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EXOGENOUS OF SILICON AND GLYCINE BETAINE IMPROVES SALINITY TOLERANCE OF PEPPER PLANTS (*CAPSICUM ANNUM* L.)

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Abstract

Soil salinity is a major abiotic factor that limiting crop growth and productivity especially in arid and semi-arid lands. Indeed, soil salinity disrupted many vital mechanisms i.e. the cellular ion and osmatic balance. Although silicon (Si) is generally considered nonessential element for growth and developments. Si uptake by plants can alleviate both biotic and abiotic stresses and using glycine betaine (GB) which also overcome growth inhibition caused by osmotic stress. The pots experiment for the growth season 2018 was carried out to study the effect of sodium chloride stress with concentration (0,100 and 150) mM which equal (0. 10.3 and 15.1) ds.m^{-1} on pepper plants and their treatment with silicon (0,1.5 and 3) mM with or without glycine betaine (100) mM. The experiment was based on completely randomized design (CRD). with three replicates per treatment and the mean were compared to the use of the least significant difference at the probability level (0.05). Data showed that all plant growth aspects such N, K, P, Si, Zn and chlorophylls contents improved under foliar silicon and GB treatment compared to those non-treatment treated plants. Among silicon treatments, concentration of 1.5 mM and GB 100 mM recorded the highest effect in mitigating salinity negative effects.

***Keywords*:** Salinity, Silicon, Glycine betaine GB, N, P, K, Si, Zn, Chlorophyll, a, b, and total.

Introduction

Food security for the expanding population and decreasing the sources of fresh water, salinity is became one of the most real environmental problems that causing a great deficiency on growth crops yield and development of plant species. In fact, salinity and desertification resemble a challenge problem in Iraq. Therefore, many trials and approaches have been attempted to mitigate the well-known negative effects of salinity on plant growth and production (Ahmad *et al*., 1992). Salt stress also induced disturbance in ionic homeostasis causes a cascade of secondary effects such as oxidative stress due to reactive oxygen species (ROS) production (Joseph and Jini, 2011), The impact of salinity and mineral nutrient solution, on productivity, photosynthesis and growth has been studies in different plants (Li et al., 2008; Taffouo *et al*., 2010). in a recent study, (Hand *et al*., 2017) observed pepper cultivars ('Granada', 'Goliath' and 'Nobili'), were subjected to four levels of NaCl (0, 50, 100 and 200 mM), Flavonoid content, K, Ca and Mg concentrations were significantly reduced with increasing salinity in all cultivars. Among those approaches is the improvement of plant nutritional status via foliar application of Si and GB to ameliorate salinity damages (Hamayun *et al*., 2010). Silicon (Si) is classified as a beneficial element. This element limits the effects of abiotic and biotic stresses in plants (Cooke and Leishman, 2016; Debona *et al*., 2017; Artyszak 2018). Interest in this research topic is apparent in the number of recent review articles published on plant stress mitigation by Si (Cooke and Leishman, 2016; Coskun *et al*., 2016; Imtiaz *et al*., 2016; Reynolds *et al*., 2016; Debona *et al*., 2017; Kim *et al*., 2017; Luyckx *et al*., 2017; Sakr, 2017; Etesami and Jeong, 2018). Also proved that silicon application can alleviate water stress by increasing water uptake by roots, maintaining nutrient balance, decreasing water loss from leaves, and promoting photosynthetic rate. At the biochemical level, silicon may improve antioxidant defense abilities by increasing the activities of antioxidant enzymes and the contents of non enzymatic antioxidants; Si may also participate to osmotic adjustment and increase photosynthetic enzymatic Activities (Zhu and Gong, 2014). In recent years, more research has been performed with regards to foliar nutrition using silicon, which brings unequivocal production benefits, and at the same time is much cheaper and more convenient to use than soil fertilization. As a result, it improves the profitability of many plant species production.

Betaine or glycine betaine is an organic nitrogenous trimethyl glycine. Compound, found the first time in sugar-beet juice *Beta vulgaris* (Ashraf and Foolad, 2007). In addition, betaine is considered to be involved in scavenging free radicals and in protecting enzymes in addition to their well-established roles as a simple osmolyte. It is reported that betaine act as enzyme protectants against abiotic stresses and protect higher plants against salt/osmotic stresses by stabilizing many functional units such as complex II electron transport, membranes and proteins and enzymes such as RUBISCO, GB may have a role in Na^+/K^+ discrimination, which substantially or partially contributes to plant salt tolerance. GB application may lead to increase free amino acids especially proline in the water stressed wheat plants and consequently increased the soluble nitrogen as well as total-N (Ambika *et al*., 2015). Exogenous GB treatments could alleviation of salt stress by increasing the total antioxidants and total phenolics (Shams *et al*., 2016). foliar GB at 10 mM to cucumber plants ameliorated the harmful effects of NaCl stress on the vegetative growth and yield through enhancing both leaf relative water content and leaf membrane stability (Youssef *et al*., 2018). The current study was therefore an attempt to NaCl stress tolerance of pepper plant using a foliar silicon (Si) and naturally plant synthesize and metabolized substance glycine betaine (GB).

Materials and Methods

The experiment was based on completely randomized design (CRD). With three replication. Seeds were sown in pots (0.30 m in diameter and 0.50 m in depth) filled with (10 Kg) of soil. Apot experiment was conducted in the green house of Biology Department, College of Education (Ibn Al-Haitham), University of Baghdad. Iraq, during the growing season 2018. to study the effect of exogenous of Si and GB and their interaction in some chemical characteristics, N, P, K, Si, Zn and chlorophyll contents under NaCl stress. After thinning only four plants were kept in each pot for further work. All plants are protected from jungles and insects and all plants care until the completion of the study.The plants were applied with treatments 2 times, the first application 30 days after transplanting with 10 days intervals. of sowing with three concentration of NaCl (0, 100 and 150) mM which equal (0 ,10.3 and 15.1) $ds.m^{-1}$ and Foliar application were three concentration of Si (0, 1.5 and 3) mM also with two concentration of GB (0, 100) mM and application was uniformly to all treatments, control plants were sprayed with distilled water. Plants were sampled after 60 days from cultivation of seedlings. Some chemical characteristics of the plant were studied.

Digested Samples:

Powdered dried samples were digested according to the method proposal by Cresser and Parsons (1979).

Estimation of nitrogen concentration in vegetative total (%) Nitrogen concentration were estimated in the digested samples of vegetative (Jakson, 1958).

Estimation of potassium concentration in vegetative total (%) the potassium concentration in of digested samples were estimated in the vegetative total of Atomic absorption spectrophotometer by Chapman and Partt (1961).

Estimation of phosphorus concentration (%) in According to Phosphomolybdate method spectrophotometric vanadium then estimated at wavelength 420 Nanometer (Cresser and Parson, 1979).

Estimation of Zinc concentration in vegetative total ($mg.Kg^{-1}$) the concentration of Zinc in the digested using Atomic absorption spectrophotometer method Allan (1961).

Estimation of Silicon by method of Bierman and Baert (1977) with UV-spectrophotometer.

Estimation of Chlorophyll according to Hiscox and Israelstazm (1979). Chl a, b and total were measured by spectrophotometer at wavelengths 663, 647 nm, respectively. Chlorophylls were calculated according to the equation described by, Nornai (1982).

Chlorophyll a =12.70 A663 – 2.79 A647

Chlorophyll b =20.76 A647 – 4.62 A663

Total Chlorophyll =17.90 A647 + 8.08 A663

Statistical Analysis

The statistical analyses were carried out using Genstat release (10.3 DE) Data obtained were analyzed statistically to determine using least significant difference (LSD) using analysis of variance (ANOVA) at $p \leq 0.05$.

Results

Nitrogen concentration in vegetative leaves of plant (%):

The result of table (1) indicated that there was significant decreasing in the mean of N% when increasing the concentration of NaCl to 150 mM the ratio of this trait was 25.32% decreasing

The effects of GB (100 mM) led to significant increase by 8.5%. For both concentrations of Si (1.5, 3) mM were positive increasing concentration of (N%) with 15.95% and 17% respectively compared to non-treated plants.

The duel interaction, between Si and GB was significantly in nitrogen concentration with Si (1.5 mM) and GB (100) mM was the highest value of N% is 1.98% comparted with non-treated plant is 1.53%.

The triple interaction among the study factors (NaCl, Si and GB), the values indicated that exogenous of Si and GB reducing the harmful effects of sodium chloride at Si (1.5) mM & GB (100) mM under NaCl concentration 150 mM the N% increased the trait from 1.19 to 1.71.

Phosphorus Concentration (%)

The data of table (2) shows the negative effect of NaCl on pepper plants. When rising the concentration of NaCl from initial state 0 to 150 mM the significant decrease of percentage recorded was 27%. When spraying with GB the P% increased up to 8.72%. By spraying with Si (1.5, 3) mM the concentration of P increased proportionally (13%, 18%) respectively.

The binary interaction between the two factors of experiment (Si and GB) was significant increase in P%, the result confirmed the at concentration of Si (1.5) mM and GB (100) mM the increasing was 30.41% compared with non-treat plant.

The interaction with the three factors (NaCl, Si and GB) the result of the table showed as following under the concentration of NaCl (150) mM and Si (1.5) mM and GB (100) mM the significant increasing in percent of P was from 0.108 to 0.171%.

Potassium concentration (%)

The results of table (3) indicated that there were significant decreasing in K% in the pepper plant due to the stress of NaCl while its concentration is raising from 0 to 150 mM the was 31.76%. At foliar application with Si at concentration (1.5) mM the concentration of K it was a significant increasing the K of the pepper with increasing rate was 17% comparing with that non-treated plants. In the same manner, the GB had a significant increasing concentration of K ratio and it was 8.8%.

The effect of binary interaction foliar application Si (1.5) mM & GB (100) mM the result was significant increasing in K concentration which increased from 1.06 to 1.37%. The reaction of three factors of experiment (NaCl, Si and GB) it was clear when foliar Si (1.5) mM and GB(100) mM under NaCl stress (150) mM the increasing ratio of K element increased from 0.38 to 1.20% with increasing percentage 68%.

Silicon concentration in vegetative total ($mg.Kg^{-1}$)

A higher concentration of sodium chloride (150) mM caused an average reduction of silicon concentration and decrease was 20.2%, the results of the table (4) also confirmed the effect of addition Si (1.5) MM in increasing the mean of Si percentage up to 17.1% while at Si (3) mM the mean of trait increased with 17%.

Table 1 : The effect of Si and GB on nitrogen concentration in pepper leaves under NaCl stress (N %).

Glycine mM	Si mM	NaCl mM			Glycine × Si
		0	100	150	
0	0	1.81	1.60	1.19	1.53
	1.5	1.91	1.93	1.56	1.80
	3	1.94	2.16	1.61	1.90
00	0	1.87	1.97	1.37	1.74
	1.5	2.08	2.14	1.71	1.98
	3	1.95	2.03	1.80	1.93
LSD 0.05		0.08			0.05
Glycine × NaCl					
Glycine mM		NaCl mM			Mean Glycine
		0	100	150	
0		1.89	1.89	1.45	1.74
100		1.97	2.05	1.63	1.88
LSD 0.05		0.05			0.03
Si × NaCl					
Si mM		NaCl mM			Mean Si
		0	100	150	
0		1.84	1.79	1.28	1.63
1.5		1.99	2.04	1.64	1.89
3		1.95	2.09	1.70	1.91
LSD 0.05		0.06			0.03
Mean NaCl		1.93	1.97	1.54	
LSD 0.05		0.03			

Table 2 : The effect of Si and GB on Phosphorus concentration in pepper leaves under NaCl stress (P%).

Glycine mM	Si mM	NaCl mM			Glycine × Si
		0	100	150	
0	0	0.180	0.159	0.108	0.149
	1.5	0.190	0.192	0.155	0.179
	3	0.193	0.215	0.160	0.189
100	0	0.186	0.197	0.136	0.173
	1.5	0.207	0.211	0.171	0.196
	3	0.194	0.202	0.179	0.192
LSD 0.05		0.010			0.006
Glycine × NaCl					
Glycine mM		NaCl mM			Mean Glycine
		0	100	150	
0		0.188	0.186	0.141	0.172
100		0.196	0.203	0.162	0.187
LSD 0.05		0.006			0.003
Si × NaCl					
Si mM		NaCl mM			Mean Si
		0	100	150	
0		0.183	0.178	0.122	0.161
1.5		0.199	0.202	0.163	0.188
3		0.194	0.208	0.169	0.190
LSD 0.05		0.007			0.004
NaCl Mean		0.192	0.196	0.151	
LSD 0.05		0.004			

Foliar GB application increased the percentage of Si concentration up to 9.33%, the effect of binary interaction for both Si (1.5) mM and GB (100) mM the significant increasing in Si value from 0.55 to 0.73 mg.Kg^{-1}.

The triple interaction between the factors of the study (NaCl, Si and GB) was as follows, at the NaCl concentration (150) mM., GB (100) mM and Si (1.5 mM the Si concentration increasing 0.51-0.73 mg.Kg^{-1} while at concentration of Si up to (3) mM. the concentration of silicon raising from 0.5 to 0.77 mg.Kg^{-1}.

Zinc concentration in vegetative total (mg.Kg^{-1})

The results of a table (5) shows there were a significant decreasing in Zinc concentration of pepper plant which under NaCl stress with concentration (150 mM) and calculated as decreasing by 31.2%. The important role of GB that reduce salinity stress which led increasing rate of this character with

4.91%, with the same way the silicon (1.5 mM) plays a positive role by increasing the ratio of Zn up to 10.3%. The binary interaction between Si and GB application to pepper plants where the data of table indicated in using Si (1.5) mM & GB (100) mM the concentration raising the Zn from 308.6 to 364.3 mg.Kg^{-1}.

The overlap between the three factors of study (NaCl-Stress, foliar application of Si and GB) the data showed at highest concentration of NaCl (150 mM), Si (1.5 mM) and GB (100 mM) the mean of this character increasing from 240.0 to 304.3 mg.Kg^{-1} with some concentration of above but Si which raising to (3 mM) the increasing is the character mean from 240.0 to 314.7 mg.Kg^{-1}.

Chlorophyll content (a, b, total) mg.g^{-1}F.W

The results of tables (6, 7, 8) indicated the harmful effect of sodium chloride to the pepper plants in all types of chlorophyll (a, b, and total) as follows.

Chlorophyll a content the negative effect of NaCl-stress (150 mM) shows the decreasing ratio in the mean of this trait was 44%. The decreasing mean percent with chlorophyll b (also same concentration of NaCl) it was 42.5%. In case of total chlorophyll the table showed decreasing in mean 43.1% (at same level of NaCl concentration.

In case of using Si (1.5, 3 mM) the value of mean increased 16.41%, 17.94% at chlorophyll a respectively. While increased in chlorophyll b with 16%, 18% respectively, but in the total chlorophyll the mean of this trait increase equally in percentage 18%.

The binary interaction with Si (1.5 mM) and GB (100 mM) these were significant increasing in all types of chlorophyll, in chlorophyll a increase the mean from 3.65 to 4.76 mg.g^{-1}F.W, chlorophyll b from 1.61 to 2.10 mg.g^{-1}F.W, in case by total it was increasing from 5.25 to 6.67 mg.g^{-1}F.W.

The overlap interaction of the three factors of study, there were a significant increasing in the means of this characteristic with (150 mM) of NaCl and GB (100 mM) and Si (1.5mM) the data which had been obtained as following.

The mean of chlorophyll a increased from 2.47 to 3.77 mg.g^{-1}F.W. The increasing of mean of chlorophyll b is was from 1.10 to 1.68 mg.g^{-1}F.W. Finally the increasing in the mean of total chlorophyll it increased from 3.57 to 5.45 mg.g^{-1}F.W.

Discussion

Plant parameters of N, P, K, Si, Zn and chla,b and total were significantly reduced when pepper plant grew under NaCl stress. While both silicon and glycine betaine behaved differently, with increases in the above traits under study**.** It is express that Si is effective for growth of many plants under different abiotic and biotic stresses (e .g. salt, drought, toxicity, and plants diseases) (Liang *et al*., 2003; Ma, 2004). Si reduces harmful effect salt stress depression on plant species (Wang *et al*., 2010). Actually our results indicated that Si purpose improve

Table 3 : The effect of Si and GB on Potassium concentration in pepper leaves under NaCl stress (K%).

Glycine mM	Si mM	NaCl mM			Glycine × Si
		0	100	150	
0	0	1.26	1.10	0.83	1.06
	1.5	1.33	1.34	1.09	1.25
	3	1.35	1.48	1.12	1.32
100	0	1.31	1.38	0.95	1.21
	1.5	1.45	1.48	1.20	1.37
	3	1.37	1.41	1.25	1.34
LSD 0.05		0.06			0.04
Glycine × NaCl					
Glycine mM		NaCl mM			Glycine Mean
		0	100	150	
0		1.31	1.31	1.01	1.21
100		1.38	1.42	1.13	1.31
LSD 0.05		0.04			0.02
Si × NaCl					
Si mM		NaCl mM			Mean Si
		0	100	150	
0		1.29	1.24	0.89	1.14
1.5		1.39	1.41	1.14	1.31
3		1.36	1.45	1.19	1.33
LSD 0.05		0.05			0.03
NaCl Mean		1.34	1.37	1.073	
LSD 0.05		0.03			

Table 4 : The effect of Si and GB on Silicon concentration in pepper leaves under NaCl stress (mg.kg^{-1}).

Glycine mM	Si mM	NaCl mM			Glycine × Si
		0	100	150	
0	0	0.77	0.69	0.51	0.66
	1.5	0.82	0.83	0.67	0.77
	3	0.83	0.93	0.69	0.82
100	0	0.80	0.85	0.59	0.75
	1.5	0.89	0.92	0.73	0.85
	3	0.84	0.87	0.77	0.83
LSD 0.05		0.04			0.02
Glycine × NaCl					
Glycine mM		NaCl mM			Mean Glycine
		0	100	150	
0		0.81	0.81	0.62	0.75
100		0.85	0.88	0.70	0.81
LSD 0.05		0.02			0.01
Si × NaCl					
Si mM		NaCl mM			Mean Si
		0	100	150	
0		0.79	0.77	0.55	0.70
1.5		0.86	0.88	0.70	0.81
3		0.84	0.90	0.73	0.82
LSD 0.05		0.03			0.014
Mean NaCl		0.83	0.85	0.66	
LSD 0.05		0.014			

Table 5 : The effect of Si and GB on Zinc concentration in pepper leaves under NaCl stress (mg.kg^{-1}).

Glycine mM	Si mM	NaCl mM			Glycine × Si
		0	100	150	
0	0	356.0	329.7	240.0	308.6
	1.5	368.7	375.7	285.3	343.2
	3	372.7	399.7	291.3	354.6
100	0	363.7	376.7	261.3	333.9
	1.5	391.7	397.0	304.3	364.3
	3	374.3	383.7	314.7	357.6
LSD 0.05		9.6			5.5
Glycine × NaCl					
Glycine mM		NaCl mM			Mean Glycine
		0	100	150	
0		365.8	368.3	272.2	335.4
100		376.6	385.8	293.4	351.9
LSD 0.05		5.5			3.2
Si × NaCl					
Si mM		NaCl mM			Si Mean
		0	100	150	
0		359.8	353.2	250.7	321.2
1.5		380.2	386.3	294.8	353.8
3		373.5	391.7	303.0	356.1
LSD 0.05		6.8			3.9
Mean NaCl		371.2	377.1	282.8	
LSD 0.05		3.9			

Table 6: The effect of Si and GB on Chlorophyll a content (mg.g^{-1} fresh wt.) in pepper leaves under NaCl stress.

Glycine mM	Si mM	NaCl mM			Glycine × Si
		0	100	150	
0	0	4.50	3.97	2.47	3.65
	1.5	4.76	4.81	3.38	4.31
	3	4.83	5.37	3.50	4.57
100	0	4.65	4.92	2.91	4.16
	1.5	5.18	5.34	3.77	4.76
	3	4.86	5.05	3.97	4.63
LSD 0.05		0.21			0.12
Glycine × NaCl					
Glycine mM		NaCl mM			Mean Glycine
		0	100	150	
0		4.70	4.72	3.12	4.18
100		4.90	5.10	3.55	4.52
LSD 0.05		0.12			0.07
Si × NaCl					
Si mM		NaCl mM			Mean Si
		0	100	150	
0		4.58	4.45	2.69	3.90
1.5		4.97	5.07	3.58	4.54
3		4.85	5.21	3.74	4.60
LSD 0.05		0.15			0.09
Mean NaCl		4.80	4.91	3.33	
LSD 0.05		0.09			

Table 7 : The effect of Si and GB Chlorophyll b content (mg.g^{-1} fresh wt.) in pepper leaves under NaCl stress.

Glycine mM	Si mM	NaCl mM			Glycine × Si
		0	100	150	
0	0	1.98	1.75	1.10	1.61
	1.5	2.09	2.11	1.51	1.90
	3	2.12	2.36	1.56	2.01
100	0	2.04	2.16	1.30	1.84
	1.5	2.28	2.34	1.68	2.10
	3	2.14	2.22	1.76	2.04
LSD 0.05		0.09			0.05
Glycine × NaCl					
Glycine mM		NaCl mM			Mean Glycine
		0	100	150	
0		2.06	2.07	1.39	1.84
100		2.15	2.24	1.58	1.99
LSD 0.05		0.05			0.03
Si × NaCl					
Si mM		NaCl mM			Mean Si
		0	100	150	
0		2.01	1.95	1.20	1.72
1.5		2.18	2.23	1.59	2.00
3		2.13	2.29	1.66	2.03
LSD 0.05		0.07			0.04
Mean NaCl		2.11	2.16	1.48	
LSD 0.05		0.04			

Table 8 : The effect of Si and GB on Total chlorophyll content (mg.g^{-1} fresh wt.) in pepper leaves under NaCl stress.

Glycine mM	Si mM	NaCl			Glycine × Si
		0	100	150	
0	0	6.47	5.72	3.57	5.25
	1.5	6.85	6.92	4.89	6.22
	3	6.96	7.73	5.06	6.58
100	0	6.70	7.08	4.20	5.99
	1.5	7.46	7.68	5.45	6.86
	3	7.00	7.28	5.74	6.67
LSD 0.05		0.30			0.17
Glycine × NaCl					
Glycine mM		NaCl mM			Mean Glycine
		0	100	150	
0		6.76	6.79	4.51	6.02
100		7.05	7.34	5.13	6.51
LSD 0.05		0.17			0.10
Si × NaCl					
Si		NaCl mM			Mean Si
		0	100	150	
0		6.58	6.40	3.89	5.62
1.5		7.15	7.30	5.17	6.54
3		6.98	7.50	5.40	6.63
LSD 0.05		0.21			0.12
NaCl Mean		6.90	7.07	4.82	
LSD 0.05		0.12			

Whole plant growth aspects under NaCl-stress condition (Ali *et al*., 2012). The study showed that foliar application of Si ameliorate the plant status under saline condition which increased in cell expansion and leaf area compared to those non-Si treated plants under salinity stress (Ahmed *et al*., 1992).

The turgor potential will increase with Si-treated plants more than plants which treated only with NaCl hence higher photosynthesis will occurrence. Cell-turgor potential gives net photosynthesis rate more 30% in case of application Si. In this study indicated that plants with Si treated increasing in nutrient contents such as N, P, K, Si and Zn in plant tissue is another mechanism of Si alleviation to salinity stress. Si reduces uptake of Na^+ by improving K^+: Na^+ and also mitigate the other heavy metals sterss (Liang and Zhergno, 1999). Silicon significantly improved Na^+ concentration in the leaf apoplast of the field bean (*Vicia faba* L.) (Shahzad *et al*., 2013). Ashraf et al. (2010a) as noted silicon application significantly decreases Na^+ but increases K^+ concentration in shoots. silicon alleviates salinity toxicity and drought stress. The major points are the following: (1) both passive and active silicon uptake may coexist in plants; (2) although silicon transporters have been identified in some plants, more silicon transporters remain to be identified, and the process of silicon transport needs further clarification; (3) the mechanisms for silicon-mediated tolerance of salinity and drought have been extensively investigated at both physiological and biochemical levels (Zhu and Gong 2014). Previous studies have shown that silicon application may increase salinity tolerance in some important crops, such as sugarcane (*Saccharum officinarum* L.) (Ashraf *et al*., 2010a, b), soybean (*Glycine max* L.) (Lee *et al*., 2010), lettuce (*Lactuca sativa* L.) (Khalifa *et al*., 2016), pea (*Pisum sativum* L.) (Shahid *et al*., 2015), pepper (*Capsicum annum* L.) (Manivannan *et al*., 2016). Added of Si increases rigidity of the mature leaves, which have a harder texture and are held more horizontally, delays leaf senescence and increase chlorophyll conent and these results were going in parallel with Mian-Uneo *et al.* (2013).

Salama *et al*. (2015) observed that NaCl treatment increased toxic ions (Na^+ and Cl^-) with a reduction in the essential ones (K^+ and Ca^{+2}) in the shoots and roots of wheat . All GB priming concentrations significantly reduced the Na^+ and Cl^- contents under salt stress. Caryopses priming in 25 mM GB was the only concentration that increased K^+ and Ca^{2+} in both shoots and roots in response to salinity. This resulted in a greatest reduction of Na^+/K^+ and Na^+/Ca^{2+} ratios in the shoots and roots. GB accumulates at high concentration in naturally accumulating plants and acts as osmoregulator in abiotic stress conditions (Giri, 2011). New evidence indicate toward the protection of reproductive organs by GB (Chookhampaeng, 2018). GB protection photosynthesis machinery and ROS detoxification during abiotic stress, GB could be involved in inhibiting ROS accumulation activation of some stress related gene and membrane protection (Alasvandyan, 2017). The increase in mean values in the tables are due to the roles of application Si and GB in increasing vegetative growth, metabolic activities, consumption of nutrient and absorption. These results are in agreement with Yongzing and Haijun (2014).

Conclusion

It could be concluded that application of silicon and GB can mitigate salt stress damages on pepper plants.

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