rate and mean germination time. Si alleviated the harmful effect of salinity stress on tomato seed germination at almost all germination characteristics.

key words: vigor index, germination percentage, germination rate, Si, tomato

INTRODUCTION

Salinity is one of the most important factors that influence greatly plant growth and their productivity in arid and semi arid regions (Jamil *et al*. 2005). Salinity decreased plant productivity and it is caused by low precipitation, high surface evaporation, weathering of native rocks, irrigation with saline water, entrance of sea water into freshwater and poor cultural practices (Gol 2009). Salinity weakens seed germination, decrease nodule formation, delay plant development and finally reduce plant yield. Cao (2010) observed that seed germination of *Lepidium latifolium* significantly was inhibited under salt stress and by increasing NaCl concentration (Cao 2010). There are a lot of reports about inhibition of germination and seedling development by salinity of cotton, sugar beet, turf grasses, cucumber and onion which confirmed that salinity is one of the most limitation factors for germination and growth (Xiao-fang *et al*. 2000,

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Dayou 1996, Jing-jun *et al*. 2002).

Si is a beneficial element that causes strengthening cell walls due to deposition of Si in form of amorphous silica and opal phytoliths. Silicon increased thichness of rice and wheat stem, so plant can accept more light and the yield was improved (Stamatakis *et al*. 2003). Silicon increased mechanical strength of plant, resistance to insect, bacterial and fungal diseases, also some physical disorders like bent neck in gerbera (Adatia & Besford 1986, Menzies *et al*. 1991, Epstein 1999, Savvas & Passam 2002) and also plant resistance to metal toxicity (Al, Cd and Mn) (Barcelo *et al*. 1993, Hammond *et al*. 1995, Horst & Marschner 1978, Iwasaki *et al*. 2002, Lin *et al*. 2009). There are a lot of reports about increasing salinity tolerance as a result of silicon application. Zuccarini (2008) studied the effect of Si on *Phaseolus vulgaris* L. under two level of salinity (30 and 60 mM). His results showed that salinity decreased growth, stomatal conductance and net photosynthetic rate. It has been showed silicon application enhanced growth of plants in salt stress condition significantly and it was more effective at lower NaCl concentration (30 mM). Lee *et al*. (2010) observed that 2.5 mM Si improved plant growth attributes like plant height, plant fresh and dry weight of biomass, chlorophyll content and endogenous gibberellins levels while had no effects on endogenous abcisic acid and free proline contents at soy bean plants under salt stress (Lee *et al*. 2010). Exogenous application of silicon could increase antioxidative enzymes in root, shoot and leaf of alfalfa under NaCl stress (Wang *et al*. 2011). Silicon increased significantly ascorbate peroxidase activity, catalase activity and peroxidase activity in different organs of alfalfa in saline condition (Wang *et al*. 2010). They found that Si application improved seed germination and antioxidant enzyme activities of *Momordica charantia* affected by salt stress.

One of the widely distributed annual vegetable crops that can be adapted to a wide variety of climates ranging from the tropics to within a few degrees of the Arctic Circle is tomato. Tomato in cultivated as two ways: seedling and directly sown to soil (Wang *et al*. 2010). Seed germination is a three-stage process: (i) imbibition, (ii) lag phase, and (iii) protrusion of the radicle through the testa (Cuartero & Fernandez-Munoz 1999). Tomato seeds complete their rapid water uptake phase after 12 h. After that activation of some enzymes occur and 72 h after imbibitions meristematic activity observe in radicals (Simon 1984). Improving of germination through the first days can enhance tomato production in saline condition. Tomato in most part of Iran is sown directly to soil or planted by seedlings. The saline soil and drought condition motivate producer to use seedlings. On the other hand, salinity of water which is used for agricultural increased and producer used urban water for seedling irrigation. The aim of this study was to evaluate the effect of Si on seed germination and growth of tomato seedling in saline condition. In order to evaluate the possibility of using Si applicationto tomato seeds sown directly to saline soil or using saline or low quality water instead of urban water for plant watering.

MATERIALS AND METHODS

Seeds of *Lycopersicum esculentum* Mill. were sterilized with 0.5% sodium hypochlorite solution for 10 min to minimize fungal growth. Thereafter; they were washed twice with distilled water. A laboratory experiment was performed on completely randomized design with three level of salinity (0, 25 and 50 mM NaCl) and three concentration of Si (0, 1 and 2 mM) with 4 replications. Germination test was carried out in 90 mm plastic Petri dishes, on one layer filter paper moistened with 6 ml of test solution (distilled water as control, 25 and 50 mM NaCl, 1 and 2 mM Si). Petri dishes were placed at 25±2°C and 16/8 h light/dark condition. Radical protrusion and radical at least 2 mm was the criterion for germination. Germinated seeds were counted every day for 10 days and germination percentage (GP%) and germination rate (GR) were calculated in the last day according to Etemadi *et al*. 2010. Seedling vigor index and vigor index was calculated according to Yong Ye *et al*. 2005.

In the end of lab experiment, radical and hypocotyl length and fresh weight measured. Plants were placed in oven at 70°C for 48h and weighted with sensitive scale.

RESULTS AND DISCUSSION

Applying silicon to the medium of tomato seed germination under NaCl levels caused great improvement on germination characteristics. Seeds germination of tomato was significantly affected by NaCl concentration (Table 1 & Fig. 1). Increasing salinity reduced germination percentage, germination rate and shoot length, significantly (Table 1, 2, 3; Fig. 1 & 2). The highest GP (germination percentage) was found in distilled water (99%) and 50 mM NaCl showed substantial reduction in it (73%). Si affected germination percentage significantly. Soaking in 1 mM Si was suitable for germination of tomato (94.66%). Seed germination was decreased with increasing the concentration of Si (2 mM) significantly (79.66%). The interaction effect of Si and salinity showed that Si alleviated the deleterious effect of salinity on seed germination (Fig. 1). Germination percentage was reduced by 8% and 32% when the salinity was 25 mM and 50 mM, respectively. On the other hand, seed germination reduced by 4% and 9% while 1 mM Si was added to 25 mM and 50 mM NaCl, respectively (Fig. 1). Although the salinity has been increased twice, GP after applying Si decreased slightly. This influence was more effective after treatment in 1 mM Si than 2 mM.

Germination rate (GR) was reduced with salinity (50 mM NaCl) by 55% as compared to control. Si in first level improved GR and at high level it had deleterious effect on GR. The lowest GR was seen in the highest salinity and Si (Table 1).

Root length did not change after NaCl and Si application significantly. Shoot length decreased under influence of salinity and Si. Interaction effect of Si did not show any improving effect of salinity on shoot length (Table 2).

Vigor index and seedling vigor index decreased along with increasing salinity. Si did not effect on vigor index and seedling vigor index significantly. The interaction effect of Si and salinity showed that with increasing Si and NaCl concentration seedling vigor index decreased (Table 3). There were no differences between two levels of Si in both NaCl concentrations. The lowest vigor index was observed in 50mM NaCl and 2mM Si (Table 4).

Table 1. Effect of salinity and Si on germination rate of tomato seed

Si \ NaCl	0 mM	25 mM	50 mM	Medium
0	7.7833 a	4.107 b	2.813 bc	4.9013A
1 mM	7.4444 a	4.157 b	3.887 b	5.1632A
2 mM	4.3425 b	3.421 bc	2.257 c	3.3407B
Medium	6.5234A	3.8956B	2.9862B	

Table 2. Effect of salinity and Si on shoot length of tomato

Si \ NaCl	0 mM	25 mM	50 mM	Medium
0	6.0691 a	5.0978 ab	4.5463 bc	5.2377 A
1 mM	4.2352 bcd	2.8394 de	4.4672 bc	3.8473 B
2 mM	3.6627 cd	2.7206 de	1.6910 e	2.6914 C
Medium	4.6556 A	3.5526 B	3.5682 B	

Table 3. Effect of salinity and Si on seedling vigor index of tomato

Si \ NaCl	0 mM	25 mM	50 mM	Medium
0	33.825 bc	59.330 ab	33.910 bc	42.355 a
1 mM	42.825 bc	25.800 c	36.811 abc	35.145 a
2 mM	69.240 a	8.464 c	10.517 c	29.407 a
Medium	48.630 A	31.198 AB	27.079 B	

Table 4. Effect of salinity and Si on vigor index of tomato

Si \ NaCl	0 mM	25 mM	50 mM	Medium
0	2.5000 a	2.3000 abc	1.7000 bc	2.3667 A
1 mM	2.4750 ab	2.3750 ab	2.2500 abc	2.1667 A
2 mM	2.4500 ab	2.0000 abc	1.5250 c	1.9917 A
Medium	2.4750 A	2.2250 AB	1.8250 B	

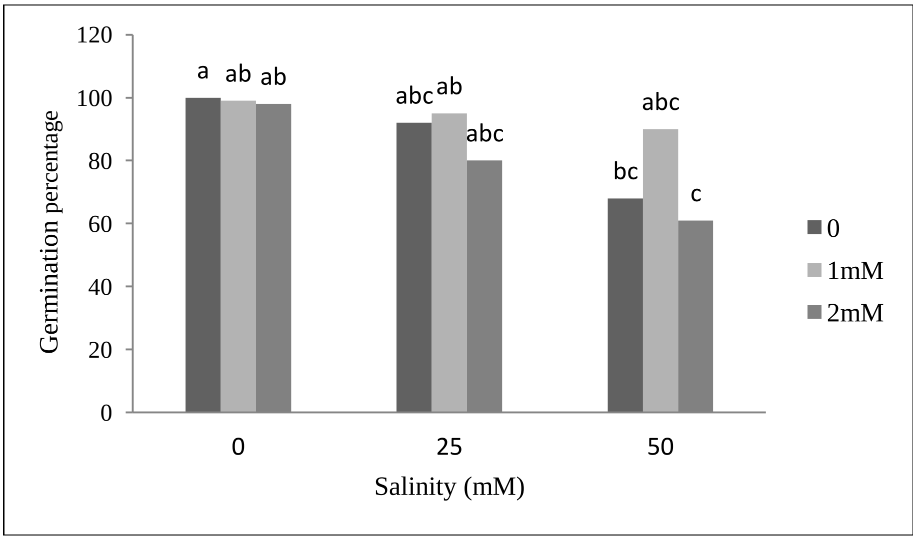

Fig. 1. Effect of salinity and Si on germination percentage of tomato seeds

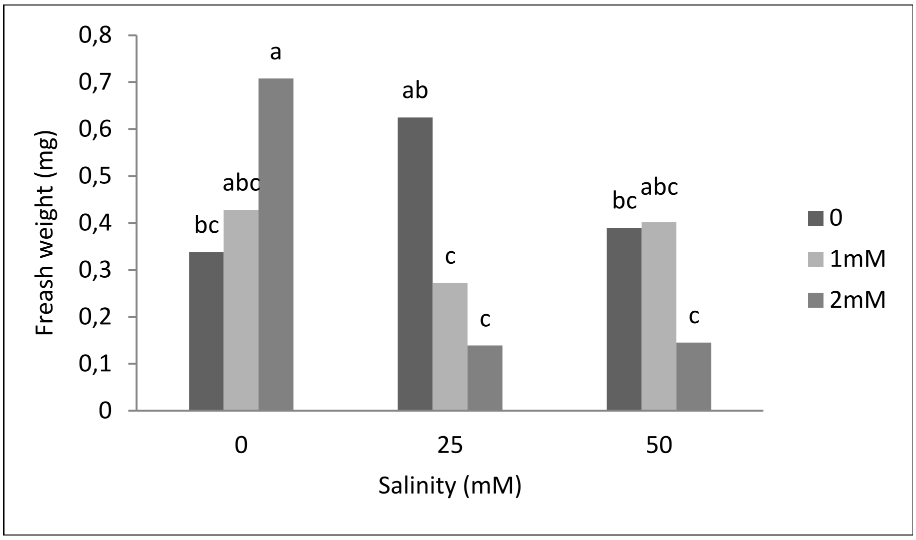

Fig. 2. Effect of salinity and Si on weight of tomato shoot dried at 70°C for 48 hours

The largest effect of Si and salinity on germination did not show any significant effect on fresh weight of seedlings (Fig. 2).

During plant growth the germination is one of the salt sensitive stages. Increasing salinity decreased germination drastically. Our results showed that germination of tomato were inhibited by increasing NaCl concentration while Si improved the germination under salinity. 1 mM Si decreased salinity harmfulness on germination by 20%. Although germination rate, shoot length and fresh weight of tomato was affected by Si application in saline condition less but they were less than Si treatment. Our results are in line with other reports that suggesting that Si leads to positive morphological and physiological change in different plants species (Wang *et al*. 2011). Seed germination and growth rate of soybean were enhanced as a results of increasing available Si content in soil (Li *et al*. 2004). In another report, it was revealed that exogenous Si under $NaHCO_3$ stress could enhance germination characteristics of cucumber seeds. According this research, Si is related to expression of defense genes during salt stress (Sun *et al*. 2010). Si reduced oxidative damages induced by salt stress. Lipid proxidation which is a result of salinity was inhibited by Si. Also, Si leads to increase some scavenging ROS enzymes like SOD and catalase (Gapińska 2008). These results showed that salt stress damages can be alleviated by Si application (Wang *et al*. 2011).

Generally it can say that in saline soil the Si application can alleviate stress influence on tomato in first stage of growth. These finding suggested that Si may prevent the structural and functional deterioration of cell membrane in plant species exposed to salinity stress. Our findings propose that mixing of Si with fertilizers can make them more effective and economical useful. But further researches in needed to make sure how Si affects the effectiveness of other elements in fertilizers.

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POZYTYWNY WPŁYW KRZEMU NA KIEŁKOWANIE NASION I WZROST SIEWEK POMIDORA W WARUNKACH STRESU ZASOLENIA

Streszczenie

Badania przeprowadzono w celu oceny skuteczności stosowania krzemu (Si) w warunkach zasolenia na kiełkowanie nasion i cechy wzrostu siewek pomidora. Wykonano doświadczenie laboratoryjne w układzie kompletnie losowym z dwoma poziomami zasolenia (25 i 50 mM NaCl) i dwoma stężeniami Si (1 i 2 mM) w 4 powtórzeniach. Określano procent kiełkowania, zdolność kiełkowania, długość pędu i korzenia siewek, świeżą i suchą masę siewek oraz średni czas kiełkowania. Na kiełkowanie nasion *Lycopersicon esculentum* L. w istotny sposób oddziaływały poziomy zasolenia, krzem i ich interakcja. Kiełkowanie nasion pomidora zmniejszało się znacznie w miarę zwiększania stężenia NaCl. Dodatek 1 mM Si miał pozytywny wpływ na kiełkowanie, zwiększając procent skiełkowanych nasion, zdolność kiełkowania i średni czas kiełkowania. Si łagodził szkodliwy wpływ stresu zasolenia na kiełkowanie nasion pomidora pod względem niemal wszystkich parametrów związanych z kiełkowaniem.