Effect of Boron and Silicon on Alleviating Salt Stress in Maize

Middle East Journal of Agriculture Research, 3(4): 1196 -1204, 2014
ISSN 2077-4605

Effect of Boron and Silicon on Alleviating Salt Stress in Maize

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ABSTRACT

Two pot experiments in sandy soil were conducted during 2012 and 2013 summer seasons to study the effect of the foliar spray with boron (B, 50 and 100 ppm) and silicon (Si, 250 and 500 ppm) and their combinations on maize plants irrigated with saline water. Two samples were taken after 90, 105 days from sowing for evaluating the responses of growth traits, yield components and some biochemical constituents. The obtained results showed that the combined treatments between B and Si were more effective than the sole treatment of each in enhancing plant height, number of leaves, shoot dry weight, ear length, weight of 100 grains, grains weight /plant, total amino acids, chlorophyll reading, total soluble sugars and proline. Generally, the combined treatment of B at 100 ppm plus Si at 500 ppm has strongly stimulating effect on growth, yield and some biochemical constituents in maize.

Key words: Maize, *Zea mays*, Boron, Silicon, Salt stress**.**

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops growing in the Arab Republic of Egypt. It is used as a food for human consumption as well as feeding animals (Moussa, 2001). Maize occupies the third order, behind wheat and rice, in area (FAO, 2005). In Egypt, the local production still under self sufficiency level. Overcoming the deficiency of maize productivity is an essential national target to reduce the gap between production and consumption. The use of saline water in agriculture is a subject of vital importance for arid and semi-arid zones to meet increasing food demand. Salinity in soil or water resources is one of the major environmental stresses that limit plant growth and productivity. Almost one third of the irrigated lands in the world are under salinity problems. Plant performance usually expressed as crop yield, plant biomass or crop quality, and may be adversely affected by salinity induced nutritional disorders. These disorders may result from the effect of salinity on nutrient availability, competitive uptake, transport or partitioning within the plant (Abou El-Nour and El-Fouly, 2006). At low salt concentrations, yields are mildly affected or not affected at all (Maggio *et al*., 2001). As the concentrations increase, the yields move towards zero, since most plants, glycophytes, including most crop plants, will not grow in high concentrations of salt and are severely inhibited or even killed by 100-200 mM NaCl. The detrimental effects of high salinity on plants can be observed at the whole-plant level in terms of plant death and/or decrease in productivity (Parida and Das, 2005). In saline conditions, nutrient imbalances can result through various ways: From the effect of salinity on nutrient availability, competitive uptake, transport or partitioning within the plant or may be caused by physiological inactivation of a given nutrient (Grattan and Grieve, 1999).

Boron (B) is an essential nutrient for normal growth of higher plants and its availability in soil and irrigation water is an important determinant of agricultural production (Saleem *et al*., 2011). B deficiency causes different effects on very diverse processes in vascular plants such as root elongation, indole acetic acid oxidase activity, sugar translocation, carbohydrate metabolism, nucleic acid synthesis, and pollen tube growth (Wimmer *et al*., 2007; Saleem *et al*., 2011).

B concentration was decreased in plants under salinity conditions (Holloway and Alston, 1992; Wimmer *et al.,* 2001). B has a critical role in growing tissues. Actually boron deficiency decreases or inhibits the growth of both vegetative and reproductive plant parts (Dell and Hung, 1997).

Furthermore, some beneficial mineral nutrients have been studied that can counteract adverse effects of salt stress. Ali *et al*. (2009) revealed that as wheat is designated as silicon (Si) accumulator, hence Si application may alleviate the salinity induced damages. Si supplementation into the solution culture improved wheat growth and K^+/Na^+ with reduced Na^+ and enhanced K^+ uptake. Si, being a beneficial element provides significant benefits to plants at various growth stages (Epstein, 1999). Si was reported to reduce harmful effects of various abiotic and biotic stress including salinity, drought, metal toxicity, nutrients imbalance, heat stress (Ma, 2004 and Currie and Perry, 2007). Si promotes the growth of various higher plants (Zhu *et al*., 2004).

Both silicon and boron applications correct to some extent the negative effects of salinity either on growth, yield, nutrients uptake (Hanafy *et al*., 2008).

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Middle East j. Agric. Res., 3(4): 1196-1204, 2014

Keeping these points in mind, the study aimed to investigate the effect of the foliar spraying of B as micronutrient and Si as beneficial element on maize plant growth, yield and some of biochemical constituents in addition to their influence in reducing the harmful effect of salinity.

Materials and Methods

A 2-year pot experiment was conducted in the greenhouse of the, Agricultural Botany Department, Faculty of Agriculture, Ain Shams University, Cairo, Egypt during the summer seasons of 2012 and 2013 to evaluate the effect of boron and silicon on maize plants cv. single cross-10 irrigated with saline water. Pots 35 cm in diameter and 50 cm in depth were used, every pot contained 30 kg of sandy soil. Grains of maize were sown in 1st May, and after emergence plants were thinned twice, 20 and 35 days after sowing (DAS) to secure three plants/ pot. Calcium super phosphate (15.5 % P_20_5) and potassium sulfate (48.5 % K_2O) at the rates of 2.29 and 1.14 g/ pot, respectively were added before sowing. Ammonium sulfate (20.5 % N) at a rate of 6.86 g/ pot was added in two equal portions at 14 and 28 DAS. Maize plants were exposed to salt stress by irrigating them with saline water (4000 ppm NaCl) during growth stages.

Experimental treatments

Pots were arranged in randomized complete block design with three replicates and sprayed by nine treatments as follow:

1. Spraying with tab water (Control)
2. Spraying with 50 ppm B
3. Spraying with 100 ppm B
4. Spraying with 250 ppm Si
5. Spraying with 500 ppm Si
6. Spraying with 50 ppm B+250 ppm Si
7. Spraying with 100 ppm B+250 ppm Si
8. Spraying with 50 ppm B+500 ppm Si
9. Spraying with 100 ppm B+500 ppm Si

Boric acid (H_3 Bo_3 17 % B) and potassium tetrasilicate (40% Si) as sources of boron and silicon, respectively, were foliar applied twice, at 21 and 42 DAS.

Assessments

Growth and yield

Growth traits of maize included plant height (cm), leaves number /plant and shoot dry weight /plant (g) were measured at 90 DAS. Moreover, ear length (cm) 100-grain weight (g) and grains weight /plant were determined at harvest (105 DAS).

Chemical constituents

At 90 DAS, the fourth leaves of maize plants were collected for measuring the chemical properties, i.e. proline, total soluble sugars, total phenols, total amino acids and chlorophyll reading (SPAD) as follows:

Total chlorophyll reading

Total chlorophyll content (SPAD value) of the maize fourth leaf was determined using chlorophyll meter (SPAD–502) according to Soil Plant Analysis Department Section, Minolta Camera Co., Osaka, Japan as reported by Minolta (1989).

Total soluble sugars

For total sugars extraction (AOAC, 1990) added 0.5 g fresh weight + 5 ml ethanol 80 % in closed tube. Put tube in water bath at 95° C for 10 minutes and centrifugation at 2500 g for 5 minutes. Take the aqueous phase and added 5 ml 80 % ethanol to solid phase (starch) in heat water bath 95° C for 10 minutes and centrifugation at 2500 g for 5 minutes. Added 5 ml 80 % ethanol to solid phase in water bath on 95°C for 10 minutes and centrifugation at 2500 g for 5 minutes,The aqueous phases were collected. When the plant sample contained color pigments added 0.5 g activated charcoal (to remove pigments) and the solution was filtrated before measurement. Take the 1 ml aqueous phase (soluble sugars) with 1 ml phenol 4 % + 2 ml H_2SO_4 96 % and then add 9 ml distilled water (Ackerson, 1981).The concentration of total sugars was determined by reading the absorption by spectrophotometer at 490 nm from standard curve (glucose).

Proline

Fourth leaf was separately prepared for the measurement of free proline concentration. Half gram of fresh weight leaf no. 4 was homogenized in 10 ml of sulfosalcilic acid. Insoluble material was removed by centrifugation at 3.800 g, Proline was measured as described by Bates *et al.* (1973). A 100 µl aliquot of the extract was reacted with 1 ml glacial acetic acid and 1 ml acidic ninhydrin (1.25 g ninhydrin dissolved in 30 ml glacial acetic acid and 20 ml phosphoric acid 6 M) for 1 h at 100°C in heat water bath and the reaction was then terminated in an ice bath for cooling solution . The reaction mixture was mixed with 4 ml toluene. The optical density was measured by spectrophotometer at 520 nm. The concentration of proline was determined from a standard curve.

Total amino acids

Free amino acids were determined using ninhydrin according to Muting and Kaiser (1963). was measured using a spectrophotometer (Mapada UV 1200) at 570 nm. The concentration of total amino acids was calculated from the standard curve.

Phenols

For extraction, one gram of fresh leaf no. 4 were randomly taken with 80 % aqueous methanol (1:10 W/V) at 40°C for 16 hours. The resulting extraction was centrifuged 6000 g for 5 minutes and the supernants were saved. The residues were re-extracted (1: 5 W/V) 80 % cold methanol under the same conditions. The supernants of both extractions were combined. The combined extracts were collected and filtered (Wt. No. 1). Then, the volume of sample was made up to 25 ml with cold methanol and concentrated under vacuum at 40° C to give semisolids; all samples were protected permanently from light (Liyana-Pathirana and Shahidi, 2007).

Total phenols were measured by adding 2 ml of extracted solution with 1 ml of 10 % Folin ciocaltus reagent. After 4 minutes incubation at room temperature plus 2 ml of 5 % sodium carbonate solution. The reaction mixture was incubated for 45 minutes in dark room. The total phenols concentration was measured at 725 nm (Daniel and George, 1972). The reaction mixture was incubated for 30 min at room temperature, and the absorbance was recorded at 765 nm using an UV/Vis spectrophotometer. The concentration of total phenols was expressed as a gallic acid equivalent in mg g^{-1} fresh weight of the sample.

Statistical analysis

Data of the two growing seasons were subjected to analysis of variance (ANOVA) according to Gomez and Gomez (1984), using software of SAS (2006). The differences among means were tested using Tukey test at 0.05% probability level.

Results and Discussion

Growth traits

Data presented in Table (1) shows the marked effect of B and Si treatments on plant height, leaves number and shoot dry weight of maize at 90 DAS in 2012 and 2013 seasons. As expected, adverse effects occurred for maize plants growth when they were irrigated by saline water as obtained in non treated plots (control). While application each of B or Si alleviated the detrimental effect of saline water used for irrigation. In this respect, the average of Si effect was more evident than B one, where the improvements by adding Si and B reached 51.5 and 23.2 % (for plant height) as well as 78.5 and 44.2 % (for shoot dry weight/pant), respectively, in comparison with the control treatment. Additionally, it looks like that there is a synergistic effect between B and Si when applied together, where, spraying B plus Si achieved enhancements in plant growth than sole application of each. Herein, the potent combinations for promoting plant height were B at a rate of 100 ppm + Si at a rate of 250 or 500 ppm. Also, B at a rate of 100 ppm + Si at a rate of 500 ppm was the most effective pattern for increasing leaves number/plant, but statistically at par with other treatments, except the treatment of B at a rate of 50 ppm and the control one. Shoot dry weight/plant possessed the maximum values with B at a rate of 100 ppm + Si at a rate of 500 ppm, B at a rate of 100 ppm + Si at a rate of 250 ppm, B at a rate of 50 ppm + Si at a rate of 500 ppm and Si at a rate of 500 ppm.

Generally, the highest values of plant height, leaves number and shoot dry weight of maize were observed with mixing B, 100 ppm, and Si, 500 ppm,. The growth of salt-stressed plants is mostly limited by the osmotic effect of salinity, irrespective of their capacity to exclude salt that results in reduced growth rates and stomatal conductance (James *et al*., 2008). High salinity affects plants in several ways: water stress, ion toxicity, nutritional disorders, oxidative stress, alteration of metabolic processes, membrane disorganization, reduction of cell division and expansion, genotoxicity (Maggio *et al.,* 2001; Munns, 2002). Mishra and Shukla (1986) reported considerable increase in plant height, metabolic rate, content of photosynthetic pigment and all dry weight fractions measured after the application of B containing amendment to maize. Ayfer *et al*., (2006) indicated that the total amount of boron in wheat shoots showed a highly significant negative correlation with decreases in shoot dry weight under boron supply. Together, these effects reduce plant growth, development and survival. Top, root and whole plant fresh or dry-weight gave their higher values when plants received 75 ppm B, while leaf area and top/root ratio increased as the B concentration increased up to 150 ppm (Hussein *et al*., 2011). Moreover, shoot and root growth of rice was inhibited by 60% in the presence of 100 mM NaCl for three weeks, but Si addition significantly alleviated salt-induced injury (Matoh *et al,*. 1986). The Si-alleviated effects have been associated with an increase in antioxidant defense abilities and enhanced plant tolerance to abiotic stresses (Liang *et al*. 2003; Liang *et al*. 2005; Gong *et al*. 2005). *Poaceae* family species accumulate large amounts of Si and its application to these crops ensured better growth (Mitani and Ma, 2005; Saudy and Mubarak, 2015). This function of Si may be ascribed to the Si-induced decrease of transpiration (Matoh *et al.,* 1986) and to the partial blockage of the transpirational bypass flow, the pathway by which a large proportion of the uptake of Na in rice occurs (Yeo *et al*., 1999). Moreover, In barley, Si increased the leaf superoxide dismutase activity and suppressed the lipid peroxidation caused by salt stress and stimulated root H^+ -ATPase in the membranes, suggesting that Si may affect the structure, integrity and functions of plasma membranes by influencing the stress-dependent peroxidation of membrane lipids, although these effects may be indirect (Liang *et al*., 2002).

Table 1: Effect of boron and silicon treatments on plant height, leaves number and shoot dry weight of maize plants irrigated with saline water in both seasons

Treatments	Plant height (cm)		Mean	Leaves number/plant		Mean	Shoot dry weight/plant (g)		Mean
	2012	2013		2012	2013		2012	2013	
Control	101.67^{ik}	92.00^{i}	96.83^{G}	7.67^{bc}	7.33^{c}	7.50^{C}	31.66^{ef}	28.00^{f}	29.83^{E}
B 50 ppm	115.66^{i-k}	107.66^{g}	111.67^{F}	8.33^{a-c}	8.00^{a-c}	8.17^{BC}	43.00^{c-e}	38.00^{df}	40.50^{D}
B 100 ppm	137.33^{gh}	116.66^{ij}	127.00^{E}	8.66^{a-c}	8.67^{a-c}	8.67^{AC}	47.00^{b-d}	44.00^{cd}	45.50^{CD}
Si 250 ppm	148.33^{e-f}	128.33^{hi}	138.33^{D}	8.66^{a-c}	8.33^{ac}	8.50^{AC}	54.66^{a-c}	47.33^{b-d}	51.00^{BC}
Si 500 ppm	166.66^{b-d}	143.33^{fg}	155.00^{C}	9.00^{ac}	8.67^{a-c}	8.83^{AC}	59.67^{a}	51.33^{a-c}	55.50^{AB}
B 50 ppm+ Si 250 ppm	173.00^{a-c}	152.33^{d-f}	162.67^{BC}	9.00^{a-c}	8.33^{a-c}	8.67^{AC}	51.33^{a-c}	47.00^{b-d}	49.17^{BC}
B 50 ppm+ Si 500 ppm	178.66^{ab}	150.66^{e-f}	164.67^{B}	9.33^{a-c}	9.00^{a-c}	9.17^{AB}	56.67^{ab}	51.67^{a-c}	54.17^{AB}
B 100 ppm+Si 250 ppm	173.66^{a-c}	160.67^{c-e}	167.17^{AB}	9.00^{a-c}	8.66^{a-c}	8.83^{A-C}	58.33^{ab}	54.33^{a-c}	56.33^{AB}
B 100 ppm+Si 500 ppm	181.33^{a}	170.33^{a-c}	175.83^{A}	10.00^{a}	9.67^{ab}	9.83^{A}	62.3^{a}	57.00^{ab}	59.66^{A}
Mean	152.93^{A}	135.78^{B}		8.85^{A}	8.51^{A}		51.63^{A}	46.52^{B}	
MSD Seasons at 0.5	2.61			N S			2.1206		
MSD Treatments at 0.5	8.99			1.346			7.3131		
MSD Seasons x Treatments at 0.5	14.459			2.1653			11.764		

B = Boric acid , Si = Potassium tetrasilicate, NS = Non Significant

Yield traits

Available results in Table (2) indicated that, the tested treatments achieved significant increases in ear length, weight of 100 grains and grains weight / plant as compared to the control at harvest in both seasons. In this connection, all B and Si combinations and Si at a rate of 500 ppm gave the highest significant values of ear length and weight of 100 grains. Also, spraying of 50 ppm B+500 ppm Si as well as 100 ppm B+250 or 500 ppm Si were the marked treatments for boosting grain weight /plant. The enhancements in maize yield traits with application of B and/or Si may be due to their beneficial effect in plant growth (Table, 1). Reduction in grain yield of stressed maize plants might be attributed to the rapid reduction in leaf photosynthetic pigments and assimilates. Therefore, translocation of assimilates from stem to grains is the main source as well as limiting factor for growth and development of grain. According to Munns (2002), salinity reduces plant productivity first by reducing plant growth during the phase of osmotic stress and subsequently by inducing leaf senescence during the phase of toxicity when excessive salt is accumulated in transpiring leaves. Salinity decreased grain yield and dry matter production of wheat (Nesiem and Ghallab, 1998; Sultana, *et al.* (1999). On the other hand, revealed that reduction in maize yield under salt stress may be related to the high level of ABA.(El-Khallal *et al*., 2009).Ziaeyan and Rajaie (2009) Stated that Zn and B fertilization significantly increased plant biological yield, grain yield, thousand grain weight, number of grains per stalk, grain protein content and the concentration of B and Zn in corn tissues grown under high $CaCO_3$ conditions. Boron as essential micronutrient plays an important role in increasing pollen grains germination and pollen tube enlargement, fruit set% and finally the yield. It is responsible for stimulating cell division, biosynthesis and translocation of sugars, water and nutrient uptake and IAA biosynthesis (Nijjar 1985 and Ahmed *et al.,*2009).

Boron has effect on the many functions of the plant such as hormone movement, flowering and fruiting process and pollen germination specially its influences on the directionality of pollen tube growth Robbertse *et al.,* (1990). Grains weights, yield parameters and B accumulation in barley grains were significantly increased under both B concentrations (Hu and Brown 1994 and El-Feky *et al.,* 2012).

On the contrary, Liang *et al.,* (2006) stated that the key mechanisms of Si-mediated alleviation of abiotic stresses in higher plants include: (1)- stimulation of antioxidant systems in plants, (2)- complexation or co-precipitation of toxic metal ions with Si, (3)- immobilization of toxic metal ions in growth media, (4)- uptake processes, and (5)- compartmentation of metal ions within plants. These results are in harmony with the findings of Liang (1998).

Table 2: Effect of boron and silicon treatments on ear length, the weight of 100 grains and grains weight /plant of maize plants irrigated with saline water in both seasons.

Treatments	Ear length (cm)		Mean	100-grain weight (g)		Mean	Grains weight /plant (g)		Mean
	2012	2013		2012	2013		2012	2013	
Control	10.67^{gh}	10.00^{h}	10.33^{E}	27.33^{ef}	25.33^{f}	26.33^{E}	96.67^{fg}	81.17^{e}	89.17^{E}
B 50 ppm	12.67^{fg}	12.00^{f-h}	12.33^{D}	35.00^{c-e}	36.67^{b-d}	33.67^{D}	111.67^{e-g}	96.77^{fg}	104.17^{E}
B 100 ppm	13.33^{ef}	13.00^{ef}	13.17^{CD}	38.33^{b-d}	36.67^{b-d}	37.50^{CD}	141.67^{b-e}	121.67^{de}	131.67^{D}
Si 250 ppm	14.67^{a-e}	14.00^{ef}	14.33^{BC}	41.00^{a-d}	38.00^{b-d}	39.50^{BC}	143.30^{b-e}	138.33^{b-e}	135.00^{CD}
Si 500 ppm	15.33^{b-d}	14.33^{ef}	14.83^{AB}	45.33^{ab}	39.67^{a-d}	42.50^{A-C}	157.33^{a-d}	147.33^{b-e}	153.33^{BD}
B 50 ppm+ Si 250 ppm	14.67^{a-e}	13.67^{ef}	14.83^{AB}	44.00^{a-c}	41.33^{a-d}	42.67^{A-C}	156.67^{a-d}	138.33^{b-e}	147.50^{BD}
B 50 ppm+ Si 500 ppm	16.00^{ab}	14.00^{e-f}	15.00^{AB}	45.00^{ab}	41.33^{a-d}	43.17^{AB}	165.00^{ab}	151.67^{a-d}	158.33^{AB}
B 100 ppm+Si 250 ppm	16.00^{ab}	15.33^{b-d}	15.67^{AB}	44.67^{ab}	41.33^{a-d}	43.00^{A-C}	160.00^{a-c}	152.33^{a-d}	156.17^{AC}
B 100 ppm+Si 500 ppm	16.67^{a}	15.67^{a-c}	16.17^{A}	48.33^{a}	44.00^{a-c}	46.17^{A}	187.33^{a}	165.00^{ab}	176.17^{A}
Mean	14.44^{A}	13.55^{B}		41.00^{A}	37.78^{B}		146.63^{A}	131.26^{B}	
MSD Seasons at 0.5	0.463			1.6354					
MSD Treatments at 0.5	1.5969			5.6398					
MSD Seasons x Treatments at 0.5	2.5688			9.0723					

B = Boric acid , Si = Potassium tetrasilicate

Chemical constituents

Distinctive effects of B and Si treatments on total phenols, proline concentration and chlorophyll reading (SPAD) of maize plants in two seasons were observed (Table, 3). B at a rate of 100 ppm along with other treatments achieved the maximal increase in phenols surpassing the control one. Si treatments alone or in combinations with B achieved increases in praline surpassing the treatments of B at a rate of 50 ppm and control. B at a rate of 100 ppm plus Si at a rate of 250 or 500 ppm as well as sole Si at a rate of 500 ppm were the excelsior practices of promoting SPAD value.

Compatible osmolytes (class of small molecules) are potent osmoprotectants that play a role in counteracting the effects of osmotic stress. Proline, glycinebetaine, polyamines, and carbohydrates have been described as being effective against salt stress (Hare and Cress, 1997). The significant increase in phenols and proline concentrations could be a good parameter for salt tolerance plant (Ibrahim *et al*., 2007; Ibrahim, 2008). Salt stress caused a remarkable increase in free proline concentration. Nevertheless, Si treatment caused a significant decrease in free proline level salt stress compared to the seedlings treated with NaCl alone. Proline has been considered as a carbon and nitrogen source for rapid recovery from stress and growth, a stabilizer for membranes and some macromolecules and also a free radical scavenger (Jain *et al.,* 2001). Free proline concentration increased remarkably in maize seedlings with salinity but decreased with Si + NaCl treatment. It seems plausible that Si shows a protective role for maize seedlings to prevent them from being severely (Romero-Aranda *et al.* 2006).In photosynthetic tissues; in fact, Na^+ accumulation affects photosynthetic components such as enzymes, chlorophylls, and carotenoids (Davenport *et al.*, 2005). The highest percentages of Chl.a, Chl.b, carotenoids and total chlorophyll were obtained by spraying 75 ppm boric acid. A reasonable dose of boric acid (75 ppm) could increase both concentration and uptake of macro and micro-nutrients by the plant tops; however the higher dose (150 ppm) led to a reverse effect (Hussein *et al.,* 2011). Mateos-Naranjo *et al.* (2013) noticed that leaf turgor potential and net photosynthesis rates were 42% and 20% higher in salt-affected plants supplied with Si. Dry matter was substantially reduced at the highest salinity treatment (680 mM) but it was not affected in plants treated with 500 µM silicon. Si can improve photochemical efficiency of PSII by increased chlorophyll content and detoxify ROS induced in tomato (Al- aghabary *et al*., 2004).

Table 3: Effect of boron and silicon treatments on phenols, proline concentrations and SPAD value of maize plants irrigated with saline water in both seasons

Treatments	Phenols (mg/g f.w.)		Mean	Proline (ug/g f.w.)		Mean	SPAD value		Mean
	2012	2013		2012	2013		2012	2013	
Control	0.82^{b}	0.95^{b}	0.88^{B}	1.80^{d}	2.77^{b-d}	2.28^{D}	37.00^{g}	36.33^{g}	36.67^{D}
B 50 ppm	1.47^{ab}	1.27^{ab}	1.37^{AB}	2.53^{cd}	3.16^{a-c}	2.85^{CD}	38.67^{fg}	39.33^{fg}	39.00^{D}
B 100 ppm	1.70^{ab}	3.80^{a}	2.75^{A}	2.83^{b-d}	3.43^{a-c}	3.13^{BC}	41.33^{e-f}	42.33^{e-f}	41.83^{CD}
Si 250 ppm	1.70^{ab}	1.53^{ab}	1.62^{AB}	3.26^{a-c}	3.80^{ab}	3.53^{AB}	47.00^{a-f}	45.00^{b-f}	46.00^{BC}
Si 500 ppm	1.83^{ab}	1.93^{ab}	1.88^{AB}	3.76^{ab}	3.66^{ab}	3.72^{AB}	49.00^{a-d}	49.33^{a-d}	49.17^{AB}
B 50 ppm+ Si 250ppm	1.60^{ab}	1.77^{ab}	1.68^{AB}	3.46^{a-c}	3.63^{ab}	3.55^{AB}	47.66^{a-e}	48.00^{a-e}	47.83^{B}
B 50 ppm+ Si 500 ppm	1.67^{ab}	1.67^{ab}	1.67^{AB}	3.80^{ab}	4.06^{a}	3.93^{A}	48.66^{a-d}	49.67^{a-d}	49.17^{AB}
B 100 ppm+Si 250ppm	1.63^{ab}	1.90^{ab}	1.77^{AB}	3.76^{ab}	3.80^{ab}	3.78^{AB}	50.33^{a-c}	50.53^{a-c}	50.33^{AB}
B 100 ppm+Si 500 ppm	1.93^{ab}	2.07^{ab}	2.00^{AB}	4.00^{a}	4.03^{a}	4.02^{A}	53.33^{a}	55.33^{ab}	54.33^{A}
Mean	1.87^{A}	1.59^{A}		3.59^{A}	3.25^{B}		46.18^{A}	45.89^{B}	
MSD Seasons at 0.05	N S			0.197			1.5899		
MSD Treatments at 0.05	1.686			0.6795			5.4829		
MSD Seasons x Treatments at 0.5	2.7121			1.093			8.82		

B = Boric acid , Si = Potassium tetrasilicate, N S = Non Significant

Total amino acids and total soluble sugars of maize were substantially responded to B and Si treatments (Table, 4). In this regard the lowest values were recorded in untreated pots (irrigated by saline water). Unlike, the superior practice for increasing total amino acids and total soluble sugars was 100 ppm B + 500 ppm Si. However, effects of all B and Si combinations in addition to 500 ppm Si (on total amino acids) as well as all sole concentrations of B and Si (on total soluble sugars) were significantly leveled in this respect.

Among the best known compatible solutes, proline and glycine betaine (GB) have been reported to increase greatly under salt and drought stresses (Munns, 2002; Sakamoto and Murata, 2002) and constitute the major metabolites found in durum wheat under salt stress, as in other Poaceae (Sairam and Tyagi, 2004; Carillo *et al.,* 2005; Shraf and Foolad, 2007). In durum wheat seedlings, proline can contribute for more than 39% of the osmotic adjustment in the cytoplasmic compartments of old leaves, while the contribution of GB can account for up to 16% of the osmotic balance in younger tissues, independently of nitrogen nutrition, unlike praline (Carillo *et al*., 2008).

One of the salt alleviation of silicon that it is reduced Na content through its effect on transpiration bypass flow (Yeo *et al.,* 1999). Ameliorative effects of silicon were correlated with reduced sodium uptake (Mateos-Naranjo *et al*., 2013). The most abundant amino acids (cysteine, arginine, methionine) constitute to about 55% of the total free amino acid content, and their content was reduced in NaCl-treated wheat plants. In contrast, the content of valine, isoleucine, aspartic acid, and proline is increased in response to NaCl stress. NaCl-treated wheat seedlings showed about 1.6-fold increase in total free amino acids compared to the control (El-Shintinawy and El-Shourbagy, 2001).

Silicon may alleviate salt stress in higher plants (Liang and Shen, 1994 ,Matichenkov *et al.*, 2001). There are several hypotheses for this effect. They are (a) improved photosynthetic activity, (b) enhanced K/Na selectivity ratio, (c) increased enzyme activity, and (d) increased concentration of soluble substances in the xylem, resulting in limited sodium adsorption by plants.Matichenkov *et al.,* (2001).

On the other site, boron plays an important role in carbohydrate metabolism and transportation (Marschner, (1995); Belvins and Lukaszewski, (1998). Carbohydrate changes under salt stress are of particular importance because of their direct relationship with biochemical processes such as photosynthesis and respiration. Among the soluble carbohydrates, sucrose and fructose have a potential role in adaptation to salt stress. Aly *et al*. (2003) indicated that the total soluble carbohydrate content might be a useful trait to select salt-tolerant maize genotype. Boron was also reported to control different reactions in carbohydrate metabolism such as á-amylase, Glucose 6-phosphate dehydrogenase, ß-amylase and reduction of UDPG-synthesis (Goldbach, 1997). Boron is stimulating for biosynthesis and translocation of sugars (Nijjar 1985 and Ahmed *et al.,*2009). Boron is stimulating for biosynthesis and translocation of sugars (Nijjar 1985 and Ahmed *et al.,*2009).

In general, a significant increase in biochemical components (phenols, proline and proteins) and mineral nutrients (N, P and K) as well as K:Na ratio could be considered as indicator for salt tolerance plant as reported by Salim *et al*.,(2011).

Table 4: Effect of boron and silicon treatments on total amino acids and total soluble sugars concentrations of maize plants irrigated with saline water in both seasons.

Treatments	Total amino acids (mg/g f.w.)		Mean	Total soluble sugars (mg/ g f.w.)		Mean
	2012	2013		2012	2013	
Control	2.33^{d}	3.13^{b-d}	2.73^{D}	15.33^{a-c}	11.26^{c}	13.30^{B}
B 50 ppm	2.80^{cd}	3.50^{b-d}	3.15^{CD}	16.68^{ab}	14.00^{a-c}	15.34^{AB}
B 100 ppm	3.03^{b-d}	3.80^{a-d}	3.42^{B-D}	17.17^{ab}	15.03^{a-c}	16.10^{AB}
Si 250 ppm	2.68^{cd}	4.23^{a-c}	3.55^{B-D}	14.96^{a-c}	13.76^{bc}	14.37^{AB}
Si 500 ppm	3.13^{b-d}	4.70^{ab}	3.92^{A-C}	15.13^{a-c}	14.26^{a-c}	14.70^{AB}
B 50 ppm+ Si 250 ppm	3.73^{a-d}	4.35^{a-c}	4.04^{A-C}	17.35^{ab}	15.38^{a-c}	16.37^{AB}
B 50 ppm+ Si 500 ppm	4.23^{a-c}	4.06^{a-d}	4.15^{A-C}	15.80^{a-c}	14.53^{a-c}	15.17^{AB}
B 100 ppm+Si 250 ppm	4.32^{a-c}	4.53^{a-c}	4.38^{AB}	15.48^{a-c}	14.16^{a-c}	14.82^{AB}
B 100 ppm+Si 500 ppm	4.47^{a-c}	5.38^{a}	4.92^{A}	18.94^{a}	15.97^{a-c}	17.46^{A}
Mean	4.19^{A}	3.42^{B}		16.32^{A}	14.26^{B}	
MSD Seasons at 0.05	0.3177			0.9292		
MSD Treatments at 0.05	1.0957			3.2044		
MSD Seasons x Treatments at 0.5	1.7625			5.1547		

B = Boric acid , Si = Potassium tetrasilicate

Finally, it could be concluded that B plus Si have a substantial role for enhancing the growth and yield of maize as being they are beneficial nutrients. Besides, under abiotic stress, i.e. salt stress, B+ Si can alleviate the detrimental impact of saline water used in irrigation of maize. But, it should not neglect the effect of such water type on soil environment.

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