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EFFECT OF FOLIAR APPLICATIONS OF SALICYLIC ACID AND POTASSIUM SILICATE ON TOLERANCE OF WHEAT PLANTS TO SOIL SALINITY

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ABSTRACT

A pot experiment was carried out under greenhouse conditions to investigate the effect of salicylic acid (SA) and potassium silicate (KSi) foliar applications in alleviating the salt stress of soil salinity (S) on wheat plants. Three soil salinity levels i.e., 3, 6 and 12 dS/m were developed. Foliar spray of salicylic acid with rates of 0, 50,100 and 150 mg/L were applied. Also, K- silicate were applied exogenously with sprayer using two levels 0 and 2 ml/L. Plants were harvested at maturity stage, then yield components and nutrients content of wheat grains and straw were determined. Salinity stress (S) significantly reduced yield components i.e., grain and straw yields of wheat plants as well as weight of 1000 grains with varying degrees. However, salinity decreased grains and straw contents of potassium (%), calcium (%) and phosphorus (%) while; sodium (%) and chloride (%) were increased positively with soil salinity.Plants treated with salicylic acid (SA) showed increasing yield components of wheat plants. Also, remarkable increases in potassium (%) calcium (%) and phosphorus (%) of grains and straw were noticed in plants sprayed with salicylic acid (SA). Meanwhile, salicylic acid application caused reduction in sodium (%) and chloride (%) in both of grains and straw. Moreover, K-silicate (KSi) application significantly improved yield components of wheat and also increased their contents of potassium (%), calcium (%) and phosphorus (%). While, adverse effects were shown with respect to the contents of sodium (%) and chloride (%) for both of grains and straw. In general, both of salicylic acid and K-silicate have enhancement role in increasing tolerance of wheat plants to salinity.
Keywords: Wheat, salinity, salicylic acid, silicate.

INTRODUCTION

Soil salinity, the presence of excessive salts in the soil, is a very serious problem for agricultural productivity (Munns, 2005). Salinity affects 7% of the world's land surface and is one of the main limiting constraints to global agricultural productivity. It is estimated that 20% of the cultivated land of the world is affected by various degrees of salinity, which inhibits plant growth and yield. Soil salinity, resulting from natural processes or from crop irrigation with saline water, occurs in many arid and semi-arid regions of the world. In salt affected areas, plant growth severely affected by salinity through water deficit and salt specific damages (Qureshi et al., 2007). There are many reports indicating that high level of these salts may cause a reduction in growth of the plants, especially in plant biomass production (Iqbal et al.,2006; Sepehr and Mahlagha, 2006). The deleterious effects of salinity were suggested because of water stress, ion toxicities, ion imbalance or combination of all these factors (Ashraf et al., 2005).

Presence of excessive salts in the growth medium adversely affects plant growth and various biochemical and physiological processes. The salinity also decreases photosynthetic activity (Sakamoto et al.,1998) and inhibits growth. It has been reported that salt stress limits plant productivity causing disturbance in various physiological and biochemical processes (Ferri et al., 2000; Zhang et al.,2005).

Salicylic acid (SA) acts as a potential non-enzymatic antioxidant as well as a plant regulator, which plays an important role in regulating a number of plant physiological processes including photosynthesis (Fariduddin et al.,2003; Arfan et al.,2007). Some earlier reports show that exogenous SA could ameliorate the damaging effects of heavy metals in rice (Mishra and choudhuri,1999), drought stress in wheat (Waseem et al.,2006), and salt stress in wheat (Arfan et al.,2007). These observations suggest that SA being an oxidant could be linked to oxidative stress.

Salicylic acid plays an important role in the defense response in many plant species to biotic stresses. It acts as a signal for the development of the systematic acquired resistance (Shirasu et al., 1997). It is also reported that salicylic acid plays an important role in determining the sensitivity of plants to various abiotic stresses (Dat et al.,1998; Bandurska and Stroinski, 2005), particularly at the seedling stage. It supports to modulate the plant response to several abiotic stresses.

Silicon (Si) is the second most abundant element on the surface of the earth, yet its role in plant biology has been poorly understood and it is not considered an essential element, but it can reach levels in plants similar to those of macronutrients (Epstein, 1994). Silicon concentration in the soil solution is controlled by silicate minerals and ranges from 0.01 to 1.99 mM (Karathanasis,2002). Further studies indicated that silicate application significantly increased plant growth under normal and stress condition including both biotic and abiotic stresses (Tahir et al.,2006; Hattori et al.,2008). The exogenous application of silicate enhances the growth of higher plants under salt stress especially in the graminaceous family (Liang et al.,2005 ; Tahir et al.,2006). A number of possible mechanisms through which silicate may increase salinity tolerance in plants have been proposed by various scientists as reviewed by Liang et al.,(2007) including improved plant water status (Romero-Arnada et al.,2006), increased photosynthetic activity and ultra structure of leaf organelles (Shu and Liu, 2001), simulation of antioxidant system (Zhu et al.,2004), immobilization of toxic Na^+ ion (Liang et al.,2003), reduced Na^+ uptake in plants and increased K^+ uptake (Liang et al.,2005; Tahir et al.,2006 ; Nasim et al.,2008).

Keeping in view the harmful effects of salinity on plants and the importance of salicylic acid and K- silicate in alleviate these effects, the present study would be chosen to test the role of foliar applications of them on increasing the tolerance of wheat plants to soil salinity.

MATERIALS AND METHODS

A pot experiment was carried out under greenhouse conditions at Agricultural Research Center, to investigate the usage of salicylic acid (SA) and K-silicate (KSi) in alleviating soil salinity stress (S) on wheat plants.

Seventy two (72) plastic pots were packed with 8 kg air dried sandy soil for each one, taken from Ismailia Governorate. Some physical and chemical properties of the experimental soil sample are presented in Table (1). In (48) pots, sodium chloride salt were added to develop salinity (S) to 6.0 dS/m for 24 pots and to 12.0 dS/m for the other 24 pots. While, the rest of 24 pots were kept as control having original EC of 3.16 dS/m. Each pot received the recommended doses of basic fertilizers i.e, 120 mg K_2O as K_2SO_4 (48 % K_2O), 360 mg P_2O_5 as superphosphate (15 %P_2O_5) and 260 mg N as NH_4NO_3 (33 %N). Each pot was sown with 10 seeds of wheat (Triticum aestivum L.,Gemmeiza 10 variety), then thinned to 5 plants/pot after complete emergence.

Table (1) : Some physical and chemical properties of the experimental soil.

Particle-size distribution (%):		**pH(1: 2.5, in suspension)**	8.12
C. Sand	52.4		
F. Sand	32.4	**EC(dS/m, in soil paste)**	3.16
Silt	9.3		
Clay	5.9	**Soluble Ions (me/L) :**	
Texture Class	Sandy	**Ca^{++}**	11.5
O.M %	0.12	**Mg^{++}**	13.5
$CaCO_3$ %	1.76	**Na^{+}**	3.8
SP %	24.0	**K^{+}**	1.72
Available nutrient (mg/kg) :		**CO^{--}_3**	-
N	23.8	**HCO^{-}_3**	3.5
P	3.4	**Cl^{-}**	9.7
K	123.0	**SO^{--}_4**	17.32
Fe	6.2		
Mn	4.6		
Zn	1.5		
Cu	0.5		

Salicylic acid (SA) rates of 0.50.100 and 150 mg/L were distributed for all the experimental pot through exogenously spray, each rate per 18 pots. Half of the experimental pots were treated with potassium silicate (K_2SiO_4, KSi) solution at rate 2 ml/L as foliar application, while the other half of pots remained without potassium silicate. The both treatments of salicylic acid and K-silicate solutions were applied separately, with approximately rates of (25) ml/pot, at three successive times 30, 60 and 80 days after sowing of wheat plants. The experiment was laid out in a randomized block design with three replicates for each treatment. Pots within each block were re-randomized every (4) days to minimize the influence of variable locations within the greenhouse. The different treatments were irrigated twice a week; soil moisture was maintained between 60 %-80% of its field capacity.

After 120 days from planting, the plants were harvested and oven-dried at 70°C for 72 hours. Dry matter of grains and straw (g/pot) were recorded, then finely ground and thereafter kept for their nutrients chemical analysis, then calculated as content (%). Also, weights of 1000 grains (g) were recorded.

Soil analysis*:* Particle size distribution, organic matter (O.M), soil pH, electrical conductivity (EC) and $CaCO_3$ (%) were determined according to Page et al.,(1982). Available nutrients were determined according to Cottenie et al., (1982).

Plant analysis*:* One half gram sample of ground plant material of each pot was wet digested using a mixture of concentrated sulphric and perchloric acids. Phosphorus was determined calorimetrically according to Holman and Elliot (1982). Potassium and sodium was determined using Corning flame photometer. Calcium was determined using atomic absorption spectrophotometer. Chloride was determined volumetrically using silver nitrate method.

Statistical analysis*:*-All obtained data were subjected to the statistical analysis of variance (ANOVA) using least significant difference (L.S.D. at 0.01 level) according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Yield components:

Data represented in Table (2) and Fig(1) showed significant reductions in dry weight of grain , straw and weight of 1000 grain due to increasing soil salinity (S) level from 3 dS/m (initial soil salinity) up to 12.0 dS/m. Relative reduction in yield components (as % from the corresponding values of the initial soil salinity i.e., 3dS/m) were 9.3% and 12.4% for grains and 8.1 and 15.3% for straw , as well as 1.3% and 2.3% for weight of 1000 weight grains as a result of increasing soil salinity level to 6 and 12 dS/m, respectively. This effect seems to be more expressed in grain straw and dry weights compared with the weight of 1000 grains. Reduction in plant biomass production is a common phenomenon under salt stress. There are a large number of reports indicated the adverse effects of salinity on biomass production in different crop plants (Meloni et al., 2001). Also, Tammam et al (2008) reported that there was a major difference in the salt tolerance of the three wheat organs , but root was the most salt sensitive organs while spikes was the most salt tolerant and shoot was intermediate. Reduction in growth due to salinity stress may attribute to ion imbalance and ion toxicity in soil solution (Marschner, 1995; Tahir et al., 2006). In this respect, 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.

Table (2): Effect of foliar application with salicylic acid (SA) and potassium silicate (KSi) on yield components of wheat plants grown under different levels of soil salinity (S).

Salinity levels (dS/m) *(S)*	Salicylic acid conc. (mg/L) *(SA)*	Grains (g/pot)		Straw(g/pot)		Weight of 1000 grains(g)	
		Potassium Silicate Solution(2ml/L), *(KSi)*					
		Without	With	Without	With	Without	With
3	0	0.96	1.32	5.62	7.96	36.35	36.50
	50	1.25	1.42	7.25	8.89	36.38	36.56
	100	1.48	1.73	8.20	9.78	37.60	37.66
	150	2.10	2.58	8.42	9.95	38.00	38.23
6	0	0.85	1.19	4.32	6.89	35.80	35.96
	50	1.19	1.40	5.88	7.78	36.02	36.46
	100	1.43	1.64	7.83	9.85	36.70	37.27
	150	1.76	2.23	8.20	10.10	37.60	37.65
12	0	0.81	1.11	4.17	6.29	35.83	35.95
	50	1.08	1.40	5.73	7.12	35.92	36.22
	100	1.40	1.59	6.94	8.29	36.26	36.82
	150	1.70	2.22	7.17	9.88	36.70	36.88
LSD (1%):	*S*	*0.15*		*0.77*		*0.19*	
	SA	*0.17*		*0.89*		*0.22*	
	KSi	*0.12*		*0.63*		*0.15*	
	*S*SA*KSi*	*ns*		*ns*		*ns*	

Data of yield components of wheat plants showed significant increases in dry weight of grain, straw and weight of 1000 grains as a result of treated plants with salicylic acid (SA). The relative increasing (RI%), as % from zero mg/L salicylic acid, of wheat grain yield were 24.04 %, 49.04% and 100.96 % as well as 21.12 %, 46.33 % and 52.46 % for straw yield, while the lowest RI% values were noticed with weight of 1000 grains and were 0.53 %, 3.30 % and 3.99 % for plants treated with 50, 100 and 150 mg/L salicylic acid, respectively. These results agreement with those obtained by El-Tayeb (2005), who reported that exogenous application of salicylic acid enhanced the photosynthetic rate and also maintained the stability of membranes, thereby improved the growth of salinity stressed barley plants.

Values of dry weight of grain, straw and weight of 1000 grain of wheat plants sprayed with k-silicate (KSi) revealed a significant increasing in their values when compared with those not sprayed with k-silicate. These increasing were more pronounced in both of grains and straw yields than in with weight of 1000 wheat grains. Whereas, they were 24.06 %, 29.82 % and o.68 % (comparing with treatments not sprayed with K-silicate) for straw, grains and weights of 1000 grains, respectively. In this respect Marschner (1995) suggested that, silicate 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 silicate not only contributes to cell wall rigidity and strengthening but might also increase cell wall elasticity during extension growth. Also, Hanafy et al., (2008) reported that the enhancement effect on dry weight shoot of wheat plants supplied with silicate might be induced through its role in both cell division and cell expansion by their effect on RNA and DNA synthesis. This attributed that the treatments affected on the number instead the volume of grain.

Fig1

Moreover, Pandey and Yadav (1999) reported that spraying silicon increased grain yield of wheat plants. 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 are at the flowering stage, productive tillers, grain yield.

Nutrients content (%) of wheat grains:

Potassium (K %):

Data presented in Table (3) and Fig (2) showed evidentially the negative effect of soil salinity **(S)** on K (%). Whereas K (%) of wheat grains was gradually and consistently decreased from 0.95 % at initial soil salinity i.e., 3 dS/m to 0.74 % with increasing soil salinity to 6 dS/m (relative decreasing ~ 22 %) and to 0.60 % at soil salinity 12 dS/m (relative decreasing ~ 37 %).These decreases could be due to the antagonism of Na^+ and K^+ at uptake sites in the roots, the effect of Na^+ on K^+ transport into the xylem or the inhibition of uptake processes (Hu and Schmldhlter, 2005).

Table(3): Contents (%) of K, Na and (Na/K ratio) of grains of wheat plants grown under different levels of soil salinity(S) as affected by salicylic acid (SA) and K- silicate (KSi) applications

Salinity levels (dS/m) *(S)*	Salicylic acid conc. (mg/L) *(SA)*	K(%)		Na(%)		(Na/K) ratio	
		Potassium Silicate Solution(2ml/L), *(KSi)*					
		Without	With	Without	With	Without	With
3	0	0.73	0.78	0.23	0.19	0.32	0.25
	50	0.81	0.89	0.19	0.16	0.24	0.18
	100	0.99	1.12	0.17	0.12	0.17	0.11
	150	1.03	1.20	0.13	0.09	0.12	0.07
6	0	0.59	0.63	0.33	0.28	0.56	0.45
	50	0.66	0.71	0.27	0.25	0.41	0.35
	100	0.73	0.77	0.24	0.21	0.33	0.28
	150	0.87	0.92	0.15	0.15	0.17	0.16
12	0	0.39	0.42	0.48	0.44	1.24	1.05
	50	0.52	0.55	0.39	0.35	0.75	0.64
	100	0.63	0.69	0.33	0.30	0.52	0.43
	150	0.78	0.81	0.15	0.15	0.19	0.18
LSD(1%):	***S***	***0.05***		***0.02***		***0.04***	
	SA	***0.06***		***0.02***		***0.05***	
	KSi	***0.04***		***0.02***		***0.04***	
	S*SA*KSi	***ns***		***ns***		***ns***	

Interestingly, an opposite pattern was exhibited an increasing in K (%) with increasing the rate of salicylic acid **(SA)** application. K (%) of wheat grain relatively increased (as % from treatment not received SA) with 16.9%, 39% and 59.3% when wheat plants sprayed with 50, 100 and 150 mg/l salicylic acid (SA), respectively. These results are in accordance with those obtained by Baghizadeh et al. (2012**)** who reported that salicylic acid increased the potassium % in the leaf and root of tomato plant under salinity condition. They attributed that SA will eliminate the damage to the plasma membrane by salt, that these membrane stabilization increase the uptake of nutrients.

Fig2

As for k-silicate (KSi) results showed a significant increase in k (%) of wheat grains due to k-silicate application with ~ 10% relatively from the plants not sprayed with K-silicate. Liang et al., (2003) noticed a significant increase in K^+ uptake under salt stress with silicate application because of increased activity of plasma membrane H.ATP ase.

Sodium (Na %):

Na (%) of wheat grains showed a significant increase with increasing soil salinity (S). The corresponding increases were 50 % and 100 % at 6 and 12 dS/m compared with Na% of grains at less level of salinity i.e., 3 dS/m , respectively. This result is in agreement with those obtained by Grattan and Grieve (1999).

An opposite trend was shown for the role of (SA) on decreasing the Na% of grain of wheat plants sever from salinity stress. As shown in Table (3) and Fig (2), sprayed wheat plants grown under soil saline conditions with 0, 50, 100 and 150 mg/l salicylic acid decreased Na (%) of their grains from 0.33 to 0.27, 0.24 and 0.14 % for the previous salicylic acid levels, respectively. This trend seems that sprayed wheat plants grow under soil saline stress with 150 mg salicylic acid /L can be alleviating of Na hazards with ~ 58%. In this respect, Parizi et al. (2011) stated that SA application sharply decreased Na^+ content in stressed basil seedlings. This may indicate that pretreatment plants with SA induced reduction Na^+ absorption, reduction in toxicity of water with high Na content and then improving dry matter production of stressed plants.

At short notice, K-silicate (KSi) foliar application caused a signification decrease in Na (%) of wheat grains with 15.38% compared with those not sprayed with K-silicate. Similarly, Tahir et al. (2010) found that silicate application significantly decreases Na^+ translocation from roots towards shoots in all wheat genotypes under studies.

(Na/K ratio):

In brief, (Na/K ratio) in wheat grains showed a significant increase with increasing soil salinity level (S). (Na/K ratio) values recorded 0.18, 0.34 and 0.63 at soil salinity of 3, 6 and 12 dS/m, respectively. Guin et al. (2003) recorded that high K^+/Na^+ ratio is more important for many species than simply maintaining a low concentration of Na^+, which makes sense given that much of the basis for Na^+ toxicity is due to competition with K^+ for K^+ binding sites.

In our study, (SA) reduced Na% and increased K%, caused a signification reduced in Na/K ratios from 0.64 at not spray with salicylic acid to 0.15 at spray with 150 mg/L salicylic acid. Hussein et al. (2007) stated that Na and K homeostasis within the cell is necessary for the activity of many cytosolic enzymes and for the maintenance of membrane potential and cells volume regulation. Similar trend was observed by Baghizadeh et al. (2012).

Such trend was noticed with using K-silicate (KSI). Whereas under saline stress Na/K ratio of wheat grains decreased from 0.42 at not K- silicate foliar application to 0.35 at spraying with 2ml/L k-silicate. This could be possibly due to the role of silicate on reduced Na uptake and enhancing K^+ uptake (Tahir et al. 2006).

Calcium (Ca %):

Ca (%) of wheat grains as shown in Table (4) and illustrated in Fig (3), was significantly decreased with increasing soil salinity (S). Relative to Ca (%) at 3 dS/m, Ca (%) decreased with 21.7 % and 30.40% at 6 and 12 dS/m, respectively. Cramer, (2002) stated that, Na^{+}/Ca^{2+} were interaction under salinity stress from a physiological perspective. Because Na^{+} readily displaces Ca^{2+} from its extracellular binding sites, Ca^{2+} availability could be seriously reduced under salinity, especially at low Ca^{2+}/Na^{+} ratios.

Table (4) Contents (%) of Ca, P and Cl of grains of wheat plants grown under different levels of soil salinity(S) as affected by salicylic acid (SA) and K- silicate (KSi) applications.

Salinity levels (dS/m) *(S)*	Salicylic acid conc. (mg/L) *(SA)*	Ca (%)		P (%)		Cl (%)	
		Potassium Silicate Solution(2ml/L), *(KSi)*					
		Without	With	Without	With	Without	With
3	0	0.36	0.40	0.47	0.49	0.43	0.40
	50	0.43	0.44	0.53	0.55	0.40	0.36
	100	0.46	0.48	0.61	061	0.33	0.30
	150	0.52	0.56	0.64	0.66	0.32	0.27
6	0	0.27	0.31	0.41	0.43	0.65	0.60
	50	0.31	0.36	0.48	0.50	0.52	0.48
	100	0.38	0.41	0.52	0.57	0.46	0.42
	150	0.40	0.44	0.60	0.62	0.43	0.40
12	0	0.22	0.25	0.38	0.40	0.89	0.75
	50	0.28	0.30	0.45	0.48	0.72	0.67
	100	0.35	0.37	0.53	0.55	0.66	0.58
	150	0.39	0.40	0.60	0.60	0.54	0.51
LSD(1%):	*S*	*0.03*		*0.07*		*0.03*	
	SA	*0.03*		*0.08*		*0.03*	
	KSi	*0.02*		*0.06*		*0.02*	
	*S*SA*KSi*	*ns*		*ns*		*ns*	

Salicylic acid (SA) applications significantly increased Ca (%) of wheat grains from 0.30% with not spraying with SA to 0.45% at rate of 150 mg/L SA. These results are in accordance with those obtained by Khan et al. (2010) who found that application of SA increased calcium concentration in mungbean under salt stress. It may be suggested that SA application generate the driving force for transport.

K-Silicate (KSi) application showed a slight significant increase in Ca (%) of wheat grains ~ 8% (Relative to Ca % with no foliar with k-silicate). In this context, Liang (1999) stated that added silicate was exhibit non significant increasing in Ca (%) of barley exposed to salinity.

Phosphorus (%):

The interaction between salinity and phosphorus nutrition of plant has a complex relation and depending upon the plant species (or cultivar), plant developmental age, the composition and level of salinity and the concentration of P in the substrate. Therefore, different results of the experiments search in these relations will be depended on the plant species (or cultivar) and conditions of the experiment.

Fig3

Data in Table (4) and Fig (3) clarified that; soil salinity (S) caused a significant mild decrease in P (%) of wheat grains. Whereas they decreased from 0.57% at S=3dS/m to 0.52% at S=6 dS/m and to 0.50 at S=12 dS/m.

In most cases, however, reduction in plant P (%) by salinity results from reduced activity of P in soil solution due to the high ionic strength of the media and low solubility of Ca-P mineral (Sharpley et al. 1992).

Salicylic acid (SA) treatments enhanced significantly P (%) of wheat grains as compared with the control at all salinity levels. Relative increasing in P (%) of wheat grains from corresponding value at zero mg/l SA were 16.28 % , 30.23 % , 44.19 % as a result of spraying with 50 ,100 and 150 mg/l salicylic acid, respectively. Concerning the stimulatory effect of salicylic acid on concentration of nutrition elements and yield components as stated by (Dawood et al. 2012) may be attributed to the effect of salicylic acid on many biochemical and physiological processes that were reflected on improving vegetative growth and active translocation of photosynthesis products from source to sink.

K-silicate (KSi) application showed a slightly increase in P (%) of wheat grains equal relatively percent ~ 4%. Roy et al. (1971) found that silicon application tended to increase the P (%) in the green tops of sugarcane (metabolically less active tissue) and decrease P(%) in the stalk (metabolically less active tissue) when P- nutrition was low. This tendency did not occur when nutrition was high. These observations suggest that P-utilization in the plant may be improved by Si- application when available- P is low.

Chloride:

Soil salinity (S) significantly increased the Cl (%) in wheat grains. Their values were 0.35%, 0.50% and 0.67% under soil salinity level 3, 6 and 12 dS/m, respectively. This result is in agreement with those of Seemann and Critchley (1985) who found that Cl(%) of leaf tissue increased linearly with increasing external NaCl concentration.

Salicylic acid (SA) application significantly decreased Cl (%) of wheat grains. Cl (%) of wheat grains were gradually declined from 0.62% at zero mg/L SA to 0.53% at 50 mg/L SA , 0.46% at 100 mg/L SA and to 0.41% ar 150mg/L SA. Similar observation were also reported by Gunes et al. (2007 a).

Also, K-silicate (KSi) application caused relative decreasing percent ~ 9% in Cl (%) of wheat grains. This result is in agreement with those obtained by Gunes et al. (2007 b).

Nutrients content (%) of wheat straw:

Potassium:

Data presented in Table (5) and Fig (4) revealed that K (%) of wheat straw showed a decreased trend with increasing soil salinity (S) levels. The relative decreases in (%) were 7.9% and 19.9% at 6 and 12 dS/m, respectively. Marschner (1995) reported that under salinity condition, high levels of external Na^+ not only interfere with K^+ acquisition by the roots, but also may disrupt the integrity of root membranes and alter their selectivity. The selectivity of the root system for K^+ over Na^+ must be sufficient to meet the levels of K^+ required for metabolic Processes, for the regulation of ion transport, and for osmotic adjustment.

Foliar applied of (SA) caused a significant increase in K(%) of wheat straw. The relative increase values reached about 36.6%, 66.7% and 47.9% at 50, 100 and 150 mg/L SA, comparing with the control one (0 mg/L SA). Exogenous application of salicylic acid enhanced the stimulated of K content (Szepesi et al., 2005).

Table (5) Contents (%) of K , Na and (Na/K ratio) of straw of wheat plants grown under different levels of soil salinity(S) as affected by salicylic acid (SA) and K- silicate (KSi) applications .

Salinity levels (dS/m) *(S)*	Salicylic acid conc. (mg/L) *(SA)*	K (%)		Na (%)		(Na/K) ratio	
		Potassium Silicate Solution(2ml/L), *(KSi)*					
		Without	With	Without	With	Without	With
3	0	1.69	2.42	1.27	1.15	0.75	0.48
	50	2.68	2.87	0.99	0.92	0.37	0.32
	100	3.16	3.52	0.78	0.67	0.24	0.19
	150	3.26	3.67	0.59	0.60	0.19	0.17
6	0	1.77	1.88	1.58	1.37	0.88	0.75
	50	2.48	2.62	1.43	1.12	0.60	0.42
	100	3.06	3.12	1.13	1.03	0.38	0.32
	150	3.12	3.32	0.88	0.83	0.28	0.25
12	0	1.57	1.62	1.67	1.59	1.06	0.99
	50	2.07	2.26	1.52	1.47	0.74	0.80
	100	2.60	2.73	1.27	1.12	0.49	0.41
	150	2.89	2.95	0.98	0.89	0.34	0.30
LSD(1%):	***S***	***0.25***		***0.14***		***0.26***	
	SA	***0.28***		***0.16***		***0.30***	
	KSi	***0.20***		***0.11***		***ns***	
	S*SA*KSi	***ns***		***ns***		***ns***	

K-silicate (KSi) sprayed had a significant effect on K (%) of wheat straw, with a remarked increase reached 9.1% compared with those plants not sprayed with K-silicate. Liang et al., (2003) reported that there is a significant increase in K^+ content and decrease in Na content under salt stress when silicate was included because of increased activity of plasma membrane H.ATP ase.

Sodium:

Concerning to Na (%) of wheat straw, data also showed a significant increment in Na (%) with increasing soil salinity levels (S), than 3dS/m, with 34.5% and 50.6 % at 6 and 12 dS/m, respectively.

It is worthy to mention that application of (SA) caused significant decrease in Na (%) which recorded 1.44 % in treatment did not received SA, reached to the lowest values (0.80 %) under treated with rate of 150 mg/L SA. similar observations were also mentioned by Al-Hakimi (2006) who found that application of salicylic acid had an inhibitory effect on the accumulation of sodium in the different organs under various level of drought and salinity.

With k-silicate (KSi) application Na (%) of wheat straw had shown a relative reduction ~ 7%. Similar reduction in Na^+ (%) of rice was achieved by (Yeo et al, 1999) and reported that reduced in Na (%) is attributed to silicate induced reduction in transpiration and to partial blockage of transpiration by bass flow.

Fig4

Sodium: potassium ratios

(Na/K) ratios of wheat straw were differed significantly among different experimental treatments. Soil salinity (S) levels significantly increased (Na/K) ratios due to reduction in K^+ uptake in plants by Na^+ through a competitive process and occurs regardless of wither the solution is dominated by Na^+ salts of Cl^- or $SO^=_4$ (Grattan and Grieve, 1999).

As shown previously, salicylic acid (SA) treatments significant reduced the Na^+ (%) of plants and increased the K (%) as compared to non SA application. As a result Na^+/ K^+ ratios become decreased with increased SA concentration. Almost Similar trend was observed by Parizi et al. (2011).

With spraying K-silicate (KSi) , Na/K ratios was non significantly decreased due to the role of silicon in increased K^+ uptake and decreased Na^+ uptake by the major mechanisms responsible for better growth of plants under Salinity (Tahir et al. 2010).

Calcium:

Calcium plays a vital role in regulating many physiological processes that influence both growth and responses to environmental stresses. Briefly, data presented in Table (6) and Fig (5) showed that Ca (%) of wheat straw was decreased from 1.21 % to 0.84 % with increasing soil salinity **(S)** from 3 to 12 dS/m ,respectively. These results are in accordance with those obtained by Cramer et al. (1986) who reported that Ca % was generally decreased whit increasing salinity because of ion interactions, precipitation and increases in ion strength. These factors would be lead to reducing in the activity of Ca^{2+} availability to the plant.

Salicylic acid (SA) spraying on wheat plants caused a significant increase in Ca (%) of wheat straw. Increment percent values than plants not treated with silicate reached about 10.2 %, 17.0 % and 28.4% at 50, 100 and 150 mg/L SA, respectively. In this context, Al-Hakimi (2006) observed that salicylic acid application enhanced the accumulation of Ca^{2+} in the different organs of soybean plant.

As for the role of spraying wheat plants with k-silicate (Ski), Ca (%) of wheat straw not treated with K-silicate (0.96%) was significantly lower than those treated with k-silicate (1.04 %). These results are in line with the finding of Ali et al. (2012) they reported that silicon application exhibited a little impact on calcium content of barley when grown under salinity stress.

Phosphorus:

Concerning to P (%) of wheat straw, data revealed that phosphorus showed a decreasing trend from 0.27% to 0.21 % with increasing soil salinity (S) from 3 to 12 dS/m, respectively. This may be due to the reduced in phosphorus availability in saline soils not only because of ionic strength effects that reduce the activity of phosphate but also because of phosphate concentrations in soil solution , which are tightly controlled by sorption processes and by the low-solubility of Ca-P minerals. Therefore, it is understood that phosphate concentration in field-grown agronomic crops decreased as salinity increased (Sharply et al., 1992).

Table (6) Contents (%) of Ca, P and Cl of straw of wheat plants grown under different levels of soil salinity(S) as affected by salicylic acid (SA) and K- silicate (KSi) applications.

Salinity levels (dS/m) *(S)*	Salicylic acid conc. (mg/L) *(SA)*	Ca (%)		P (%)		Cl (%)	
		Potassium Silicate Solution(2ml/L), *(KSi)*					
		Without	With	Without	With	Without	With
3	0	1.01	1.16	0.19	0.21	2.79	2.46
	50	1.12	1.23	0.24	0.26	2.48	2.19
	100	1.18	1.35	0.28	0.30	2.34	2.00
	150	1.21	1.38	0.33	0.34	2.26	1.92
6	0	0.88	0.84	0.18	0.20	4.12	3.56
	50	0.91	0.95	0.21	0.23	3.42	3.20
	100	0.95	0.98	0.24	0.25	3.27	2.95
	150	1.06	1.15	0.28	0.28	3.22	2.76
12	0	0.72	0.74	0.14	0.16	6.28	4.85
	50	0.79	0.80	0.20	0.22	5.76	4.57
	100	0.82	0.87	0.22	0.25	5.53	4.22
	150	0.99	0.99	0.25	0.25	5.34	4.16
LSD (1%):	*S*	*0.06*		*0.01*		*0.27*	
	SA	*0.07*		*0.01*		*0.31*	
	KSi	*0.05*		*ns*		*0.22*	
	*S*SA*KSi*	*ns*		*ns*		*ns*	

Exogenous supply of salicylic acid (SA) had a significant increased in the P (%) of wheat straw. P (%) of wheat straw was the lowest (0.18 %) in plants not received salicylic acid and then increased gradually from 0.23 % to 0.26 % and then to 0.29 % with increasing SA spraying level from 50 to 100 and to 15o mglL ,respectively. These results are in agreement with those obtained by Aldesuquy et al. (2010) who reported that application of SA caused additional accumulation in phosphorus in wheat plants, attributed to the enhanced role of salicylic acid in photosynthetic metabolism.

Generally, K-silicate (KSi) application showed a non significant effect on P (%) of wheat straw. These results are in accordance with those obtained by Ma and Takahash (1990) they found that phosphorus was not strongly affected by silicon of the nutrient solution.

Chloride:

As presented in Table (6) and Fig (5), Cl (%) of wheat straw showed marked increases as increasing soil salinity **(S)**. Whereas, they increased from 2.31 % (at 3dS/m) to 3.31 % (at 6 dS/m) and to 5.09 (at 12 dS/m) .This result is in agreement with those of Khan et al. (2000) who reported that increase in salinity resulted increasing both Na^+ and CL^- in leaf of forssk plants.

Salicylic acid (SA) application showed a slight decreasing effect on chloride (%) with increasing SA rate, which becomes more observed at high rate of salicylic acid (150 mg/L). Cl (%) of wheat straw were 4.06 % (at no SA) , 3.60 % (at 50 mg/l SA) , 3.39 % (at 100mg/SA) and 3.27 % (at 150% SA). Similar observation were also reported by Gunes et al. (2007 a), who stated that salicylic acid strongly inhibited Na^+ and Cl^- accumulation, but stimulated N, Mg, Fe, Mn and Cu concentrations of salt stressed maize plants.

Fig5

These results suggest that SA could be used as a potential growth regulator to improve plant salinity stress resistance.

On the other hand, Cl (%) of wheat straw showed a tendency to decrease relatively with addition K-silicate (KSi) to 18 % than no-addition. This result is harmony with those observed by Gunes et al. (2007 b).They reported that Si reduced B and also Na and Cl, translocation from the roots to shoots of , decreasing the transport of B, Cl and Na could be related to Si being irreversibly precipitated as amorphous silica (SiO_2 – nH_2o) in the cell walls and lumens. This has been suggested to reduce the translocation of salts to shoots.

CONCLUSION

This it can be concluded that Salinity stress significantly reduced yield components i.e., grain and straw yields of wheat plants. However, salinity decreased grains and straw contents of potassium (%), calcium (%) and phosphorus (%) while; sodium (%) and chloride (%) were increased positively with soil salinity .Plants treated with salicylic acid showed increasing yield components of wheat plants. Also, remarkable increases in potassium (%) calcium (%) and phosphorus (%) of grains and straw. Moreover, K-silicate application significantly improved yield components of wheat and also increased their contents of potassium (%), calcium (%) and phosphorus (%).In general, both of salicylic acid and K-silicate have enhancement role in increasing tolerance of wheat plants to salinity.

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تـأثير استـخدام الـرش الـورقى بحـامض السلسيلك وسـليكات البوتـاسيوم علـى تحمـل نباتات القمح لملوحة التربة

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أجريت تجربة أصص تحت ظروف الصوبة النباتية لدراسة تـأثير استخدام الرش الـورقى لحـامض السلسيلك وسـليكات البوتاسيوم فـى التخفيف مـن الاجهـاد الملحـى لنباتـات القمح المنزرعة تحت مستويات مختلفة من ملوحة التربه . وقد استخدم فى هذه التجربة ثلاث مستويات من الملوحة وهى 3, 6, 12 ديسيسيمنز/م وتم استخدام 4 تركيزات من حـامض السالسيلك وهـى صـفر, 50, 100, 150 ملجم/لتر وايضـا تم استخدام سليكات البوتاسيوم السائلة رشا بتركزين صفر و 2ملل/لتر.وتم حصد النباتـات فـى مرحلـة النضـج وتـم تقدير مكونات المحصول ومحتواه من العناصر الغذائية.

وقد دلت النتائج على أن زيادة الملوحة أدت الى خفض محصـول القمـح مـن القش والحبوب معنوياوايضا وأدت زيادة الملوحة إلى خفض تركيز كل من البوتاسيوم والكالسيوم والفسفور فـى كـل مـن القش والحبوب لنباتـات القمح وعلـى العكس ادى زيـادة الملوحـة الـى ارتفاع تركيز كل من الصوديوم والكلوريد فى كل من القش والحبوب.

كما أدت المعاملة بحامض السالسيلك الـى زيـادة كـل مـن محصـول القش والحبـوب ووزن 1000 حبـة مـن نباتـات القمـح وأيضـا أدت إلـى زيـادة تركيـز البوتاسيوم والكالسيوم والفوسفور فى كل من القش والحبوب ، بينما أدت على العكس إلى خفض تركيز الصـوديوم والكلوريد فى القش والحبوب

فى حين أدت إضافة سليكات البوتاسيوم إلى زيادة معنوية فى الوزن الجاف لكل من القش والحبوب لنباتات القمح ,وكذلك حدثت زيـادة ملحوظـة فـى تركيـز البوتاسيوم والكالسيوم والفوسفور بينما انخفض تركيز الصوديوم والكلوريد فى كل من القش والحبوب.

وبصفة عامة يمكن القول بأن الاضافات الورقية لكل من حامض السلسيلك وسليكات البوتاسيوم أدت إلى التخفيف من الأثر الضار للإجهاد الملحى وزيادة تحمل النباتات لملوحة التربة.

قام بتحكيم البحث

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