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Improving Vegetative Growth and Productivity of Navel Orange (*Citrus sinensis* L.) Trees under Salt Affected Soil Using Glycinebetaine and Potassium Silicate

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ABSTRACT

A field experiment was conducted during two successive seasons of 2018 and 2019 on Washington Navel orange trees (*Citrus cinensis* L.) grown at a private orchard, El-Riyadh district, Kafr El-Sheikh Governorate, Egypt, to investigate the impact of foliar application of Glycine betaine and Potassium silicate on growth, leaf nutrient content, productivity and fruit quality. The study consisted of seven treatments as follow; Glycine betaine concentration (25, 50 and 75 Mm), Potassium silicate (0.1, 0.2 and 0.3%) and control treatment (untreated trees) as randomized complete block design. The results showed that foliar application of Glycine betaine at 50 Mm and Potassium silicate 0.2% induced a significant improvement of vegetative growth in terms of shoot length and thickness, leaf area, leaf nutrient and pigment contents, Also, yield, number of fruits per tree was significantly increased. Moreover, Fruit quality as weight (g), fruit volume (cm^3), juice% and SSC% were significantly increased, while leaf proline content and acidity were decreased. The best treatments were potassium silicate 0.2 % and Glycine betaine at 50 Mm which showed an increase in the average yield of the two seasons than the control by 40.42% and 37.95%, respectively. The results suggested that Glycine betaine at 50 Mm or potassium silicate 0.2% have a great potential in alleviating salinity stress and enhancing vegetative growth and productivity of Navel orange trees.

Keywords: fruit quality, glycine betaine, potassium silicate, salinity, Washington Navel Orange, yield.

INTRODUCTION

Citrus is one of the most popular and commercially remarkable fruit crop in Egypt. The harvest area is around 452 hectares, which produced 6279 tons according to (FAO, 2019). Navel orange ("*Citrus sinensis* L.) is considered one of the common fresh citrus fruits in Egypt due to its aroma characteristic, flavour, seedless, and large size. Salinity is one of the serious factors that supress the growth, nutritional status, yield and fruit quality of citrus trees. Citrus is considered very sensitive to salinity (Storey and Walker 1999). During salt stress, plants accumulate specific organic solutes such as proline, free amino acids, sugars and quaternary ammonium compounds (Glycine betaine) which are called compatible solutes.

These chemicals are present in cytoplasm and certain ion such as Na^+ and Cl^- are preferentially sequestered into vacuole which leads to help in turgor maintenance during osmotic stress. Glycine betaine is a methylated derivative of glycine (N, N, Ntrimethylglycinebetaine), widely distributed in microorganisms, higher plants and animals, and is one of the most common betaines found in the plants (Rhodes and Hanson 1993). Besides its involvement in osmotic adjustment (Al-Hassan *et al.* 2016), has been indicated to act as osmoprotectant via reducing ROS and hence stabilizing cellular macromolecules under adverse conditions (Ashraf and Foolad 2007, Chen and Murata 2008, Ahmad *et al.* 2016). It also plays a key role in protection of thylakoid membranes, maintaining of photosynthetic enzyme activity and photosynthesis (Genard *et al.* 1991). It has been also proved that the application of GB helps plants, keep osmotic balance, stabilize photosynthetic pigments, and protect the plant cells against the disorders caused by salt stress (Gadallah 1999). Foliar application of GB at 50 and 100 mM on Washington navel orange increased plant height, leaf area, leaves number, and total chlorophyll content in leaves, while they did not affect the branches number (Abdallah *et al* .,2017). Denaxa *et al.* (2012) stated that exogenous GB application enhanced leaf Chl. a, b, and total Chl. content in olive trees under salt stress. In addition, it has been observed that plants treated with GB showed better growth and lesser Na^+ accumulation under salt stress

It has also been reported that plants are able to use foliar-applied GB and to translocate it to almost all plant parts, especially developing organs (Mäkelä *et al.*, 1996). Thus, foliar applications may increase the levels of GB in plants that are unable to synthesize this compound. Application of exogenous glycine betaine as a foliar spray enhanced salinity tolerance in some crops, e.g., olive (Roussos *et al.*, 2010), papaya (Mahouachi *et al.*, 2012), Navel orange (Abdallah *et al.*, 2017), Mango (Hamza and Shalan, 2020) and grape (Seif *et al.*, 2020).In all previously mentioned studies Glycine betaine enhanced vegetative growth parameters, yield and fruit quality under salt stress.

Silicon (Si) is considered as an excellent growth promoting agent, which increases plant growth and stimulates productivity in various crop plants. Furthermore, its application strengthened the plant biomass, height, and productivity under different stressed conditions (Ma, 2004). Also, (Santos *et al.*,

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2014) reported that silicon has a beneficial role in nutrient uptake, enhancing photosynthesis, transport of water and improve tolerance of mango trees to environmental stresses.It also a growth triggers by providing strength and extensibility to plant cells. It is known as a vital element that enhances the potential against biotic and abiotic stresses, i.e. salinity, cold, drought, heavy metals, and disease. In addition, it well known by its contribution in efficient water utilization of plants by improving leaf water potential, transpiration rate, and photosynthesis under abiotic stressed conditions. It is also highly associated with osmotic adjustment because it accelerates the accumulation of various organic and inorganic substances like proline, glycine betaine (GB), and antioxidant activities in plants that are subjected to stressed environments (Ahmad and Haddad, 2011).

Silicate has been shown to mitigate adverse effects of water and mineral deficiency (Ma *et al*., 2001) as well as alleviate the adverse effects of biotic stresses including salt stress, metal toxicity and nutrient imbalance (Ma, 2004).

On Navel orange trees, Habasy (2016) reported that foliar spray of potassium silicate at 0.05 to 0.2% boosted all vegetative growth parameters, leaf nutrients and pigments, fruit setting and fruit retention %, also yield and fruits physical and chemical characteristics over the control treatment. Moreover, Abo El-Enien *et al*., (2017) reported that foliar application of potassium silicate at 2 g/l improved leaf N, P and K contents in Valencia orange seedlings.

In a study on Olinda Valencia orange trees, Mohamed and Kamar (2018) revealed that application of Potassium silicate at 2000 ppm increased yield, resistance of the plant to the adverse effects of salinity, produced higher concentration of leaf total chlorophyll and increased leaf mineral content. Also, improved fruit peel quality, but reduced leaf proline content .Also, in Mango, Hamza and Shalan (2020) revealed that GB and si foliar sprays significantly induced vegetative growth parameters i.e., leaf number, stem diameter and length as well as fresh and dry weight of leaves, leaf chlorophyll content, on the other hand reduced accumulation of sodium Na+ and increased N, P, and K concentrations in mango leaves.

So, the present study was aimed to investigate the effect of foliar application of potassium silicate and Glycine betaine on yield and fruit quality of Washington navel orange under salt stress.

MATERIALS AND METHODS

The present stud was carried out during 2018 and 2019 seasons at a private orchard (N 31.13794 E 30.95122), kafr Elsheikh Governorate, North Nile Delta of Egypt. The agro-meteorological data of Sakha Station during both growing seasons are shown in Table (1). Fifteen years old Washington navel orange (*Citrus sinensis* L.) budded on sour orange rootstock (*Citrus aurantium*) planted at 5x5m apart and growing in clay soil under drip irrigation system. The selected trees were received the normal agricultural practices that ordinary adapted in the commercial citrus orchards recommended in the experimental area.

Table 1. Mean of some Meteorological data for kafr Elsheikh area during the two grown seasons of 2018 and 2019.

Seasons	Months	Air temperature (C°)			Relative humidity %			Wind speed (Km/day)	Pan evaporation (mm/day)	Rain (mm/month)
		Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	
2018	January	18.90	13.60	16.25	89.40	64.40	76.90	44.90	2.63	36.40
	February	21.60	14.60	18.10	87.60	63.40	75.50	34.70	2.78	16.60
	March	25.40	16.60	21.00	82.30	48.30	65.30	46.40	4.22	0.0
	April	27.80	20	23.9	80.90	43.90	62.4	74	5.32	0.0
	May	31.20	23.80	27.5	75.6	43.90	59.75	95.80	6.34	0.0
	June	32.60	25.3	28.95	75.50	48.0	61.75	98.60	7.71	0.0
	July	34.20	25.40	29.8	82.60	51.0	66.8	89.50	7.37	0.0
	August	33.90	25.20	29.55	51.40	82.40	66.9	76	6.42	0.0
	September	32.80	23.50	28.15	83.10	48.30	65.7	68.7	4.98	0.0
	October	29.50	20.60	25.05	82.50	49.60	66.05	57.90	3.24	0.0
	November	25	17.40	21.20	86.60	54.60	70.60	24.20	1.60	0.0
	December	19.50	13.90	16.70	88.70	62.40	75.55	24.50	0.83	21.70
2019	January	18.9	12.3	15.6	82.3	53.3	67.8	33.1	113.8	33.45
	February	19.7	14.3	17	86.9	58.6	72.75	28.6	177.6	3.3
	March	21.7	17.6	19.65	87.8	56.6	72.2	45.7	285.8	3
	April	25.1	21.3	23.2	80.8	48.9	64.85	44.8	369.5	1.95
	May	31.9	25.4	28.65	76.4	37.9	57.15	68.4	682.9	0.0
	June	33	28	30.5	81.5	50	65.75	103	845.7	0.0
	July	33.5	28.4	30.95	85.2	54.4	69.8	83.8	807.7	0.0
	August	34.2	28.9	31.55	89.7	55.6	72.65	68.7	682.4	0.0
	September	32.4	27.9	30.15	83.4	52.9	68.15	76.9	589.6	0.0
	October	30.3	26.7	28.5	87.3	54.3	70.8	56.6	383.7	0.0
	November	27.4	25.1	26.25	82.8	48.3	65.55	36.6	230.8	14.3
	December	21.4	13.4	17.4	86.9	58.9	72.9	38.5	266.6	10.3

Source: Meteorological Station at Sakha (31° 07' N Latitude, 30° 05' E Longitude).

This experiment involved seven treatments and arranged in a randomized complete block design. Each treatment contains 6 trees (2 trees /replicate).

The treatments were applied as follows:

T1- Control (untreated trees).
T2= Glycine betaine 25 mM.
T3= Glycine betaine 50 mM.
T4= Glycine betaine 75 mM.
T5= Potassium silicate 0.1 %
T6= Potassium silicate 0.2 %
T7= Potassium silicate 0.3 %

Potassium silicate (K_2SiO_3) was (SiO_2 25% + K_2O 10%). Triton B was used as a wetting agent added to all treatments at 0.05 %. All foliar spray treatments were applied three times, beginning of 15 March, 15 April and 15May. Spraying was done till runoff (6 L water/ tree).

The following parameters were determined.

1- **Growth parameter**: shoot length (cm), shoot thickness (cm), leaf area (cm^2), at mid-August of both studied seasons. One year old shoots were labeled at the beginning of each season in March for following shoot length (cm), shoot thickness (cm), leaf area (cm^2) determination.

2- **Leaf total chlorophyll and carotenoids pigments** were determined colorimetrically by extracting them with 85% acetone solution according to Wettestein (1957).
3- **Total carbohydrates** %: were determined in leaves of spring growth cycle (1st week of Sept.) according to (Doubois 1956).

Table 2. Some physical and chemical soil properties of the experimental site (0-60 cm, depth).

Soil variable	values
Physical properties	
Sand %	9.54
Silt%	33.16
Clay%	57.30
Texture class	clay
Chemical properties	
Soluble Cations meq / L	
Ca^{++}	0.84
Na^{+}	1.27
Mg^{++}	0.27
K^{+}	0.03
Soluble anions meq / L	
CO_3^{--}	-
HCO_3^{-}	0.45
Cl^{-}	0.23
SO_4^{--}	1.71
pH	7.87
1:2.5	2.22
EC ds/m	1.64
O.M.%	

OM: Organic matter

4- **Leaf proline content**. Leaf proline content was determined in fresh leaves according to the method described by Bates, *et al.,* (1973).
5- **Fruit set%:** was came out by dividing number of set fruits on total number of flowers at balloon stage (number of flower per shoot X 100).
6- **Fruit retention %:** also was calculated by dividing the number of fruits at harvest time on the number of set fruits x 100.
7- **Yield**: Number of fruits per tree at harvesting time were counted then yield kg/tree and total yield (ton/ fed.)were estimated.
8- **Fruit quality**:

Twenty fruits of Washington navel orange were randomly chosen in the two seasons for each replicate and the following determinations were carried out:

a. **Fruit physical properties:** average fruit weight (g), fruit diameter (cm), fruit height (cm), fruit volume (cm3) and fruit peel thickness (cm)

B. **Fruit chemical characteristics:** Soluble solids content (SSC%) was determined by hand refractometer and total acidity (TA) as a citric acid percentage. Vitamin C as ascorbic acid in mg/100ml juice was estimated by using 2, 6 dichlorophenol indophenol, according to A.O.A.C. (2000).

9-**Leaf mineral content**. Leaf samples were collected according to Jones and Embleton, (1960) to determine leaf content of N, P,K, Mg and Na 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 recommended by Anderson *et al*., (1968).

Statistical analysis

The obtained data were subjected to analysis of variance according to Snedecor and Cochran (1990). Duncan's multiple range test (Duncan, 1955) at 5% level was used to compare the mean values.

RESULTS AND DISCUSSION

A-Vegetative growth characteristics

Results in Table (3&4) cleared that all exogenous applications of GB and potassium silicate significantly enhanced the vegetative growth parameters (shoot length (cm), shoot thickness (cm), leaf area (cm^2), total carbohydrates %, of Washington navel orange trees compared to the control.

As for, shoot length trees treated with GB at 50 Mm achieved the highest values of shoot length (10.11 & 10.12 cm), followed by potassium silicate at 0.2 % (10.01 & 10.03 cm) then trees sprayed with potassium silicate 0.3% (9.83&9.84 cm) On the contrast, the lowest values recorded with control trees in both seasons (9.21 &9.23 cm) respectively.

Concerning shoot thickness, spraying trees with GB at 50Mm achieved the highest values of shoot thickness (0.24 &0.25 cm) by potassium silicate at 0.2 % (0.23&0.24 cm) without significant differences between them in both seasons but un treated trees scored the lowest values (0.11 &0.12 cm) in both season .

leaf area, trees sprayed with GB at 50 Mm gave the largest leaf area (25.01cm^2) in the first season while 0.2 % potassium silicate gave the highest values in the second season (26.1cm^2) while, the lowest values were obtained from control in both season (22.31&22.41cm^2)

The positive effect of GB and potassium silicate foliar applications on vegetative growth under different stresses are in harmony with many previous studies (Zayan *et al.*,2016,Habasy (2016), Abdallah *et al.*(2017) on Navel orange, Mohamed and Al- kamar (2018) on Valencia orange, Abo-Ogiala (2018) on pomegranate, Hamza and shalan (2020) on Mango and Seif *et al.*,(2020) on grape).

Moreover (Makela, *et al.*, 1996) reported that growth improvement may be due to that GB improved photosynthetic rate and stomatal conductance. In addition, exogenously applied glycine betaine has been shown to penetrate into plant leaves after application and is readily translocated to roots, meristems and expanding leaves Therefore, developing and expanding plant organs are primarily protected from stress and enhanced growth and reproduction.

Table3. Effect of exogenous application of Glycine betaine and potassium silicate on some vegetative growth parameters in leaves of Navel orange tress during 2018 and 2019 seasons.

Treatments	Shoot length (cm)		Shoot thickness (cm)		Leaf area (cm^2)	
	2018	2019	2018	2019	2018	2019
T1	9.21g	9.23g	0.11e	0.12e	22.31f	22.41f
T2	9.56d	9.58d	0.18c	0.19c	23.96e	23.97e
T3	10.11a	10.12a	0.24a	0.25a	25.21a	25.41b
T4	9.31f	9.34f	0.14d	0.15d	22.22g	22.25g
T5	9.53e	9.55e	0.18c	0.19c	24.15d	24.24d
T6	10.01b	10.03b	0.23a	0.24a	25.01b	26.01a
T7	9.83c	9.84c	0.21b	0.22b	24.61c	24.71c

Means followed by different letter are significantly different within columns by Duncan's multiple range test, P≤0.05

T_1-Control (tap water), T_2- Glycine betaine at 25 mM ,T3- Glycine betaine at 50 mM , T4- Glycine Betaine at 75 mM ,T5- K_2SiO_3 at 0.1%,T6- K_2SiO_3at 0.2%, T7- K_2SiO_3 at 0.3%.

Leaf chemical composition

The averages of the leaf total chlorophyll, total carotenoids and total carbohydrates content during the two seasons (2018 and 2019) were positively affected by Glycine betaine and potassium silicate treatments in both seasons (Table 4). Potassium silicate treatments caused a clear enhancement of average leaf total chlorophyll content compared with control treatment and 0.2% potassium silicate was more effective than other treatments followed in a descending order by trees sprayed with 0.3% potassium silicate then GB at 50 Mm while, average of total chlorophyll concentration were lower with control .

As for, total carotenoids content potassium silicate at 0.3% achieved the highest values in the first season while potassium silicate at 0.2% recorded the highest values in the second season compared to control treatment.

Regarding total carbohydrates , GB at 50 Mm gave the highest values for total carbohydrates percentage (8.01&7.41%) in both seasons followed by GB at 25 Mm (8.01&7.31) compared to control (6.01&5.19%) for both season respectively .

These results are in harmony with many previous studies (Habasy (2016) on Navel orange, Mohamed and Al-kamar (2018) on Valencia orange, Abo-Ogiala (2018) on pomegranate, Hamza and shalan (2020) on Mango and Seif *et al., (*2020) on grape). Moreover, Mostafa and Saleh (2006) who revealed that spraying potassium at different sources had a positive effect on total carbohydrate and total chlorophyll in the leaves of Balady mandarin trees.

These results are in harmony with those obtained by Maghsoudi, *et al*., (2015) they revealed that, foliar application of potassium silicate improved chlorophyll pigment concentration and plant growth parameters under water stress.

As for proline, Fig. 1 showed that proline content increased in untreated plants (1.1 mg/ g FW) during both seasons of (2018 and 2019) followed significantly by trees sprayed with potassium silicate at 0.3% (0.73 mg/ g FW) and potassium silicate at 0.2 (0.62 mg/ g FW), while averages of proline content decreased by GB application at 50Mm and reached to (0.53 mg/ g FW) then GB at 25 Mm (0.54mg/g FW). Many studies have linked salt stress and the accumulation of proline (Munns and Tester, 2008), and it may play a defensive role against the osmotic potential generated by salt (Hoque, *et al*., 2008). There is a positive relationship between plant stress and accumulation of proline. Proline is an amino acid which has extremely useful role in plants under various stress circumstances. Hence, during stress it works as an excellent osmolyte, plays three main roles, i.e., an antioxidative defense molecule, as a signalling molecule and metal chelator, (Shamsul, *et al*., 2012).These results agree with those obtained Habasy (2016) on Navel orange , Abo El-Enien *et al*., (2017) Valencia orange seedlings, Mohamed and Al-kamar (2018) on Valencia orange , Abo-Ogiala (2018) on pomegranate, Hamza and shalan (2020) on Mango and Seif *et al*.,(2020) on grape).

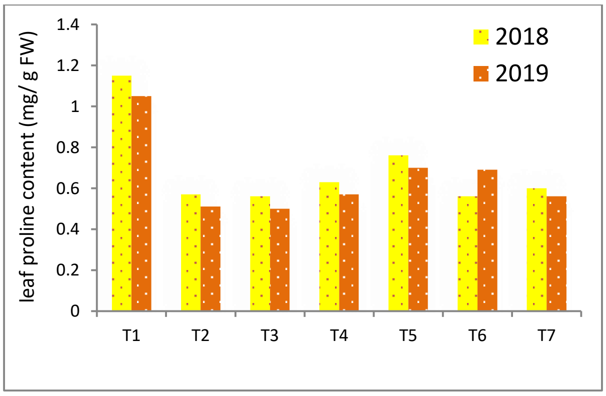

Fig. 1. leaf proline content (mg/ g FW) during 2018 and 2019 seasons.

Table 4. Effect of exogenous application of Glycine betaine and potassium silicate on total chlorophyll, total carotenoids and total carbohydrates content the leaves of Navel orange tress under salt affected soils during 2018and 2019 seasons.

Treatments	total chlorophylls ($\mu g/cm^2$)		Total carotenoids (mg/100g F.W)		Total carbohydrates %	
	2018	2019	2018	2019	2018	2019
T1	61.49 g	61.61 g	1.19 g	1.31 f	6.01f	5.19g
T2	62.41 c	62.51c	1.34 d	1.35d	8.01a	7.31b
T3	62.01e	62.31 e	1.29 f	1.31 f	8.01a	7.41a
T4	61.61f	62.76 e	1.31 e	1.32 e	7.01e	6.41f
T5	62.31d	62.41 d	1.61 c	1.62 c	7.51d	6.54e
T6	63.21 a	63.25 a	2.01 b	2.21 a	7.71c	6.91d
T7	63.01 b	63.11b	2.11a	2.2b	7.91b	7.01c

Means followed by different letter are significantly different within columns by Duncan's multiple range test, P≤0.05

T_1-Control (tap water), T_2- Glycine betaine at 25 mM ,T3- Glycine betaine at 50 mM , T4- Glycine Betaine at 75 mM ,T5- K_2SiO_3 at 0.1%,T6- K_2SiO_3at 0.2%, T7- K_2SiO_3 at 0.3%.

Leaf nutrient content

Data in table (5) cleared that Foliar spraying with GB and potassium silicate were significantly alleviated the effect of salt over the control treatment. Furthermore, the results indicated that, all treatments significantly enhanced the percentages of N, P, K and in the plant leaves compared to the untreated trees. The highest values of leaf N, P and K content recorded with 50 Mm GB followed by 25GB in both seasons. These results in harmony with many previous studies (Chen, and Murata 2008, Chun *et al.* 2009, Rodríguez-Zapata *et al*., 2015, Abo-Ogiala 2018 on pomegranate cv. wonderful).

Table 5. Effect of exogenous application of Glycinebetaine and potassium silicate on leaf nutrient concentration of Navel orange tress during 2018 and 2019 seasons.

Treatments	N%		P%		K%		Na%	
	2018	2019	2018	2019	2018	2019	2018	2019
T1	1.33 d	1.3 d	0.11e	0.1 e	1.38 f	1.41 f	0.27 a	0.26 a
T2	1.53 b	1.51 b	0.19b	0.2 b	1.43 d	1.47d	0.15bc	0.14bc
T3	1.6a	1.58a	0.22a	0.23a	1.48 a	1.52 a	0.13 d	0.12d
T4	1.42c	1.4c	0.16d	0.17 d	1.41e	1.45 e	0.16 b	0.15 b
T5	1.53 b	1.51 b	0.15cd	0.18cd	1.46 bc	1.5 bc	0.14cd	0.13cd
T6	1.59 a	1.57 a	0.26a	0.22a	1.47 ab	1.51ab	0.1cd	0.13cd
T7	1.53 b	1.51 b	0.18bc	0.19bc	1.45 c	1.49 c	0.15bc	0.14bc

Means followed by different letter are significantly different within columns by Duncan's multiple range test, P≤0.05

T_1-Control (tap water), T_2- Glycine betaine at 25 mM ,T3- Glycine betaine at 50 mM , T4- Glycine Betaine at 75 mM ,T5- K_2SiO_3 at 0.1%,T6- K_2SiO_3at 0.2%, T7- K_2SiO_3 at 0.3%.

Concerning leaf Na^+ content, the uptake of Na^+ by untreated trees was more elucidate (0.27 and 0.26%) during the 2018 and 2019 seasons, respectively as a result of the growing trees under salt stress, however, application of GB and potassium silicate treatments significantly reduced accumulation of Na^+ in leaves of Washington navel orange trees .the obtained results are in line with those reported by (Chen, and Murata 2008, Chun *et al.* 2009, El-Sayed *et al.* 2014 and Rodríguez-Zapata *et al*., 2015, Habasy 2016 on navel orange , Mohamed and Al- kamar 2018 on Valencia orange , Abo-Ogiala 2018 on pomegranate cv. wonderful).

Yield

Data in (Table 6&7) and Fig.2 cleared that all studied treatments significantly increased percentage of initial fruit setting and fruit retention, yield , number of fruits per tree, fruit weight/kg and productivity as ton per fed. As compared with untreated trees.

Concerning the fruit number it is observed that, trees sprayed by potassium silicate at 0.2 % recorded the maximum number of fruit (365 and 370) followed by GB 50 (365and 367) as compared with control (310 and 311), also, potassium silicate at 0.2% gave the heaviest fruit weight (220 and 222g) followed by GB at 50 (217and 219 g) comparing with fruits produced from untreated trees (184 and 186gm) in the first and second season, respectively.

Regarding, productivity data presented in (Table 7) and (Fig. 3) showed that all treatments increased the productivity of Washington navel orange trees from 9.81 to 40.42% over control treatment. Yield of trees that sprayed with potassium silicate at 0.2% increased by (40.42%) over control, followed by trees sprayed with GB at 50 mM (37.95%) followed by trees sprayed with GB at 25 mM (31.93%) , then the trees sprayed with potassium silicate at 0.1 % (20.75%) while, trees that received GB at 75mM showed an increase in yield (9.81%) over control.

The positive impact of exogenous GB and potassium silicate on fruit yield under variable conditions are in agreements with many previous studies (Chen, and Murata 2008, Chun *et al.* 2009, El-Sayed *et al.* 2014 and Rodríguez-Zapata *et al*., 2015, Habasy 2016 on navel orange , Mohamed and Al- kamar 2018 on Valencia orange , Abo-Ogiala 2018 on pomegranate cv. wonderful).

The positive effect of foliar application of different sources of potassium specially potassium silicate treatments on fruit weight and yield may be due to the significant absorption of NPK nutrients (Table 5), the pronounced positive effects on leaf chlorophyll and carbohydrate contents as well as vegetative growth (Table 3&4) which leads to healthy trees with a good nutritional status and hence improve fruit weight and increasing yield. These explanations agree with Kumar and kivno (2006) and Quaggio *et al*., (2011).

Table 6. Effect of exogenous application of Glycine betaine and potassium silicate on the percentage of initial fruit setting and fruit retention of Navel orange tress during 2018 and 2019 seasons.

Treatments	Initial fruit setting %		Fruit retention %	
	2018	2019	2018	2019
T1	3.18f	3.15 f	1.53g	1.54 g
T2	3.27d	3.24d	1.6 d	1.61d
T3	3.52a	3.49a	1.57e	1.58e
T4	3.22e	3.19 e	1.55f	1.56 f
T5	3.29c	3.26c	1.65 c	1.66c
T6	3.51a	3.48 a	1.74b	1.75 b
T7	3.44b	3.41b	1.76a	1.77a

Means followed by different letter are significantly different within columns by Duncan's multiple range test, P≤0.05

T_1-Control (tap water), T_2- Glycine betaine at 25 mM ,T3- Glycine betaine at 50 mM , T4- Glycine Betaine at 75 mM ,T5- K_2SiO_3 at 0.1%,T6- K_2SiO_3at 0.2%, T7- K_2SiO_3 at 0.3%.

Table 7. Effect of exogenous application of Glycinebetaine and potassium silicate on fruit weight and yield of Navel orange tress during 2018 and 2019 seasons.

Treatments	No. of fruits/tree		Fruit weight (g.)		Yield/tree (kg.)		Productivity (Ton/fed.)	
	2018	2019	2018	2019	2018	2019	2018	2019
T1	310.01f	311.99g	184.99 f	186.99 g	57.35g	58.33 g	9.63 g	9.80g
T2	360.01b	365.01 c	210.01d	211.01e	75.60 c	77.02 c	12.70 c	12.93c
T3	365.01a	367.01 b	217.00b	219.01b	79.21 b	80.376 b	13.30 b	13.50 b
T4	315.01e	317.01 f	200.00 e	202.01 f	63.00f	64.03 f	10.58 f	10.75 f
T5	365.01a	355.01d	215.01 c	216.01c	75.25 d	76.68d	10.58f	12.8 d
T6	365.01a	370.01 a	220.01 a	222.01 a	80.30 a	82.14 a	13.49 a	13.80a
T7	320.01d	325.01 e	217.01b	213.01d	69.44 e	69.23e	11.6 e	11.63 e

Means followed by different letter are significantly different within columns by Duncan's multiple range test, P≤0.05

T_1-Control (tap water), T_2- Glycine betaine at 25 mM ,T3- Glycine betaine at 50 mM , T4- Glycine Betaine at 75 mM ,T5- K_2SiO_3 at 0.1%,T6- K_2SiO_3at 0.2%, T7- K_2SiO_3 at 0.3%.

Fruit quality

Physical characteristics

Data in Table (8) show the effect of foliar spray of Glycine betaine and potassium silicate on some fruit physical and chemical characters of Navel orange trees. AS for, external fruit quality in terms of fruit height (cm), fruit volume (cm3), fruit peel thickness (cm) and fruit volume (cm3), results in Table 8 showed that heaviest and largest fruits were harvested from trees treated with Potassium silicate at 0.2% followed by 0.3% where control treatment scored the lowest values for these physical characters. For fruit peel thickness, the results showed that all GB and potassium silicate significantly reduced fruit peel thickness compared to control treatment.

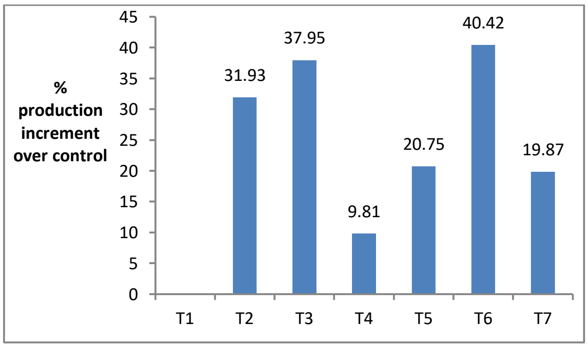

Fig. 2. Production increment percentage over control during the 2018 and 2019 seasons.

T_1-Control (tap water), T_2- Glycine betaine at 25 mM ,T3- Glycine betaine at 50 mM , T4- Glycine Betaine at 75 mM ,T5- K_2SiO_3 at 0.1%,T6- K_2SiO_3at 0.2%, T7- K_2SiO_3 at 0.3%.

These results are similar with the findings of Sarrwy *et al*., (2012), Habasy 2016, El-Salhy *et al*., (2017), Abo-Ogiala 2018, Mohamed and Al- kamar 2018. This may be explained by the role of silicon and potassium which plays a vital role in enzymes activity, carbohydrates metabolism ,enhance fruit quality, increase fruit size and weight (Quaggio *et al.*, 2011).

Table 8. Effect of Glycine betaine and potassium silicate on some physical characteristics of the fruits of Navel orange tress during 2018 and 2019 seasons.

Treatments	Fruit diameters (cm)		Fruit height (cm)		Fruit volume (cm^3)		Fruit peel thickness (cm)	
	2018	2019	2018	2019	2018	2019	2018	2019
T1	7.02b	7.09b	8.03f	8.01f	126.99f	124.99f	0.36a	0.37a
T2	7.15a	7.18a	8.18c	8.16c	150.01d	148.01d	0.32bc	0.33bc
T3	7.14a	7.17a	8.12d	8.1d	159.01	157.01	0.34b	0.34bc
T4	7.14a	7.17a	8.1e	8.08e	152.01c	151.01b	0.34b	0.35b
T5	7.16a	7.19a	8.2b	8.18b	148.01e	145.01e	0.33bc	0.34bc
T6	7.17a	7.20a	8.23a	8.21a	154.01b	150.01c	0.28d	0.29d
T7	7.17a	7.2 a	8.22a	8.2a	159.01a	157.01a	0.31c	0.32c

Means followed by different letter are significantly different within columns by Duncan's multiple range test, P≤0.05

T_1-Control (tap water), T_2- Glycine betaine at 25 mM ,T3- Glycine betaineat50 mM , T4- Glycine Betaine at 75 mM ,T5- K_2SiO_3 at 0.1%,T6- K_2SiO_3at 0.2%, T7- K_2SiO_3 at 0.3%.

Chemical characteristics:

Data in Table (9) cleared that the highest values of SSC% were found in the trees sprayed with 0.2% potassium silicate but, control treatment gave the lowest values of SSC in both seasons. As for acidity, all treatments decreased the percentage of fruit acidity content as compared with control treatment. SSC/acid ratio is one of the most important characters for citrus ripening and exportation. The results cleared that, potassium silicate at 0.2% scored the highest values for T.S.S/acid ratio compared to the control treatment.

Regarding acidity, potassium silicate at 0.3% was the best treatment for vitamin C content while control treatment gave the lowest values of vitamin C in both seasons.

Concerning reducing and total sugar, data presented in Table (10) cleared that the reducing and total sugar percentages in fruit juice were affected by spraying Glycine betaine and potassium silicate concentrations in both seasons.

Improvement SSC% content could be attributed to the vital importance of potassium in enhancing synthesis of photosynthates and their transport to fruit. These results are similar with the findings with many previous studies (Taha *et al.*, 2014, Habasy (2016) on navel orange, Zayan *et al.*2016 on peach, Mohamed and Al- kamar (2018) on Valencia orange, Abo-Ogiala (2018) on pomegranate cv. Wonderful and Vijay *et al*., (2019).

Table 9. Effect of Glycine betaine and potassium silicate on some chemical characteristics of the fruits of Navel orange tress during 2018and 2019 seasons.

Treatments	SSC%		Total acidity %		SSC/ acidity	
	2018	2019	2018	2019	2018	2019
T1	11.61g	11.62g	1.21a	1.2a	9.59e	9.68 f
T2	12.81b	12.85b	0.99e	0.98d	12.94b	13.11b
T3	12.01e	12.41e	1.11c	1.1b	10.82d	11.28e
T4	11.91f	12.01f	1.06d	1.01c	11.23c	11.89c
T5	12.71c	12.76c	1.13b	1.11b	11.25c	11.49d
T6	13.61a	13.64a	0.96f	0.95e	14.17a	14.35a
T7	12.41d	12.46d	1.12bc	1.11b	11.08c	11.22e

Means followed by different letter are significantly different within columns by Duncan's multiple range test, P≤0.05

T_1-Control (tap water), T_2- Glycine betaine at 25 mM ,T3- Glycine betaine at 50 mM , T4- Glycine Betaine at 75 mM ,T5- K_2SiO_3 at 0.1%,T6- K_2SiO_3at 0.2%, T7- K_2SiO_3 at 0.3%.

Generally, it is clear from Tables 7, 8, 9, 10 and Fig. 3 that, spraying Washington Navel orange trees with Glycine betaine at (25,50 and 75mM) and potassium silicate with three concentrations(0.1, 0.2 and 0.3%) increased fruit length, diameter, weight, , acidity, SSC% and vitamin C especially Glycine betaine 50Mm and potassium silicate at 0.2% in both seasons. These results reveal a positive relationship that can arise between fruit quality and foliar spray of potassium combined with silicon the present results are in a general harmony with Habasy (2016) on valencia orange.

Table 10. Effect of Glycine betaine and potassium silicate on some chemical characteristics of the fruits of Navel orange tress during 2018 and 2019 seasons.

Treatments	Reducing sugars %		Total sugars %		Vitamin C content (mg/100 ml juice)	
	2018	2019	2018	2019	2018	2019
T1	3.26 d	3.3 d	10.46f	10.61f	41.01g	41.39g
T2	3.67 b	3.7 b	11.32b	11.47b	43.01d	43.61c
T3	3.76 a	3.8 a	11.59a	11.74a	42.41e	42.51e
T4	3.13 f	3.17f	10.46f	10.61f	42.01f	42.41f
T5	3.23e	3.27e	11 d	11.15d	42.01f	43.45d
T6	3.45c	3.49 c	11.06c	11.21c	45.91b	45.96b
T7	3.45c	3.49c	10.46f	10.61f	46.51a	46.56a

Means followed by different letter are significantly different within columns by Duncan's multiple range test, P≤0.05

T_1-Control (tap water), T_2- Glycine betaine at 25 mM ,T3- Glycine betaine at 50 mM , T4- Glycine Betaine at 75 mM ,T5- K_2SiO_3 at 0.1%,T6- K_2SiO_3at 0.2%, T7- K_2SiO_3 at 0.3%.

CONCLUSION

Under the soil affected by salinity, Washington navel orange trees were sprayed with glycinebetaine and potassium silicate at different concentrations at three times beginning of full bloom stage , four weeks and eight weeks after full bloom, this led to ameliorates the harmful effects of salt, enhanced the vegetative growth and reflected an increase of yield over control ranged from 37.95% when using Glycine betaine at 50 Mm and 40.42%, with potassium silicate at 0.2% Hence, it could be recommended to spray Navel orange trees with potassium silicate 0.2% or Glycine betaine at 50 Mm to alleviate the salinity stress and enhance the vegetative growth and productivity.

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تحسين النمو الخضرى والمحصول وانتاجيه اشجار البرتقال ابوسره تحت ظروف الاجهاد الملحى باستخدام الجليسين بيتايين وسيليكات البوتاسيوم

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أجريت الدراسة الحالية على أشجار البرتقال ابوسره صنف واشنجتن البالغة من العمر خمسه عشر عاما والناميه في مزرعه خاصه بمركز الرياض بمحافظة كفر الشيخ مصر خلال موسمي 2018 و 2019 لدراسة تأثير الرش بالجليسين بيتايين بثلاثه تركيزات 25و50و75 ملليمول، و سيليكات البوتاسيوم بتركيز 0.1 و 0.2 و 0.3 % على النمو الخضرى والحالة الغذائية والمحصول وجودة الثمار تحت ظروف الاجهاد الملحى. تم الرش في ثلاث مرات بداية من منتصف مارس و15 أبريل و15 مايو. أظهرت النتائج أن رش الاشجار بسيليكات البوتاسيوم عند 0.2% و بالجليسين بيتاين وخاصة عند تركيز 50 ملليمول كان له تأثير إيجابي على النمو الخضرى ومحتوى الاوراق من الكلوروفيل الكلي و النيتروجين والفوسفور و البوتاسيوم والكربوهيدرات الكلية مما انعكس على المحصول وتحسين صفات الثمار الطبيعية مثل وزن و حجم و طول وقطر الثمار و زيادة المحصول عن الكنترول ب 40.42% و ايضا تحسين صفات الثمار الكيماوية مثل محتواها من المواد الصلبة القابلة للذوبان ونسبة المواد الذائبه الكليه / الحموضه وفيتامين ج وذلك عند المقارنة مع الكنترول و المعاملات الأخرى. و بناء علية،توصى الدراسه برش اشجار البرتقال ابوسره صنف واشنجتن بسيليكات البوتاسيوم بمعدل 2% البرتقال ابوسره صنف واشنجتن ثلاث مرات بداية من منتصف مارس و ابريل و مايو و والتي تعتبر أفضل معاملة تستخدم لتحسين النمو الخضرى والانتاجيه تحت ظروف الاجهاد الملحى.