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Effects of salicylic acid and potassium silicate foliar sprays on growth and yield of Valencia orange trees growing in soil influenced by salinity under El-Bustan condition

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ABSTRACT

In Egypt, the area of agricultural land affected by salts is increasing as a result of climate change, water shortage and scarcity of rainfall. Under soil conditions affected by salinity, (where EC was 3.40 ds/m) at El Bustan district, El Behera Governorate, Olinda Valencia orange (*Citrus sinensis*) trees were sprayed with salicylic acid and potassium silicate (as a source of silicon) at full bloom stage and two weeks later during two seasons (2016 and 2017) . The study included seven treatments as follow: Salicylic acid at concentrations (200,400 and 600 ppm), potassium silicate at (1000, 2000 and 3000ppm) and untreated tree (control treatment). The best treatments were salicylic acid at 400 ppm and potassium silicate at 2000 ppm, which showed an increase in the average yield of the two seasons than the control by 32.74% and 42.36%, respectively, where these treatments increased the resistance of the plant to tolerate the adverse effects of salinity. The results indicated that the use of potassium silicate at 2000ppm produced higher concentration of leaf total chlorophyll, increased leaf mineral content especially the ratio between K^+ and Na^+ in the leaves (where, lower Na^+ is a good indicator of salt tolerance in plants), improved fruit peel quality, where, (the peel firmness and thickness increased, fruit peel was more lightness and had good rind color), so it seemed more attractive and had high quality. Potassium silicate treatments could earlier the harvest dates by increasing fruit T.S.S/ acid ratio and decreasing juice acidity. On the other hand, leaf total proline content was decreased due to applied treatments. Also, all treatments slightly reduced soil electrical conductivity (EC) and pH. It could be recommended to spray Olinda Valencia orange trees by either potassium silicate at 2000 ppm or salicylic acid at 400 ppm, according to the available material and the economic return.

***Keywords*: Salicylic acid, Potassium silicate, Yield, Fruit quality and Valencia orange trees.**

Introduction

Soil salinity is one of the major problems of agriculture. Plants are exposed to extreme climatic factors such as drought and high temperatures. Under these conditions, soluble salts can accumulate in the soil due to inadequate ion filtration. Salt accumulation in upper soil layers may also be due to inadequate irrigation management. Plants grown in the presence of excess salt suffer from oxidative stress, osmotic regulation, and ionic imbalance, which weaken plant metabolism and growth, (Amal, *et al*., 2007).

Many approaches have been adopted to find the best horticultural practices to solve this problem. Recently, the use of salicylic acid and silicon had beneficial effects that increase the tolerance of plants to the unfavorable environment (Epstein and Bloom, 2003). Salicylic acid (SA) has phenolic nature and it is an endogenous growth regulator, which is involved in the organization of physiological processes in the plant, (Shakirova, *et al*., 2003). It is assumed that it plays a role as a natural indicator of heat generation to refer flowering in a group of plants to control ion absorption by roots and conductivity of stomata, (Raskin, 1992). Also it is involved in regulating signal gene expression in the context of leaf senescence, (Morris, *et al*., 2000).Several studies showed that salicylic acid is a key element in plant resistance to pathogens and is involved in plant response to adverse environmental conditions, (Bosch, *et al*., 2007). Silicon (Si) is a very important element for alleviating salt stress in plants. Hence, several hypotheses were made; a) enhanced photosynthetic

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activity and enzyme activity, b) increased K^+/Na^+ selectivity ratio and c) increased amount of soluble substances in the xylem. This effect led to minimizing sodium adsorption by plants (Liang, 1999). In this respect, silicon application to citrus trees accelerated growth from 30 to 80 % and increased fruit yield (Taranovskaia, 1939) and maintained an adequate supply of essential nutrient and reduce sodium uptake and its transport to shoots (Tuna, *et al.,* 2008). In addition, silicon application enhanced chlorophyll fluorescence and photosynthesis in sorghum plants under water stress, (Hattori, *et al*., 2005). Moreover, Hoda, *et al*., (2013) revealed that application of Diatoms as a source of silicon can improve fruit peel quality and earlier the harvest date by increasing fruit T.S.S/ acid ratio and Vitamin C. of Valencia orange trees.

The aim of this study was to study the effect of salicylic acid and potassium silicate foliar spray on growth and yield of Valencia orange trees growing in soil influenced by salinity.

Materials and Methods

The present research was conducted during 2016 and 2017 seasons at El Bustan district, El Behera Governorate, Egypt. Eight years old trees of Olinda Valencia orange (*Citrus sinensis*) budded on Volkamer lemon rootstock (*Citrus Volkameriana*) in a private orchard planted at 4x6m apart and growing in soil affected by salinity. Trees were selected according to vigor for data collection. Drip irrigation system was adapted. Exogenous application of salicylic acid (SA) and potassium silicate as a source of silicon (Si) were used under study. A complete randomized block design was done. The experiment involved seven treatments as follow:

1- Control (untreated)
2- 200 ppm salicylic acid (0.2 g /L).
3- 400 ppm salicylic acid (0.4 g /L).
4- 600 ppm salicylic acid (0.6 g /L).
5- 1000 ppm potassium silicate (5 cm^3/ L).
6- 2000 ppm potassium silicate (10 cm^3/ L).
7- 3000 ppm potassium silicate (15 cm^3/ L).

Salicylic acid was dissolved in absolute Ethanol and then added drop wise to water (Ethanol alcohol: water, 1:1000, v/v) (Williams, *et al.,* 2003). Potassium silicate (K_2SiO_3) was (SiO_2 25% + K_2O 10%). Triton B as a wetting agent was added to all treatments at 0.05 %. All treatments were applied as foliar spray at (full bloom stage and two weeks after full bloom). Spraying was done till runoff (6 L water/ tree).

The following parameters were determined.

Leaf total chlorophyll. Leaf total chlorophyll was determined according to the method mentioned by Moran and Porath, (1980).

Leaf proline content. Leaf proline content was determined in fresh leaves according to the method described by Bates, *et al*., (1973).

Yield. Number of fruits per tree at harvesting time (mid March) was done and the yield per tree (kg), yield (ton/ fed.) were determined .

Fruit quality. Ten fruits of Olinda Valencia orange were randomly taken in the two seasons for each replicate and the following determinations were carried out:

Total soluble solids (T.S.S %), total acidity (%), T.S.S/ acid ratio and juice weight percentage were determined in fruit juice according to (A.O.A.C, 1995). Peel thickness (mm) was measured by using a digital vernier caliper. Peel firmness was measured with Effegl, Pentrometer (11.1 mm diameter prop, Effegl, Alfonsing, Italy and expressed as Lb/inch2). Rind color measurement (Hue angle) was determined by using a Hunter colorimeter type (DP-9000) for the estimation of a, b and hue angle (h°). In this system of color representation the values a*, and b* describe a uniform two-dimensional color space, where a* is negative for green, and positive for red, and b* is negative for blue and positive for yellow. From a & b values, a/b were calculated Hue angle (h^o= arc tan b*/a*) determines the red, yellow, green, blue, purple, or intermediate colors between adjacent pairs of these basic colors Hue angle (0°= red-purple, 90° = yellow, 180°=bluish-green, 270°= blue), as described by (McGuire,1992).

Leaf mineral content. Leaf samples were collected according to Jones and Embleton, (1960) to determine leaf content of N,P,K, Na and Si on leaf dry weight basis. Total nitrogen (%) was determined using microkjeldahl method according to (Pregl, 1945). Phosphorus (%) was determined according to Troug and Meyer, (1939). Potassium (%) was determined according to Brown and Lilliland, (1966). Sodium (%) was determined the method by Anderson *et al*., (1968). Iron, Manganese and Zinc (ppm) were determined as ppm using atomic absorption according to Carter, (1993). Silicon (ppm) was determined according to Youshida, (1975).

Soil analysis

Soil samples were taken three times (before starting the experiment in October 2015, at the end of the first and second seasons in December 2016 and 2017. Soil physical and chemical properties were determined. Available nitrogen was determined according to Black, (1982). Available phosphorus was determined spectrophotometrically as mentioned by Watanabe and Olsen, (1965).Available potassium was determined using flame-photometric method (APHA, 1992). Soil reaction (pH) was measured in 1: 2.5 soil water extract using glass electrode pH meter Model (955), and electric conductivity (EC) was measured in 1:5 soil water extract using glass electrode conductivity meter Model Jenway 4310. Table (1) shows Physical and chemical analyses of the soil.

Table 1: Physical and chemical analyses of the soil before starting the study.

Physical properties of soil (%)						
Corse sand	Fine sand	Silt	Clay	Texture	O.M	$CaCO_3$
71.3	6.35	5	17.35	Sandy loam	0.34	1.8

Chemical properties of soil										
Cations meq / L						Anions meq / L				
pH 1:2.5	ECds/m	Ca^{++}	Na^{+}	Mg^{++}	K^{+}	$CO3^{--}$	$HCO3^{-}$	Cl^{-}	$SO4^{--}$	SP (%)
8.2	3.40	20.1	7.58	3.45	1.87	-	7.34	19.31	6.35	28%

Available macro and micro nutrients (mg / kg) of soil					
N	P	K	Fe	Zn	Mn
21.1	18.6	228	4.10	1.04	5.3

Where SP = Saturation percentage.

Results and Discussion

Leaf total chlorophyll content.

Analysis of the total chlorophyll content of the leaves is an important approach for assessing the health of the plant's internal system during photosynthesis and provides an accurate and rapid technique for detecting and measuring tolerance of plants for stress (Li, *et al*., 2006). Fig.(1) illustrates the averages of the total determinate leaf chlorophyll (a, b) content during the two seasons (2016 and 2017) and they were significantly and positively affected by potassium silicate and salicylic acid treatments in both seasons. Potassium silicate treatments caused a noticeable enhancement of average leaf chlorophyll (a & b) content in contrast with control treatment (salt stress) and 2000ppm potassium silicate was more effective (133.15 µg/ cm^2) followed in a descending order by trees sprayed with 1000 ppm potassium silicate (126.5 µg/ cm^2) and 3000 ppm treatment (125 µg/ cm^2) then salicylic acid at 400 ppm (122.85 µg/ cm^2), while, averages of total chlorophyll (a, b) concentration were lower with control treatment (112.2 µg/ cm^2). These results are in the same line with those obtained by Li, *et al*., (2014),who reported that, salicylic acid induced salinity tolerance and increased biomass of *Torreya grandis* as a result of enhanced chlorophyll content and the activity of antioxidant enzymes that activated the photosynthetic process and alleviated oxidative stress. Also, foliar application of silicon improved plant growth parameters and chlorophyll pigment concentration under water stress, (Maghsoudi, *et al*., 2015).

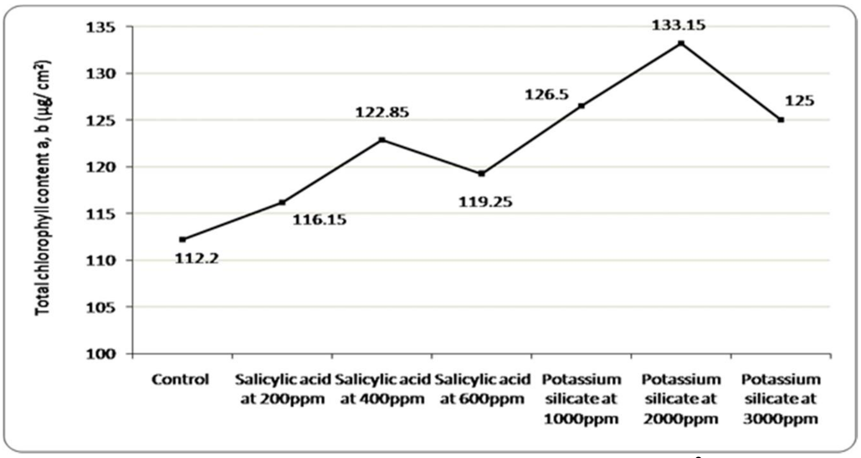

Fig. 1: Averages of leaf total chlorophyll content a, b (µg/ cm^2) during the two seasons (2016 and 2017).

Leaf proline content.

There is a positive relationship between accumulation of proline and plant stress. Proline, an amino acid, plays extremely useful role in plants exposed to various stress conditions. During stress it works as an excellent osmolyte, plays three major roles, i.e., an antioxidative defense molecule, as a signaling molecule and metal chelator, (Shamsul, *et al*., 2012). Fig. (2) shows the averages of proline content during the two seasons (2016 and 2017), it could be noticed that proline content increased with control treatment (1.06 mg/ g FW) followed significantly by trees sprayed with salicylic acid at 200 ppm (0.86 mg/ g FW) and salicylic acid at 600 ppm (0.76 mg/ g FW), while averages of proline content decreased by potassium silicate application at 2000ppm and reached to (0.41 mg/ g FW). Numerous studies have linked the accumulation of proline to salt stress (Munns and Tester, 2008), and it may play a protective role against the osmotic potential generated by salt (Hoque, *et al*., 2008).

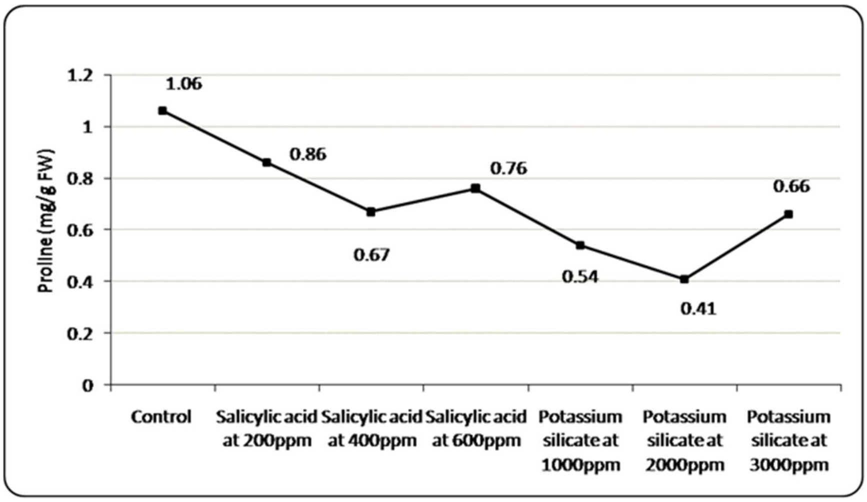

Fig. 2: Averages of leaf proline content (mg/ g FW) during the two seasons (2016 and 2017).

Yield

Data in (Table 2) demonstrated that there were significant differences among treatments. Regarding the fruit number it is noticed that, trees treated by potassium silicate at 1000ppm motivated the maximum number (627 and 600) as compared with control treatment (403 and 423), also it can be seen that, potassium silicate at 2000ppm resulted in the biggest fruit weight (208 and 223gm) comparing with fruits produced from untreated trees (203 and 205gm) of the first and second seasons (2016 and 2017), respectively. On the other hand, results presented in (Table 2) and (Fig. 3) showed the productivity (kg/ tree), productivity (ton/fed.) and averages change rate of productivity during two seasons and indicated that, all treatments increased the productivity of Olinda orange trees from 20.75 to 42.36% over control treatment (salt stress). In more details, on trees sprayed with potassium silicate at 2000 ppm, yield increased by (42.36%) over control, followed by trees sprayed with potassium silicate at 1000 ppm (35.02%) , while, trees that received the application of salicylic acid at 400 ppm showed an increase in yield (32.74%) compared to plants that did not receive the application of any product. Similar results were obtained by Khodary, (2004) who found that, application of SA increased fruit weight and fruit number on barley, dry weights and yield on soybeans, (Gutierrez-Coronado, *et al*., 1998). The role of salicylic acid was reported by Raskin *et al*., (1987) who stated that SA functioned as endogenous growth regulators of flowering and florigenic effects. Also, silicon application increased the yield on rice Arab, *et al*. (2011) and on sugarcane (Bokhtiar, 2011).

Table 2: Yield of Olinda Valencia orange trees as affected by foliar application of salicylic acid and potassium silicate.

Treatments	Fruit No.		Fruit weight (gm)		Productivity (kg/ tree)		Productivity (Ton/fed.)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	403 d	423 e	203ab	205 c	81.8 e	86.7 e	14.3 e	15.2 e
(SA) at 200 ppm	530 c	490 d	190ab	210bc	100.7d	102.9 d	17.6 d	18.0 d
(SA) at 400 ppm	513 c	570 b	204ab	210bc	104.7cd	119.7ab	18.3cd	20.9 ab
(SA) at 600 ppm	533bc	523 c	193ab	210bc	102.9cd	109.8 c	18.0cd	19.2 c
K_2SiO_3 at 1000 ppm	627 a	600 a	180 c	190 d	112.9ab	114.0bc	19.8ab	20.0 bc
K_2SiO_3 at 2000 ppm	557bc	557 b	208 a	223 a	115.9 a	124.2 a	20.3 a	21.7 a
K_2SiO_3 at 3000 ppm	577 b	523 c	186bc	217ab	107.3bc	113.5bc	18.8bc	19.9 bc

In each column, differences between all treatments means having a same letter(s) are not significantly different by Duncan's multiple range tests at the 5% level. (SA) refer to salicylic acid, (K_2SiO_3) refer to potassium silicate.

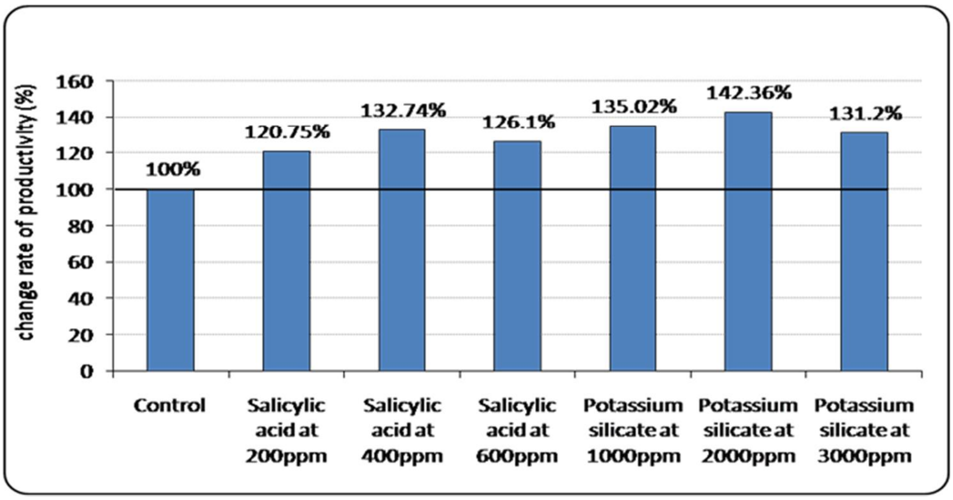

Fig. 3: Averages of the change rate of productivity during the two seasons (2016 and 2017).

Fruit quality.

As for the internal and external quality of Olinda orange fruits data in (Tables 3, 4) pointed out that, potassium silicate treatments increased Juice weight (%) of fruits .Meanwhile, the other treatments recorded the intermediate values in this regard. As for T.S.S percentage, it could be noticed that there were slightly fluctuations among all treatments during the two seasons. Also all treatments decreased the percentage of fruit acidity content as compared with control treatment, while the differences among other treatments didn't show any obvious trend during the two seasons. T.S.S/acid ratio is an important characteristic for citrus ripening and exportation. The results indicated that, potassium silicate application was the best treatments. Data presented in (Table 4) resulted that peel thickness data revealed that, the differences between all treatments were high to be significant, and it could be seen that, fruits of control treatment had thinner fruit peel than the other treatments, while trees treated by potassium silicate treatments had thicker fruit peel. As for peel firmness, data indicated that there were no significant differences between all treatments in the first season, (2016) and the differences between all treatments were low to be significant in the second season, (2017). Concerning peel lightness and peel color, it could be noticed that, fruits treated by potassium silicate treatments had more lightness and had good rind color, so it seemed more attractive and had high quality than the other fruits which treated by other treatments. The foregoing results are in harmony with Taranovskaia (1939) who reported that, the application of silicon accelerated citrus growth by 30–80 %, speeded up fruit maturation by 2-4 weeks, and increased fruit quantity. A similar pattern was observed for corn by Matichenkov, (1990). It also, enhances the growth, yield, crop quality and protects the plant from various biotic and abiotic hurdles (Tripathi, *et al*., 2013). In this respect Han and Li (1997) reported that apple fruits had an increase in SSC without decreasing firmness and had good fruit quality when treated with salicylic acid.

Table 3: Internal fruit quality of Olinda Valencia orange trees under study.

Treatments	**Internal fruit quality**							
	Juice weight (%)		**T.S.S (%)**		**Acidity (%)**		**T.S.S/acid ratio**	
	1st season	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
Control	55.7ab	54.8c	9.50 c	10.5ab	1.18a	1.13a	8.05e	9.29d
(SA) at 200 ppm	53.0bc	57.2b	9.75bc	10.5ab	1.07b	1.05b	9.11d	10.0c
(SA) at 400 ppm	52.4 c	53.8c	10.0ab	10.3bc	0.96c	0.95c	10.4c	10.8b
(SA) at 600 ppm	55.3ab	55.1c	9.50 c	10.0bc	1.00c	1.02b	9.50d	9.80c
K_2SiO_3 at 1000 ppm	58.3ab	60.1a	10.0ab	10.3bc	0.90d	0.92c	11.1b	11.2b
K_2SiO_3 at 2000 ppm	58.7ab	59.4a	10.0ab	9.75 c	0.85d	0.80e	11.8a	12.2a
K_2SiO_3 at 3000 ppm	60.2 a	59.3a	10.3 a	11.0 a	0.90d	0.88d	11.5a	12.5a

In each column, differences between all treatments means having a same letter(s) are not significantly different by Duncan's multiple range tests at the 5% level. (SA) refer to salicylic acid, (K_2SiO_3) refer to potassium silicate.

Table 4: External fruit quality of Olinda Valencia orange trees under study.

Treatments	**External fruit quality (Peel quality)**							
	Peel thickness (mm)		**Peel firmness**		**Peel lightness**		**Peel color (hue angle)**	
	1st season	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
Control	3.65 c	3.41 d	20.5a	19.0b	65.28e	63.47e	67.60e	65.4e
(SA) at 200ppm	3.47 c	3.53 d	20.7a	20.7ab	65.9de	64.56d	69.45d	67.7d
(SA) at 400ppm	3.52 c	3.84 c	20.9a	21.2a	66.7cd	65.99c	69.7cd	68.7c
(SA) at 600ppm	4.70 a	4.52 b	20.0a	20.2ab	66.41d	64.44d	68.64d	67.7d
K_2SiO_3 at 1000ppm	3.85bc	4.73ab	20.5a	20.7ab	68.37b	67.32b	71.6ab	71.5b
K_2SiO_3 at 2000ppm	4.32ab	4.81 a	19.9a	20.6ab	69.98a	68.74a	71.84a	72.8a
K_2SiO_3 at 3000ppm	4.56 a	4.95 a	19.3a	19.5ab	67.6bc	66.78b	70.7bc	71.8b

In each column, differences between all treatments means having a same letter(s) are not significantly different by Duncan's multiple range tests at the 5% level. (SA) refer to salicylic acid, (K_2SiO_3) refer to potassium silicate.

Leaf mineral content.

Data presented in (Table 5) disclosed that trees sprayed with both Salicylic acid and potassium silicate treatments significantly alleviated the effect of salt compared with untreated trees.

Also results revealed that, trees sprayed with potassium silicate treatments were more effective than the other trees sprayed with salicylic acid treatments. In more details, leaves of Olinda trees had higher significant values of N, P and K contents with potassium silicate application at 2000ppm compared with control treatment (salt stress) and the other treatments gave the intermediate values with slight fluctuations in this regard in the first and second seasons (2016 and 2017).

Table 5: Leaf macro element content of Olinda Valencia orange trees under study.

Treatments	N^+ (%)		P^+ (%)		K^+ (%)		Na^+ (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	2.32 d	2.36 d	0.55 d	0.63 c	0.55 d	0.63 c	0.20a	0.21 a
(SA) at 200 ppm	2.38 c	2.41cd	0.74 c	0.76 b	0.74 c	0.76 b	0.14b	0.16ab
(SA) at 400 ppm	2.42ab	2.46bc	1.0 ab	1.05a	1.0 ab	1.05a	0.13b	0.14 b
(SA) at 600 ppm	2.40bc	2.42 c	0.95 b	1.03a	0.95 b	1.03a	0.13b	0.15 b
K_2SiO_3 at 1000 ppm	2.46ab	2.49ab	1.05a	1.05a	1.05a	1.05a	0.11b	0.13 b
K_2SiO_3 at 2000 ppm	2.48 a	2.52 a	1.05a	1.07a	1.05a	1.07a	0.11b	0.12 b
K_2SiO_3 at 3000 ppm	2.43ab	2.45bc	1.03a	1.05a	1.03a	1.05a	0.12b	0.13 b

In each column, differences between all treatments means having a same letter(s) are not significantly different by Duncan's multiple range tests at the 5% level. (SA) refer to salicylic acid, (K_2SiO_3) refer to potassium silicate.

Regarding leaf Fe and Zn concentrations (ppm), data in (Table 6) clearly show that, trees sprayed with potassium silicate at 2000ppm had maximum values compared with other treatments and the minimum values were obtained by control treatment (salt stress), while, leaves of trees treated by potassium silicate at 3000ppm contained the highest concentration of Mn ppm and the other treatments didn't show any obvious trend between them. Also, it is clear that, there was an increase in the level of leaf silicon content of Olinda Valencia orange trees by increasing potassium silicate concentrations application. Moreover, it could be noticed that, the second season had higher leaf silicon content than the first season; this increase may due to spraying trees with potassium silicate as a source of silicon. As for leaf Na^+ content (Table 5) it is clear that, the uptake of Na^+ by control treatment was more pronounced (0.20 and 0.21%) during the two seasons (2016 and 2017), respectively as a result of salt stress, however, application of all treatments significantly reduced accumulation of Na^+ in leaves and there were no significant between them.

Table 6: Leaf micro element content of Olinda Valencia orange trees under study.

Treatments	Fe (ppm)		Zn (ppm)		Mn (ppm)		Si (ppm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	51.7d	57.3e	25.7d	23.8f	78.4g	89.5e	830 f	951 g
(SA) at 200 ppm	77.9c	78.4d	45.8c	40.5e	93.7f	108 d	900 e	970 f
(SA) at 400 ppm	86.7b	87.7c	54.8b	49.7c	116 d	123 c	976 d	1110d
(SA) at 600 ppm	76.8c	80.4d	43.9c	45.4d	98.6e	142 a	982 d	995 e
K_2SiO_3 at 1000 ppm	98.6a	95.5b	66.3a	63.4b	130 b	124 c	1240c	1313c
K_2SiO_3 at 2000 ppm	97.4a	106 a	65.4a	72.5a	125 c	132 b	1360b	1417b
K_2SiO_3 at 3000 ppm	85.8b	93.7b	53.6b	50.9c	136 a	140 a	1410a	1522a

In each column, differences between all treatments means having a same letter(s) are not significantly different by Duncan's multiple range tests at the 5% level. (SA) refer to salicylic acid, (K_2SiO_3) refer to potassium silicate.

On the other hand, results presented in (Fig. 4) illustrated averages of K^+/Na^+ ratio during the two seasons and it is noticed that, trees treated with potassium silicate at 2000ppm achieved the highest value (9.23) followed by potassium silicate at 1000ppm (8.81) and potassium silicate at 3000ppm (8.33) then trees treated with salicylic acid at400ppm (7.6) while control treatment scored the lowest ratio (2.88). Lower Na^+ uptake is a good indicator of salt tolerance in plants.

It is obvious that, increased K^+ concentration shows the ability of trees to combat the salt stress that will strongly depend upon Na^+ and silicon content. In this respect Ma, *et al*., (2001) showed that the reduction of Na^+ toxicity in maize plant was due to the formation of Na^+ and Si complexes in solution compared to any other physiological effect of Si on the plant. Also, trees treated with Si absorbed more nutrients than the untreated trees (Wutscher, 1989).Similar results were obtained by Daneshmand, *et al*., (2009). They indicated that the application of SA increased K^+/Na^+ ratio in plants grown under salt stress conditions. In addition, the SA's protective role has been reported in the integrity of the membrane and the regulation of ions including nutrient absorption. Salicylic acid can be involved in the regulation of absorption of many beneficial elements of plants such as manganese, calcium, copper, iron, phosphor and zinc thus reducing oxidative stress under lead stress (Wang, *et al*., 2011).

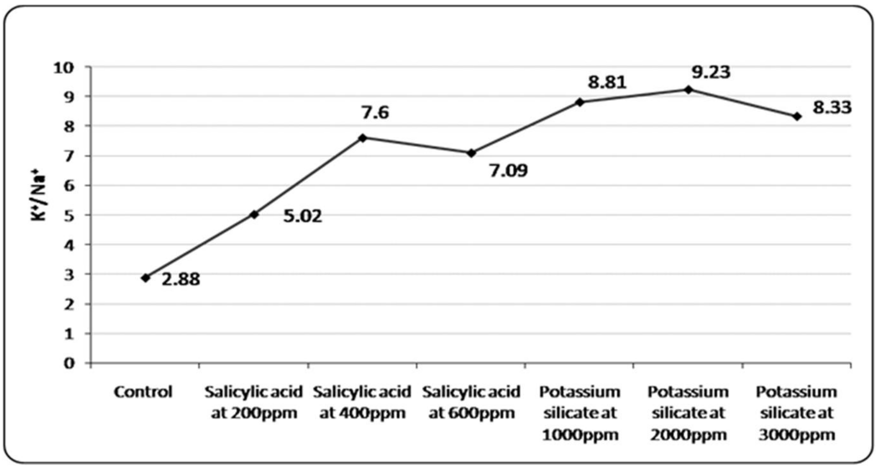

Fig. 4: Averages the ratio between leaf K^+ and Na^+ content during the two seasons (2016 and 2017).

Soil analysis:

Soil analyses were done at the end of the first and second seasons (2016& 2017). Regarding soil electric conductivity (EC) data in (Table 7) showed a slight decreasing in soil EC and the highest values were recorded from control treatment (salt stress) in the first and second seasons. As for soil pH it was observed that, all treatments decreased slightly in soil pH and no obvious trend was observed during two seasons. Meanwhile, salicylic acid and potassium silicate treatments increased K^+ and reduced Na^+, Cl^- values in the root rhizosphere as compared with control treatment.

Table 7: Soil chemical analysis at the end of the first and second seasons.

Treatments	pH	E.C	Cations meq/ L				Anions meq/ L			
	1:2.5	ds/m	Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^-	HCO_3^-	Cl^-	SO_4^{--}
Control	8.28	3.61	11.41	15.21	7.92	1.66	-	6.27	24.1	5.83
(SA) at 200ppm	8.13	3.48	18.31	8.58	5.34	2.57	-	6.15	16.49	12.16
(SA) at 400ppm	8.02	3.48	16.60	9.53	6.14	2.53	-	6.17	16.29	12.34
(SA) at 600ppm	8.03	3.51	17.48	8.59	6.19	2.74	-	5.76	16.4	12.90
K_2SiO_3 at 000ppm	7.87	3.60	18.61	8.61	6.15	2.63	-	6.27	20.07	9.66
K_2SiO_3 at 000ppm	7.42	3.37	18.37	6.31	6.10	2.82	-	6.63	15.32	11.65
K_2SiO_3 at 000ppm	8.02	3.36	19.37	5.31	6.31	2.61	-	6.63	15.58	11.39
Control	8.20	3.42	12.00	12.76	8.26	1.80	-	5.77	22.20	6.85
(SA) at 200ppm	8.01	3.41	12.40	14.47	6.00	1.83	-	8.54	17.13	9.03
(SA) at 400ppm	7.92	3.31	11.90	12.04	6.70	2.75	-	6.24	21.91	5.28
(SA) at 600ppm	7.95	3.40	13.90	11.37	6.13	2.60	-	6.60	17.39	10.01
K_2SiO_3 at 000ppm	7.89	3.32	15.77	9.57	6.34	1.50	-	6.34	20.1	6.74
K_2SiO_3 at 000ppm	7.85	3.16	14.51	9.22	6.41	2.60	-	6.62	20.0	5.12
K_2SiO_3 at 000ppm	7.91	3.20	13.90	10.20	6.80	1.50	-	5.10	20.20	7.10

Where :(SA) refers to salicylic acid; (K_2SiO_3) refers to potassium silicate.

Also, it is evident from (Table 8) that the changes of available macro and micro elements were slightly fluctuated in the soil in both seasons and no obvious trend could be detected. The results showed that spraying Olinda Valencia orange trees with potassium silicate (as a source of silicon) or salicylic acid led to a slight improvement in the soil characteristics especially in relation to the reduction of sodium and chloride ions and increase of potassium ion s in the root rhizosphere, which reflects an increase of the capability of trees to tolerate the harmful effect of soil salinity. The obtained results are in general agreement with the finding of Matichenkov, *et al*., (1995); Apte and Thomas, (1997) and Liang, *et al.,* (2005).

Table 8: Soil available nutrient contents at the end of the first and second seasons.

Treatments	1st season						2nd season					
	Available (ppm)						Available (ppm)					
	N	P	K	Fe	Zn	Mn	N	P	K	Fe	Zn	Mn
Control	20.1f	22.4e	230d	5.9b	1.2d	6.1g	23.2d	23.7f	238d	5.3d	1.1d	6.4d
(SA) at 200 ppm	24.2c	29.7a	238bc	5.7b	1.6a	7.4a	26.5ab	27.6c	250c	7.4a	1.4b	6.5cd
(SA) at 400 ppm	21.6e	25.3d	247a	6.3a	1.4c	6.9d	26.2ab	25.3e	258b	5.9c	1.6a	6.9bc
(SA) at 600 ppm	23.3d	27.3c	239bc	6.0b	1.5b	6.7e	25.3c	28.5b	279a	6.8b	1.5d	7.5a
K_2SiO_3 at 000 ppm	25.4b	28.1b	245a	6.0b	1.6a	7.1c	25.4bc	26.3d	260b	6.6b	1.4b	6.8bc
K_2SiO_3 at 000ppm	26.5a	28.7b	241b	5.8b	1.3d	7.3b	27.1a	27.2c	252c	6.4b	1.3c	7.4ab
K_2SiO_3 at 000ppm	22.8d	26.8c	236c	6.5a	1.5b	6.5f	26.7a	29.6a	261b	5.6cd	1.4b	6.7cd

In each column, differences between all treatments means having a same letter(s) are not significantly different by Duncan's multiple range tests at the 5% level. (SA) refer to salicylic acid, (K_2SiO_3) refer to potassium silicate.

Conclusion

Under the soil affected by salt conditions, Valencia orange trees were sprayed with salicylic acid and potassium silicate at different concentrations at two times (full bloom stage and two weeks after full bloom), this led to an increase in the ability of trees to bear the harmful effects of soil salinity and reflected increasing of yield over control ranged from 32.74% when using 400 ppm salicylic acid and 42.36% with potassium silicate at 2000 ppm. Hence, it could be recommended to spray Olinda Valencia orange trees by one of these products according to its availability and cheapest price in the markets.

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