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Use of Silicate and Different Cultivation Practices in Alleviating Salt Stress Effect on Bean Plants

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Abstract: A field experiment was cultivated with faba bean on saline soil of 7.5 dS/m, where the following treatments were applied: 1) three cultivation practices (Furrow with mulch, furrow without mulch and line), 2) five foliar applications (potassium silicate, magnesium silicate, potassium sulfate and magnesium sulfate) and control. Moreover, the interaction between treatments was also considered. The results showed that furrow with mulch method had a major effect compared to other cultivation methods on shoot height (cm), root length (cm), shoot dry weight (g) and root dry weight (g) at 70 and 90 days after sowing and on straw weight (g/plant), root weight (g/plant), basic branch, pods number/plant, pods weight and seed yield (g/plant and kg/fed.) at harvesting. All measured parameters were significantly increased by silicon solutions as compared with sulphate solutions, although potassium silicate was the best. Magnesium silicate solution gave the highest values of N% and P% in contrast to K_2SiO_4 which gave the highest K% values in plant tissue. Generally, furrow method reduced the salinity on sides of ridge, salts moved from sides towards top of ridge. Furrow with mulch treatment decreased soil salinity more than other cultivation practices, so it is the best practice to avoid salinity hazard in salt affected soils.

Key words: Silicate – Cultivation methods – Salt stress - Bean plants

INTRODUCTION

Salinity toxicity is a worldwide agricultural and eco-environmental problem. It is one of the most important problems in crop growth and production (Ashraf, 2009). Approximately one-third of the world land surface is arid and semi-arid, of which one half is affected by salinity (Liang *et al.*, 1996). It is estimated that about a third of the world's cultivated land is affected by salinity (Perez-Alfocea *et al.*, 1996). The problem of salinity is of special importance in Egypt for both the old cultivated area as well as for the newly reclaimed lands. The major constraints for plant growth and productivity are ion toxicity with excessive uptake of mainly Cl^- and Na^+ as well as nutrients imbalance caused by disturbed uptake or distribution of essential mineral nutrients (Hu and Schmidhalter, 2005). Living with salinity is the only way of sustaining agricultural production in the salt-affected soil (Al-Rawahy *et al.*, 2011). So that, it is must to find the best management to alleviate salt hazard.

Silicon has not been proven to be an essential element for higher plants, but its beneficial effects on growth have been reported in a wide variety of crops, including rice, wheat, barley and cucumber. Si fertilizer is applied to crops in several countries for increased productivity and sustainable production (Ma *et al.*, 2001). The amount of Si in soil may vary considerably from 1 % to 45 % (Sommer *et al.*, 2006). Most Si is present in the soil as insoluble oxides or silicates, but plants can easily absorb silicilc acid $Si(OH)_4$ from soil. Silicic acid is generally found in the range of 0.1-0.6 mM in soils (Epstein, 1994 and 1999). Unfortunately, soluble Si polymerizes rapidly if the concentration of Si increases above 2 mmol L^{-1} (Iler, 1979). In contrast, large molecules of polysilicates in the form of colloids, are very stable, but have shown to be less accessible to the plant (Voogt and Sonneveld, 2001). Silicon concentrations vary greatly in plant aboveground parts, ranging from 0.1 to 10.0% of dry weight. This wide variation in Si concentration in plant tissues is attributed mainly to differences in the characteristics of Si uptake and transport (Epstein, 1994). The agricultural benefits of silicon amendments on a soil ecosystem are well established. Silicon has been shown to mitigate adverse effects of water, mineral deficiency (Ma *et al.,* 2001) and alleviate the effects of biotic stresses including salt stress, metal toxicity and nutrient imbalance (Ma, 2004).

There are numerous studies on the use of silica amendments in hydroponics system. However, the information on the role of Si in allaying the salinity induced harmful effects on bean crop is not much in the literature. To our knowledge, there is currently no information available about the possible beneficial effects of silicon in the performance of bean plants grown under salt stress.

Due to high temperatures of Egyptian region between April and October, there exists very high water evaporation rate. Surface mulch (Mulch refers to a material placed on the soil surface) has a significant effect on

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reducing evaporation of water; therefore, it can decrease salt accumulation as well (Al-Rawahy *et al.,* 2011). Many materials have been used as mulch, such as plastic film, crop residue, straw, paper pellets, gravel-sand, rock fragment, volcanic ash, poultry and live-stock litters, city rubbish, etc (Yan-min *et al.,* 2006). However plastic film and straw were used most commonly (Bu *et al.,* 2002).

The aim of our work was to study the effect of various Si sources (potassium silicate and magnesium silicate) compared to sulphate (as a traditional source of potassium and magnesium) on some growth parameters of bean plants, which were grown by different cultivation methods under salt stress condition. Further, there is strong demand to improve the knowledge of the relationship between Si and other nutrients and role of Si in alleviating salt stress especially under Egyptian conditions. Where, Egypt is characterized by high temperature, high evapotranspiration, shortage in irrigation water, considerable amount of under-ground saline water and wide area of saline soil.

MATERIALS AND METHODS

A field experiment was carried out in Ismailia Governorate (Latitude: 30 35 Longitude: 32 16 Elevation: 11.2) to investigate the usage of silicate and different methods of agriculture in alleviating salt stress on bean plants. Field affected with salinity (7.5 dS/m) was divided into 3 main plots. The main plots contained different three methods of cultivation (Furrow with mulch, furrow without mulch and line), rice straw was used for mulch. Each main plot was divided into 5 sub-plots. The first sub-group was sprayed with water (control) whereas the second and third sub-plots were sprayed with two different sources of silicate [potassium silicate (K_2SiO_4) and magnesium silicate ($MgSiO_4$)] but fourth and fifth sub-plots were sprayed with common source of potassium and magnesium [potassium sulfate (K_2SO_4) and magnesium sulfate ($MgSO_4$)]. In case of the four solutions, one rate of silicon (300 ppm), K (390 ppm), Mg (120 ppm) and SO_4 (480 ppm) was applied, irrespective of its source. These solutions were prepared by dissolving 580, 850, 780 and 600 mg/L of $MgSiO_4$, K_2SiO_4, K_2SO_4 and $MgSO_4$, respectively. Foliar application treatments were applied at three successive times 30, 60 and 80 days after sowing faba bean plants (*Vicia faba* L.) var. Giza 73 in winter season (2009-2010). Some physical and chemical properties of the soil used (surface layer) are given in Table (1).

Table 1: Some physical and chemical properties of the studied soils (surface layer)

Characteristics	Value
pH (1 : 2.5 soil : water ratio)	8.1
EC (Soil paste extraction) dSm^{-1}	7.5
Soluble cations (m.e./100g soil):	
Calcium	13.6
Magnesium	7.5
Potassium	0.9
Sodium	45.5
Soluble anions (m.e./100g soil):	
Carbonate	-
Bicarbonate	3.2
Chloride	65.5
Sulphate	6.3
Physical properties (%):	
Coarse sand	33.6
Fine sand	39.9
Silt	18.7
Clay	8.5
Textural class	Sandy loam

Nitrogen and phosphorus fertilization was carried out according to the recommendation of Ministry of Agriculture. Ammonium sulphate (20.6% N) was added at rate of 20kg N /fed. in three equal portions before cultivation, after two weeks from cultivation and after three weeks from second addition. Super-phosphate (15.5% P_2O_5) was added before planting at the rate of 200 kg/fed.

Four randomly selected plants were taken at 70 and 90 days after sowing. The following measurements were recorded: shoot height (cm), root length (cm), shoot dry weight (g) and root dry weight (g). Dry weights were measured after drying plant parts for 3 days at 70C. At harvest (120 days after sowing), yield and yield components were estimated as follows: Straw and root weight (g/plant), basic branch, pods number/plant, pods weight and seed yield (g/plant and kg/fed.). Nitrogen, P and K were determined in the dry material of straw at harvest as described by Cottenie *et al.,* (1982).

The salt distributions under three cultivation methods were compared to assess the degree of salt movement under each treatment. So that, soil samples were collected at depths of 0-20, 20-40 and 40-70cm at four different points on both furrow with and without mulch [i.e., bottom of ridges (A), side of ridges (B), top of ridges (C) and between drippers (D)] and one point on the line method (between drippers) as shown in Fig. (1). The collected samples were analyzed for electrical conductivity (expressed in dSm-1) using conductivity meter, in the extract of saturated soil paste as outlined by Page *et al.*, (1982).

The experiment was placed in a split split design with four replicates of each treatment. Analysis of variance of data for each attribute was computed using the CoStat program. The least significant difference (LSD) test to assess the significant difference between the mean values was calculated as described in Snedecor and Cochran (1980).

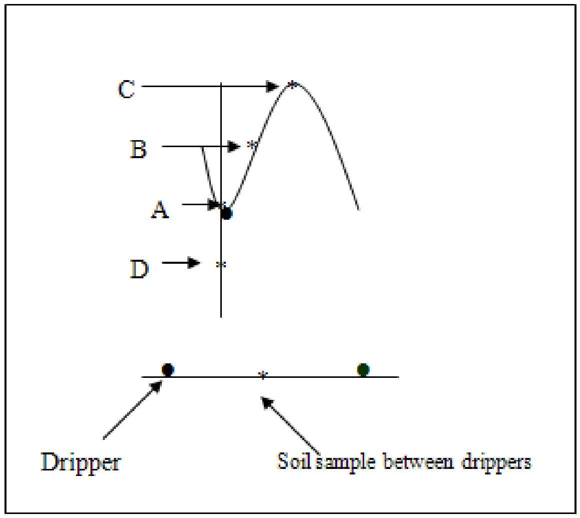

Fig. 1: Soil sampling position under the furrow and line methods.

RESULTS AND DISUCSSIONS

Plant Height and Root Length:

For plant height and root length (cm) at 70 and 90 day, furrow with mulch method had significant effect compared to furrow without mulch and line methods (Table 2-a). There is one exception in root length at 70 day, whereas no significant between furrow with mulch and line. Generally, furrow without mulch method had a minor effect. The superiority of mulch method may be due to mulch significant effect on reducing evaporation of water; therefore, it decreases salt accumulation (Al-Rawahy *et al.*, 2011) and increases moisture content (Gicheru *et al.*, 2006). The low effect of furrow without mulch method may be due to the soil disturbance induced in soil which raises evaporation and increase water loss more than minimum tillage in line method, therefore, it increases salt accumulation. Greenway and Munns (1980) suggested that salinity exerts its effect directly on cell extension and/or division, which is in line with our observation. Darwish (2006) reported that the liner method was better and gave the maximum values of plant height compared with both broadcast and furrow methods.

Concerning the effect of foliar treatments (Table 2-b), plant height and root length increased significantly by sprayed all solutions compared with control (sprayed with water). Silicate solutions had the superiority effect compared with sulphate solutions. This may be refer to silicon which promotes the growth of various higher plant species (Zhu *et al.*, 2004), although there is a plenty supply of sulphate by addition of all commercial fertilizers and rarity of silicate supply. In addition to role of Si in increasing growth as mentioned by Hashemi *et al.*, (2010) they found that silicon nutrition ameliorated the deleterious effects of salinity on the growth of canola plants through lowering tissue Na^+ contents, maintaining the membrane integrity of root cells as evidenced by reduced lipid peroxidation, increased reactive oxygen species scavenging capacity and reduced lignifications. In this respect Marschner (1995) suggested that, silicon application might exert their favorable effect to counteract the detrimental effects of salinity when the plants would show obvious stunting. In this connection, evidence has been provided that silicon not only contributes to cell wall rigidity and strengthening but might also increase cell wall elasticity during extension growth. Hanafy Ahmed *et al.*, (2008) reported that the enhancement effect on shoot height of wheat plants supplied with Si might be induced through its role in both cell division and cell expansion by their effect on RNA and DNA synthesis.

The high increases in plant height and root length were obtained when bean plants treated with potassium silicate followed by Mg silicate. No significant difference exists between potassium sulphate and Magnesium sulphate in most cases.

The interaction effect between cultivation practices and foliar treatments were significant (Table 2-c). These results are in harmony with those reported by Parveen and Ashraf (2010), they found that, applied Si in varying levels significantly increased the shoot length of maize plants under saline conditions. Silicon treatment (100ppm) had significantly increased shoot length of rose (Hwang *et al.*, 2008 and Reezi *et al.*, 2009) and wheat plants (Hanafy Ahmed *et al.,* 2008).

Table (2): Plant height (cm) and root length (cm) of Faba bean plants at 70 and 90 days as affected by foliar treatments and different Agricultural methods under soil salinity condition.

(a) Individual Effect Of Agricultural Methods

Agricultural Methods	Plant Height (cm)		Root length (cm)	
	70	90	70	90
Furrow with mulch	40.31	62.67	9.23	18.13
Furrow without mulch	36.19	58.31	8.27	15.48
Line	38.33	60.87	9.53	16.20
LSD at 5%	1.52	1.20	0.62	0.81

(b) Individual Effect Of Foliar Application

Foliar applications	Plant Height (cm)		Root length (cm)	
	70	90	70	90
Control	26.94	50.09	7.17	10.13
K_2SiO_4	46.11	66.33	11.00	20.78
$MgSiO_4$	42.00	63.67	11.00	17.78
K_2SO_4	36.44	61.56	8.11	17.44
$MgSO_4$	39.89	61.44	7.78	16.89
LSD at 5%	1.96	1.55	0.80	1.04

(c) The Interaction Between Agricultural Methods And Foliar Application

agricultural methods	Foliar treatments	Plant Height (cm)	Root length (cm)		
		70	90	70	90
Furrow with mulch	Control	27.53	51.03	7.50	11.0
	K_2SiO_4	50.00	70.67	11.67	22.00
	$MgSiO_4$	44.33	65.33	11.67	20.67
	K_2SO_4	37.67	63.00	7.33	19.33
	$MgSO_4$	42.00	63.33	8.00	17.67
Furrow without mulch	Control	26.30	48.90	7.00	9.40
	K_2SiO_4	42.0	62.00	9.67	20.00
	$MgSiO_4$	39.67	61.00	9.33	17.00
	K_2SO_4	35.33	59.67	8.33	16.00
	$MgSO_4$	37.67	60.00	7.00	15.00
Line	Control	27.00	50.33	7.00	10.00
	K_2SiO_4	46.33	66.33	11.67	20.33
	$MgSiO_4$	42.00	64.67	12.00	15.67
	K_2SO_4	36.33	62.00	8.67	17.0
	$MgSO_4$	40.00	61.00	8.33	18.00
LSD at 5%		3.40	2.68	1.39	1.80

Shoot and Root Dry Weight:

Statistical analyses of shoot and root dry weight data at 70 and 90 day revealed that, furrow with mulch treatment increased dry weight compared to furrow without mulch and line methods. There is one exception in shoot dry weight at 90 day where, no significant difference exists between furrow with mulch and line method (Table 3-a). McIntyre *et al.,* (2000) found that mulched treatments produced over three times more biomass than bare soil treatments. Mulched banana took up more water from both the 0-0.3 and 0.3-0.5 m depths than banana grown without mulch and soil water recharged more quickly in the mulched treatments as a result of increased porosity from 0-0.3 m depth. Gicheru *et al.,* (2006) found that surface mulched treatments had significantly higher soil moisture content than the bare with conventional tillage, bare with minimum tillage, incorporated mulch with conventional tillage, manure with conventional tillage and manure with minimum tillage. Both of shoot and root dry weight at 70 day increased by used furrow without mulch than line, but the opposite was true at 90 day. This could be due to the good aeration under furrow without mulch method at 70 day by increasing soil moisture depletion and salt accumulation by time compared to line method.

As for effect of foliar treatments irrespective of cultivation methods (Table 3-b), potassium silicate records the highest values of shoot and root dry weigh except root dry weight at 90 day whereas, no significant difference between potassium and magnesium silicate. Wang and Galletta (1998) concluded that foliar spray with K silicate increased plant growth of strawberry. Hashemi *et al.,* (2010) reported that salinity decreased plant growth parameters such as tissue fresh and dry weights. These decreases were accompanied by increased lignin contents, Na^+ ion accumulation, increased lipid peroxidation and decreased chlorophyll contents in plants.

Silicon nutrition, however, enhanced plant growth parameters and led to the prevention of lignin and the Na^+ accumulation in shoots, reduced levels of lipid peroxidation in the roots and higher levels of chlorophyll. Parveen and Ashraf (2010) showed that application of Si significantly increased the root dry mass of both maize cultivars under saline regimes.

Table 3: Shoot and root dry weight (g) of Faba bean plants at 70 and 90 days as affected by foliar treatments and different agricultural methods under soil salinity condition.

(a) Individual Effect Of Agricultural Methods

Agricultural methods	Shoot dry weight (g/plant)		Root dry weight (g/plant)	
	70	90	70	90
Furrow with mulch	27.71	33.90	17.88	29.57
Furrow without mulch	23.01	31.34	17.16	28.32
Line	20.51	34.38	16.96	28.94
LSD at 5%	0.49	0.81	0.88	0.94

(b) Individual Effect Of Foliar Application

Foliar applications	Shoot dry weight (g/plant)		Root dry weight (g/plant)	
	70	90	70	90
Control	18.94	21.66	10.55	19.86
K_2SiO_4	28.24	37.54	21.28	32.07
$MgSiO_4$	26.62	35.54	20.17	33.18
K_2SO_4	23.71	33.69	16.87	28.12
$MgSO_4$	21.21	37.6	17.8	31.49
LSD at 5%	0.64	1.05	1.14	1.20

(c) The Interaction Between Agricultural Methods And Foliar Application

agricultural methods	Foliar treatments	Shoot dry weight (g/plant)		Root dry weight (g/plant)	
		70	90	70	90
Furrow with mulch	Control	19.33	22.40	10.93	20.40
	K_2SiO_4	35.87	38.40	21.33	37.67
	$MgSiO_4$	31.80	36.73	20.27	31.87
	K_2SO_4	30.76	35.60	16.87	25.93
	$MgSO_4$	20.80	36.37	20.00	32.00
Furrow without mulch	Control	18.50	20.80	10.00	19.27
	K_2SiO_4	26.00	33.93	21.07	30.33
	$MgSiO_4$	26.40	33.37	19.50	35.80
	K_2SO_4	21.93	27.83	17.47	27.17
	$MgSO_4$	22.23	40.77	17.77	29.03
Line	Control	18.99	21.77	10.73	19.92
	K_2SiO_4	22.87	40.30	21.43	28.20
	$MgSiO_4$	21.67	36.53	20.73	31.87
	K_2SO_4	18.43	37.63	16.27	31.27
	$MgSO_4$	20.60	35.67	15.63	33.43
LSD at 5%		1.10	1.82	1.97	1.64

No clear trend was observed in shoot and root dry weight as affected by the interaction between foliar and cultivation treatments (Table 3-c).

Growth Parameters, Yield and Yield Components at Harvest:

It is clear from the data demonstrated in Table (4-a) that, surface mulch increased straw weight, root weight basic branch, pods number, pods weight and seed yield significantly than other cultivation methods. All mentioned parameters follow the same trend and increased gradually in the order: furrow with mulch > line > furrow without mulch. This may be refer to 1) mulch practice can contribute to sustain agriculture through water saving, decreasing evaporation, increasing salt leaching, decreasing salt accumulation and increasing water intake. There are numerous studies reported that, mulching was proved as the best practice in conserving soil water content, reducing salt in soil surface and resulting in higher yield of sorghum (Al-Dhuhli *et al.*, 2010 and Al-Rawahy *et al.,* 2011), corn (Bu *et al.,* 2002), potato (Jemison and Reberg-Horton 2004, Kar and Kumara 2007), tomato (Al-Wahaibi *et al.,* 2007) and wheat (Deng *et al.,* 2006 and Yan-min *et al.,* 2006), 2) The minimum tillage done in line agriculture method resulted in higher soil moisture content than furrow method. This increased in available water led to significant marketable bean yield in line method than furrow without mulch method. In this respect Darwish (2006) showed that line method was the best and gave the highest harvest index. Huge amount of irrigation water can be saved if this knowledge was transferred to farmers through agriculture extension. In contrast, Choudhary *et al.,* (2008) showed that the furrow-bed and furrow-ridge planting techniques produced high wheat yield compared to flat border under flood irrigation. These techniques reduce salinity on the sides of the beds in the vicinity of plants as a result of capillary movement of irrigation water.

Concerning the effect of foliar treatments on yield and yield components, all measured parameters were significantly increased by both silicon solutions (potassium silicate and magnesium silicate) as compared with sulphate solutions (potassium sulphate and magnesium sulphate) and values were arranged in the order: K_2SiO_4> $MgSiO_4$> $MgSO_4$> K_2SO_4>control (Table 4-b). In this respect, Pandey and Yadav (1999) reported that spraying silicon increased grain yield/plant of wheat. They referred that to an increase in plant water status, chlorophyll content, biological yield and harvest index, coupled with reduced values of water potential, increase in dry matter accumulation, dry matter production rate, leaf area/plant at the flowering stage, productive tillers, grains and grain yield/main spike and per plant and transpiration rate coupled with a decrease in stomata conductance. Hanafy Ahmed *et al.,* (2008) showed that the lowest level of silicon significantly increased all the studied growth characters of wheat plants, while all levels of silicon significantly increased number of spikes and grains as well as grains yield when compared with control non-sprayed plants, however, the lowest level of silicon (250ppm) had the superiority effect. Silicon application correct to some extent the negative effects of salinity either on growth, yield, nutrients uptake.

Potassium assists in the processes which ensure carbon assimilation and the transport of photosynthates through the plant for increasing sugars, proteins and growth. Potassium is important for water regulation, intake and increase water use efficiency. Sufficient potassium help plants resist frost, drought and certain diseases. Tahir *et al.,* (2006) reported that potassium has a significant role in improving plant water status and mitigating the toxic effects of Na.

The interaction between cultivation methods and foliar treatments was significant in case of yield and all yield components (Table 4-c). The maximum values of straw weight (g/plant), root weight (g/plant), basic branch, pods number, pods weight (g/plant) and seed yield (kg/fed.) were 122, 56.8, 5, 21.7, 106.3 and 1246, but the minimum values were 41.7, 31.1, 3, 8.8, 34.3 and 441, respectively. The magnitude of increase was obtained when growing bean plants by furrow with mulch method and foliar by potassium silicate solution. While the small record was gained when using furrow without mulch method and sprayed by water (control).

Table 4: Straw and root weight (g/plant), basic branch, pods number/plant, pods weight and seed yield (g/plant and kg/fed.) of Faba bean plants at harvest as affected by foliar treatments and different agricultural methods under soil salinity condition.

(a) Individual Effect Of Agricultural Methods

agricultural methods	Straw weight g/plant	Root weight g/plant	Basic branch	Pods number/plant	Pods weight g/plant	Seed yield	
						g/plant	kg/fed
Furrow with mulch	94.79	44.61	3.93	14.50	70.50	46.43	836
Furrow without mulch	49.61	36.05	3.60	11.54	50.33	34.39	619
Line	63.59	41.52	3.60	12.10	58.57	41.86	754
LSD at 5%	1.61	1.21	0.35	1.48	1.58	0.75	14

(b) Individual Effect Of Foliar Application

Foliar application	Straw weight g/plant	Root weight g/plant	Basic branch	Pods number / plant	Pods weight g/plant	Seed yield	
						g/plant	kg/fed.
Control	43.27	33.00	3.00	9.28	35.06	25.14	453
K_2SiO_4	83.47	46.64	4.44	16.39	78.90	54.40	979
$MgSiO_4$	79.51	45.92	4.33	14.61	70.87	47.85	861
K_2SO_4	68.82	39.01	3.22	11.45	55.35	37.04	667
$MgSO_4$	71.58	39.04	3.56	11.84	58.65	40.05	721
LSD at 5%	2.08	1.56	0.27	0.89	2.06	0.98	18

(c) The Interaction Between Agricultural Methods And Foliar Application

agricultural methods	Foliar treatments	Straw weight g/plant	Root weight g/plant	Basic branch	Pods number / plant	Pods weight g/plant	Seed yield	
							g/plant	kg/fed.
Furrow with mulch	Control	44.60	34.07	3.00	9.99	35.84	25.85	466
	K_2SiO_4	122.07	56.83	5.00	21.67	106.32	69.22	1246
	$MgSiO_4$	115.80	52.17	5.00	16.00	92.32	60.19	1084
	K_2SO_4	95.53	41.57	3.00	11.00	56.09	35.44	638
	$MgSO_4$	95.93	38.40	3.67	13.84	61.92	41.45	746
Furrow without mulch	Control	41.70	31.07	3.00	8.84	34.25	24.45	441
	K_2SiO_4	53.80	37.00	4.33	14.17	60.95	43.44	782
	$MgSiO_4$	52.50	39.30	4.00	14.17	54.80	36.44	656
	K_2SO_4	47.97	35.40	3.33	10.00	49.64	33.69	607
	$MgSO_4$	52.07	37.47	3.33	10.50	52.02	33.95	611
Line	Control	43.50	33.87	3.00	9.00	35.09	25.10	452
	K_2SiO_4	74.53	46.10	4.00	13.34	69.92	50.55	910
	$MgSiO_4$	70.23	46.30	4.00	13.67	65.49	46.92	845
	K_2SO_4	62.97	40.07	3.33	13.34	60.34	41.99	756
	$MgSO_4$	66.73	41.27	3.67	11.17	62.00	44.75	806
LSD at 5%		3.60	2.70	0.61	3.98	1.99	3.56	1.69

Numerous experiments have shown that application of Si can promote growth of most plant species. Silicon deposition in the plant tissues could improve yield, biotic stress, and abiotic stress of rice plants (Epstein, 1999). This increase in plant growth due to Si application not only takes places under normal growth conditions (Hossain *et al.,* 2002), but also under stressful conditions (Ma, 2004).

In El-Behera governorate (ECe=2.44dS/m) seed yield ranged between 1550 to 1932 kg/fed. (Mona *et al.,* 2011). Although, data in Table 4-c revealed that seed yield ranged between 441 to 1246 kg/fed. This wide range in seed yield refer to 1) plants in control treatments (without silicon addition) characterized by low salt tolerance and affected by high salinity of studied area (ECe=7.5dS/m), and produced low seed yield. To describe the property of salt tolerance of a crop, a certain percentage of yield usually 50% relative to that of the control was taken. In case of beans, the values of ECe (in paste extract) at which 10, 25 and 50% yield reduction are 1.1, 2.1 and 3.0 dS/m, respectively (Carter, 1975). 2) Silicon treated plants revealed high salt tolerance and produced high seed yield. These results are agreements with those obtained by Ma, (2004) who reported that, Si could alleviate the effects of abiotic stresses including salt stress.

Nitrogen, Phosphorus and Potassium Concentration (%) and Uptake:

Table (5-a) show that cultivation method affect significantly N, P, K concentration (%) and uptake (mg/kg), whereas they follow same order: Furrow with mulch> line> furrow without mulch. This trend is consistent with the records of bean yield and its components. Furrow with mulch gave the highest values (Bu *et al.,* 2002) because more water induces more solubility of mineral fertilizers (Abou-Baker, 2008). These results are in agreement with Bu *et al.,* (2002) who reported that surface applied mulches provide several benefits to crop production through improving water and nutrient status in soil, preventing soil and water loss and preventing soil salinity from flowing back to surface.

Generally, silicon taken up as $Si(OH)_4$ by plants, is transported and deposited mainly in the apoplast since Si transport and distribution follows that of water. This makes it rather likely that it influences the physical and chemical properties of the apoplast. In order to investigate the effect of Si on the properties of the leaf apoplast, mineral concentrations and binding forms of ions (Wiese *et al.,* 2007) should be considered. Nutrients concentration and uptake were affected significantly with foliar treatments (silicate and sulphate solutions) irrespective of agricultural methods but every element follows different trend (Table 5-b). Silicon can directly or indirectly affect other elements absorption in plants (Datnoff *et al.,* 2001). Nitrogen concentration (%) in bean straw follows the order: silicate solutions > sulphate solutions > control but $MgSiO_4$ > K_2SiO_4 and $MgSO_4$ > K_2SO_4. This trend is true under the individual effect of foliar application irrespective of agricultural methods (Table 5-b) and in most interactions between foliar treatments x agriculture methods (Table 5-c). It was in contradict line with those obtained by yield, these could refer to 1) dilution effect because the growth of plants in K_2SiO_4 and K_2SO_4 treatments was higher than those obtained in $MgSiO_4$ and $MgSO_4$ 2) Magnesium is a primary constituent of chlorophyll and without chlorophyll plants would fail to carry on photosynthesis, improves utilization and mobility of phosphorus, activator and component of many plant enzymes, increases iron utilization in plants.

Nitrogen uptake values in both tables (5-b and 5-c) support the results of yield and yield component, whereas it fallow the order: K_2SiO_4 > $MgSiO_4$ > $MgSO_4$ > K_2SO_4 > control.

Data in Tables (5-b and 5-c) show effect of foliar treatments irrespective of cultivation methods and effect of the interaction between them on phosphorus concentrations (%) and uptake (mg/kg) of bean straw. The data indicated that $MgSiO_4$ gave the highest values of P% followed by K_2SO_4 and K_2SiO_4 without significant difference between them. The next is $MgSO_4$ treatment followed by control. Similar trend was observed by P uptake in two tables, with one exception, whereas K_2SiO_4 treatment enhanced P uptake more than K_2SO_4 treatment. This difference due to high dry weight value of K_2SiO_4 treatment compared to K_2SO_4 treatment. Silicate can increase the quantity of mobile phosphates in the soil (Singh and Sarkar 1992, O'Reilly and Sims 1995). In addition to stimulating desorption of phosphate anions from soluble phosphates of calcium, aluminum, iron and magnesium, silica fertilizers also have a good adsorption capacity and decrease P leaching by 40-70% (Matichenkov and Bocharnikova 2001). It is argued that Si promotes growth by improving the imbalances of nutrients, especially P. In contrast Ma *et al.,* (2001) reported that Si decreases P uptake in rice, tomato, cucumber, soybean, and strawberry.

Table 5: Nitrogen, phosphorus, potassium concentration (%) and uptake of Faba bean straw at harvest as affected by foliar treatments and different agricultural methods under soil salinity condition.

(a) Individual Effect Of Agricultural Methods

agricultural methods	Concentration %			Uptake mg/kg		
	N%	P%	K%	N	P	K
Furrow with mulch	3.28	0.43	1.61	3170	433	1569
Furrow without mulch	3.02	0.38	1.53	1522	190	767
Line	3.24	0.41	1.53	2086	268	986
LSD at 5%	0.02	0.02	0.08	58	16	38

(b) Individual Effect Of Foliar Application

Foliar application	Concentration %			Uptake mg/kg		
	N%	P%	K%	N	P	K
Control	2.88	0.26	1.32	1283	112	572
K_2SiO_4	3.36	0.44	1.81	2822	372	1532
$MgSiO_4$	3.38	0.5	1.56	2716	405	1228
K_2SO_4	3.13	0.45	1.47	2180	315	1024
$MgSO_4$	3.16	0.39	1.63	2297	282	1181
LSD at 5%	0.03	0.03	0.10	74	21	53

(c) The interaction between agricultural methods and foliar application

agricultural methods	Foliar treatments	Concentration %			Uptake mg/kg		
		N%	P%	K%	N	P	K
Furrow with mulch	Control	2.87	0.25	1.32	1280	114	588
	K_2SiO_4	3.44	0.46	1.95	4203	557	2380
	$MgSiO_4$	3.50	0.54	1.50	4057	628	1737
	K_2SO_4	3.24	0.47	1.53	3092	452	1458
	$MgSO_4$	3.36	0.43	1.75	3220	413	1682
Furrow without mulch	Control	2.89	0.26	1.35	1291	108	562
	K_2SiO_4	3.28	0.41	1.77	1767	219	953
	$MgSiO_4$	3.21	0.44	1.62	1685	231	851
	K_2SO_4	2.83	0.42	1.34	1358	200	641
	$MgSO_4$	2.90	0.37	1.59	1510	194	826
Line	Control	2.87	0.26	1.30	1279	113	565
	K_2SiO_4	3.35	0.46	1.70	2497	340	1263
	$MgSiO_4$	3.42	0.51	1.56	2405	356	1095
	K_2SO_4	3.32	0.46	1.54	2090	292	972
	$MgSO_4$	3.24	0.36	1.55	2160	240	1034
LSD at 5%		0.05	0.04	0.18	129	36	118

Both of potassium concentration (%) and uptake (mg/kg) under individual effect of spraying addition and the interaction between agriculture methods and foliar treatments follow one order: K_2SiO_4 > $MgSiO_4$ > $MgSO_4$ > K_2SO_4. Tahir *et al.,* (2006) reported that silicon concentration was positively correlated with K concentration in shoots and significantly (P<0.01) increased K concentration and uptake in leaves of wheat genotypes under normal and in saline environments. This order exactly confirms with yield and yield components trend. The highest values of K concentrations and uptake are 1.95% and 2380 mg/kg were produced by addition of K_2SiO_4 under furrow with mulch treatment. These results are in accordance with those obtained by Liang *et al.,* 1996 and Liang, 1999, whereas they found that silicon could increase K absorption, uptake and transport in barley plants.

In this respect, Silicon addition may improve nutritional balance under saline soil conditions, thereby a better growth performance and consequence yield production was obtained. Hanan (1996), Hanafy Ahmed *et al.,* (2002) and Gharib and Hanafy Ahmed (2005) noted that, silicon foliar applications enhanced N and K concentrations in pea shoots. Berthelsen *et al.,* (1999) showed that silicon is playing an important role in improving P nutrition. In field experiment, silicon significantly increased N P and K concentrations in shoots as well as in grains (Chen *et al.,* 2002 and Hanafy Ahmed *et al.,* 2008).

The present results warrant further studies to explore different mechanisms in plants working by which Si stimulates growth and yield under both non-saline and saline soil, whereas there are several direct and indirect mechanisms. These mechanisms include 1) Decreasing mutual shading through improving leaf erectness (Marschner 1995), 2) Silicon enhanced salt tolerance is attributed to selective uptake and transport of potassium and sodium by plants, and enhanced K:Na selectivity ratio, which mitigated against the toxic effects of sodium (Liang *et al.,* 1996 and Tahir *et al.,* 2006) and reduced electrolytic leakage of the leaves (Liang *et al.,* 1996), 3) Addition of Si decreased the permeability of plasma membrane of leaf cells (Liang, 1999 and Reezi *et al.,* 2009) and significantly improved the photosynthetic activity and ultra-structure of chloroplasts which were badly damaged by the added NaCl (Liang, 1998 and Shu and Liu, 2001). 4) Silicon application increase leaf chlorophyll content and plant metabolism and mitigate nutrient imbalance and metal toxicity in plants (Epstein,1999, Datnoff *et al.,* 2001), 6) Silicon application led to improvement in plant water status (Romero-Aranda *et al.,* 2006), 7) It could mitigate the inhibitory effect of salinity on net photosynthesis and this effect was associated with lower Na and Cl translocation (Savvas *et al.,* 2009), 8) Silica treatment leads to reinforcement of cell walls due to deposition of Si in the form of amorphous silica that reduce the translocation of salts to the shoots (Epstein, 1999), 9) Silica deposition in the leaf limits transpiration and hence salt accumulation (Bradbury and Ahmad 1990).

Electrical Conductivity of Soil at Harvest:

Salinity stress is one of the most devastating stressful environments for plant growth and production (Ashraf, 2009 and Tuna *et al.,* 2008). However, living with salinity by different soil managements like mulch is considering an important practice to sustaining agricultural production. Results of electrical conductivity at depths of 0-20, 20-40 and 40-70cm taken at four different points under three agricultural methods are shown in Table (6) and Fig. (2). It is evident from Table 6 that salt concentration increased with depth irrespective of cultivation methods. Furrow with mulch practice decreased salinity significantly by 30.14 and 28.86% compared to furrow without mulch and line treatments irrespective of soil depths. Furrow without mulch method is extensively used in Egypt but it led to excessive evapotranspiration and increased salinity especially at first layer (0-20cm). A minimum tillage of line method with drip irrigation may include downward leaching of salts to deeper layers (20-40 and 40-70cm). Choudhary *et al.*, (2008) mentioned that salts tend to move to the higher elevation, which act as evaporating zone. Therefore, greater concentration of salts at the top layer exists (Fig. 2). These results are in harmony with those obtained in all growth traits and confirm above mentioned data.

It is evident from Table 7 and Fig. 3 that the salt concentration was the lowest at bottom of furrow and increased constantly towards sides and top of furrow. However, the EC values at the top furrow (C in first layer) increased by 5.3, 4.2 and 3.0 times in furrow with mulch and by 2.4, 2.2 and 1.9 time in furrow without mulch compared to bottom of ridge A, side of ridge B and between drippers D positions.

These results are in line with the findings of Choudhary and Quraeshi (1991), who reported that during growing season, the salt moved from sides of the ridges towards top-centre of the furrow-ridge.

Table 6: Electrical conductivity (EC dSm^{-1}) of soil at harvest time as affected by three different agricultural methods.

Agricultural Methods	Depth (cm)	EC (dS/m)
Furrow with mulch	0-20	2.53
	20-40	4.3
	40-70	4.8
Mean		3.89
Furrow without mulch	0-20	4.47
	20-40	5.47
	40-70	6.47
Mean		5.53
Line	0-20	3.67
	20-40	5.5
	40-70	7.17
Mean		5.44
Mean	0-20	3.56
	20-40	5.09
	40-70	6.22
LSD at 5%	M=0.24 D=0.24 M*D=0.41	

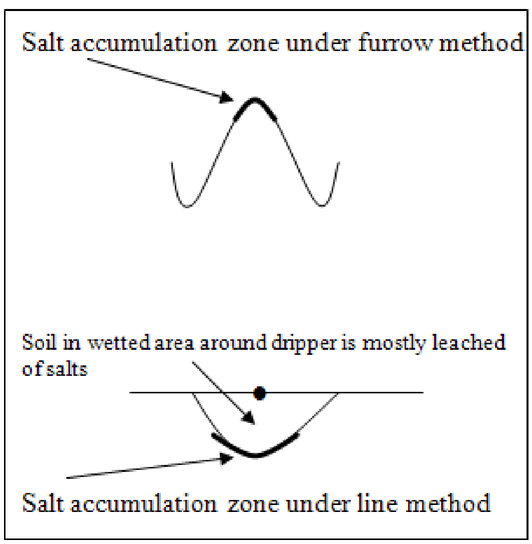

Fig. 2: Salt distribution under surface drip irrigation in furrow and line methods.

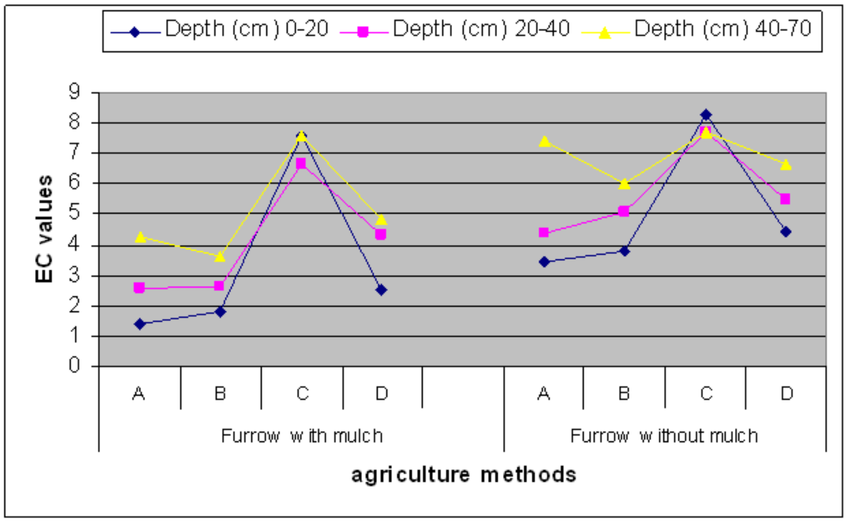

Fig. 3: Salt distribution at three depths in four locations as affected by mulch treatment.

Table 7: Electrical conductivity (EC dSm^{-1}) at harvest time as affected by mulching in case of four different positions of soil samples.

agricultural methods	Location of soil sample	Depth (cm)		
		0-20	20-40	40-70
Furrow with mulch	A	1.43	2.6	4.27
	B	1.83	2.63	3.63
	C	2.53	4.3	4.83
	D	7.6	6.67	7.6
Furrow without mulch	A	3.47	4.37	7.43
	B	3.8	5.07	6.03
	C	4.47	5.47	6.67
	D	8.27	7.73	7.7
LSD at 5%	0.37			

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