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Influence of Nano-silicon Treatment on Growth Behavior of 'Sukkary' and 'Gahrawy' Mango Root-stocks Under Salinity Stress

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ABSTRACT

The experiment was carried out in two consecutive seasons (2017/18 and 2018/19) on 'Sukkary' and 'Gahrawy' mango root-stocks seedlings and the purpose of the research was to investigate the effectiveness of applying Nano-silica to increase the tolerance of 'Gahrawy' and 'Sukkary' mango rootstocks. The tested treatments were tap water irrigation (TWI),TWI and spraying Nano silicon (SNSi) at 1.0g/L,Sea water irrigation (SWI) at 1750ppm, SWI at 1750ppm and SNSi, SWI at 3500ppm, and SWI at 3500ppm and SNSi. Foliar sprays of Nano-silicon were done four times;the first at the beginning of the experiment, and then three times at 45-days intervals.The effect of treatments on the behavior of the seedlings of the two rootstocks including vegetative characteristics (new leaf area, seedling height increase%, seedling stem diameter increase, root length and width, number of lateral and secondary roots and root growth coefficient), physiological parameter "Leaf pigments, total phenols and soluble carbohydrates contents",leaf mineral contents " N, P, K, Na, Ca and Mg" and Non-enzymatic antioxidants"proline content and DPPH" as well as salinity symptoms parameters were studied. Increasing levels of salinity caused a decrease in most parameters and an increase in the sodium and proline content, and salinity symptoms of the leaves. Irrigation with salty water at 1750ppm together with foliar spraying Nano-silicon enhanced leaf content of pigments, soluble carbohydrate and total phenols, Mg, N, P, K and decreasing of salinity symptoms parameters.The results confirmed that the effects of Nano-silicon on the behavior of treated seedlings differ according to the variety under salinity conditions.

Keywords: Mango seedlings, Salinity stress, Nano-Silicon, Physiological and salinity symptoms parameters, antioxidants

INTRODUCTION

Salinity is one factor of the major abiotic stress that severely affects the soil quality of agricultural lands and limits crop productivity in the worldwide (Muchate *et al.,* 2016). Soils are classified as saline when an electrical conductivity (EC) of the saturation soil-paste is ≥4 dSm−1 equal about 40 mM NaCl (Munns & Tester 2008). Salinity stress affects the biochemical and physiological processes, and morphological characteristics of plants (Singh & Chatrath, 2001 and Ashraf, 2004). High salinity decreases plant growth, photosynthesis, yield, biomass and water use efficiency, as well as it leads to physiological drought and ion toxicity in plants, thus reducing agricultural productivity and yields (Shahid *et al.*, 2018). Salinity stress also results in the osmotic effect, water use insufficiency, nutrient (N, K, P and Mg and Ca) deficiency and ionic imbalances, which leads to oxidative stress in plants (Rehman *et al*., 2019).

Reactive oxygen species (ROS) are produced in plant cells, either in non-radical or a radical form, under normal physiological conditions (Winterbourn, 2019). However, excessive production of ROS leads to oxidative damage in nucleic acids, proteins, lipids and plasma membrane of the cell. The plant produces, during normal processes of cellular metabolism, several antioxidant enzymes for the detoxification of ROS. Moreover, salinity stress and high production of ROS significantly decrease the uptake of phosphorus and potassium, while increase the uptake of toxic elements such as sodium and chlorine, which have negative effects on plant growth and productivity. High concentrations of Na^+ create osmotic stress, which consequently leads to cell death (Munns, 2002; El-Dengawy *et al*., 2011 and Safdar *et al*., 2019).

Moreover, Photosynthesis system is affected by salinity stress, mainly due to reducing the leaf area, stomatal conductance, and chlorophyll levels efficiency (Netondo *et al*., 2004). Any mechanism that keep optimal K^+/Na^+ ratio, nutrient concentrations and ROS production in plants are thus likely to provide effective resistance against salinity stress (Assaha *et al*., 2017). Biotic and abiotic stresses including drought, scarcity of water, reducing quality of irrigation water and salinity in soil and water are problems, which are becoming acute (Flowers, 2004). These stresses can severely affect growth and development of both rootstocks and/or scions, thus reducing both fruit production and fruit quality.

Mango is the most important crop all over the world, especially in tropical and subtropical region. Mango, the king of fruits, is one of the major fruit crops in Egypt. Most of the mango cultivars are most sensitive to soil or water salinity (Bajpai *et al*., 2017), albeit with variation in its ability to tolerate salinity depending on rootstock (Kadman *et al*., 1976). It is very sensitive to soil salinity at younger stage. Under conditions of arid and semi- arid regions like Egypt, lack of adequate supplies of irrigation water is the most problem restricted agriculture development in desert areas and newly reclaimed (Abo-Rekab, 2014). However,

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salinization of soil is one of the major restrictions in the management of irrigated agriculture. Although this fact, many studies have reported that saline water can be used for irrigation with variable degrees of success (Gowing *et al*., 2009).

The seedlings of mango at younger stage in the beginning of the establishment of the orchard are exposed to many stresses, the most important of which is the stress of salinity. Salinity tolerant rootstocks is considered a special importance in Vertical and horizontal expansion. Also, tolerant rootstocks to different abiotic stresses like drought, salinity, temperature abnormality etc. were applied to control of salinity problem and may be an alternative approach face these challenges (Nimbolkar etal., 2016).

Recently, Nano-compound materials have given a lot of attention by the agricultural researchers (Pourkhaloee *et al*., 2011). Because of their tiny size, Nano materials show unique characteristics. They can change physico-chemical properties compared to bulk materials, they have greater surface area than bulk materials and due to this larger surface area, their solubility and surface reactivity tend to be higher (Cheng *et al*., 2014). Nano-silicon (NSi) is one of the useful Nano materials which are reported to have a beneficial effect in modern agriculture (Torney *et al*., 2007). Silicon is not classed as an essential nutrient, but it is involved in a number of metabolic pathways that enhance the tolerance of plants to biotic and abiotic stresses such as drought and salinity stress (Bao-Shan *et al*., 2004 and Coskun *et al*., 2016). The key mechanisms of Si-mediated alleviation of abiotic stresses in higher plants include stimulation of antioxidant systems in plants, complexation, co precipitation of toxic metal ions with Si, immobilization of toxic metal ions in growth media, uptake processes, and compartmentation of metal ions within plants (Liang *et al*., 2007).

Many reports indicated that Nano silicon and silicon mitigated the adverse effects of salinity stress and increased significantly photosynthetic contents; chlorophyll a, b, total chlorophyll and carotene; (Haghighi & Pessarakli (2013) On tomato, Tantawy *et al*., (2015) on sweet pepper, and Avestain *et al*., (2019) on strawberry plants). Also under water stress, silicon treatments can increased vegetative and root parameters such as stem diameter, plant height, leaf area, root length and numbers of laterals roots (Tantawy *et al*., (2015) on sweet pepper, and Almutairi (2016) on tomato plants and Safoora *et al*., (2018) on strawberry. Moreover, Abdul Qados & Moftah (2015) and Tantawy *et al*., (2015) on faba bean and sweet pepper, respectively reported the benefits of silicon or Nano-silicon for plants grown under salinity stress relates to increase nutrient elements (Ca, Mg, N, P and K) and decrease toxic ions (Na).

Si had different effects on proline where Si can increase proline accumulation in plants like Talh trees (Al-Huqail *et al*., 2017) and potato plants Crusciol *et al*., 2009). On the other hand Si can reduce proline concentration under salinity stress in tomato (Haghighi & Pessarakli, 2013) and in Soy bean (Yin *et al*., 2014). Silicon application may reduce the loss of water through the cuticle due to silica deposition underlying epidermal cells of leaf and stem plants influencing water loss (Liang *et al*., 2015).

Application of Nano-silica mitigated the adverse effects of salt stress; it reduced the uptake of Na^+, increased significantly proline, total carbohydrates and total phenol contents under salt stress (Abdel-Haleim *et al*., 2017). Silicon reduces transpiration due to the accumulation in the tissues of the cuticles Keller *et al*., (2015). Nano-silica by soil or by spraying increased significantly the absorption of N, P and K content and reduced the uptake of Na+ content in wheat seedlings under salinity stress Ayman *et al*., (2020).

Although, there are a lot of references regarding interaction between salinity and silicon in higher plants, there is currently little information available about the possible beneficial effects of Nano-silicon application to reduce salt stress damages in mango seedlings. Gahrawy variety is widely cultivated in the north of the delta, especially in the coastal governorates and it also represents the main mango cultivar in Damietta Governorate. Therefore, this study was conducted to investigate the effectiveness of applying Nano-silica to reduce the negative influences of saline irrigation water on growth, biochemical and physiological characteristics of 'Gahrawy' and 'Sukkary' mango rootstocks. To determine the extent of salinity of irrigation water that can be tolerated by the two mango rootstocks under study.

MATERIALS AND METHODS

The present investigation was carried out during two successive seasons 2017/2018 and 2018/2019 at the nursery of pomology department of agriculture faculty, Damietta university, Egypt.

The plant material: One year old seedlings of two poly embryonic mango cultivars were used for this research namely Sukkary (the certified tolerant rootstock in Egypt, according to Galán Saúco, 2016), and Gahrawy planted in Damietta governorate especially at Om EL-Reda village (Doaa & Shalan, 2020). Mango fruits of Sukkary and Gahrawy were brought from a private orchard in Om EL-Reda village at Damietta governorate. Seeds were freshly extracted from ripen fruits and washed twice in tap water and sown at the end of August and September for 'Sukkary' and 'Gahrawy' cultivars, respectively. The collected seeds were sown in perforated black polyethylene bags (40 x 20 cm) filled with peat moss and sand at ratio of 1:2v/v, respectively (one seed for each). The bags were watered regularly. Two months later the sexual seedlings were removed and nucellar seedlings were transplanted. Six months after sowing, the nucellar seedlings of uniform growth vigor were selected and transplanted singly into perforated 20 cm pots filled with prescribed medium. After the transplantation with two months, the healthy seedlings were classified into nine similar groups (15 seedlings for each). Each group was arranged into three replicates (5 seedlings for each) and then subjected to one of the following treatments during both two seasons.

Tap water irrigation (TWI) as control (T_1), TWI and spraying Nano silicon (SNSi) at 1.0g/L (T_2), Sea water irrigation (SWI) at 1750ppm (T_3), SWI at 1750ppm and SNSi (T_4), SWI at 3500ppm (T_5), and SWI at 3500ppm and SNSi (T_6).

Foliar application of NSi in concentration of 1 g/L was performed using a small pressure pump after adding Tween 20 (0.5%) as a wetting agent. Foliar sprays were done 4 times, the first at the beginning of the experiment, and another three at 45-days intervals. The irrigation treatments were supplied twice a week (500 ml/pot) for one year (growth period in each season from the autumn growth cycle to the summer growth cycle). The used levels of salinity were prepared by dilution of Mediterranean Sea water stock with tap water and added at the mentioned scheduled irrigation intervals from start to the end of experiment. Every three weeks, each pot was washed with 500 ml tap water to prevent increasing the osmotic potential resulting from the accumulation of salts by the successive irrigation procedures (Abdul Qados & Moftah, 2015). The Nano-silicon used in the research was purchased from Al-Gomhoria Company, Mansoura, Egypt and the mean size Zeta-Potential test was determined in Electron Microscopy Unit of Mansoura University (Fig. 1).

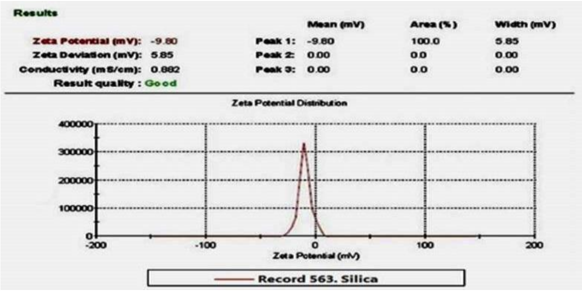

Fig. 1. Zeta potential distribution for the silicon nanoparticles (NSiP).

The measurements performed

At the beginning of the current research, we measured some of morphological parameters such as plant height, leaf area and stem thickness, as the starting line for the state of seedlings included in the experiment. The seedlings were given the mentioned saline doses until the symptoms appeared, such as yellowing in the leaf, burning of its edges and fall it.

At the end of experiment, the following measurements were taken on the treated seedlings:

Vegetative characteristics

Percentage of seedling height increase (PSHI)

The height of the seedlings (cm) was measured, at both the start (Hs) and the end (He) of experiment, from the soil surface level to the terminal apex of the seedling main stem. The PSHI was calculated by the following formula:

$$PSHI = [(He - Hs)/Hs] \times 100.$$

Seedling stem diameter increase (SSDI)

The increase in seedling diameter was calculated by subtracting the diameter of the seedling at a height of 5 cm from the soil surface at the beginning of the experiment from its diameter on the end of the experiment at the same height.

New leaf area (NLA)

The length and width of the fourth and fifth leaves in the seedlings were measured. Then new leaf area was determined according an equation given by Ahmed and Morsy (1999) as follow:

$$\text{Leaf area (cm}^2) = 0.70 \times (\text{leaf length} \times \text{leaf width}) - 1.06$$

Root parameters of the treated seedlings

At the end of experiment, the root system of tested seedlings were carefully removed from the soil, washed with tap water, cleaned and dried with paper towels and then used to measure the parameters of root system.

Root length and width (RL &RW)

Root length of the treated seedling was measured from the collar region to the growing tip of the primary root (cm). The width of the root (cm) was obtained by measuring the longest lateral roots at both sides of the root.

Number of lateral and secondary roots (NLR &NSR)

They were counted as an average of number in root system of two seedlings for each replicate (in 6 seedlings per treatment).

Root system growth coefficient

Root system growth coefficient (RSGC) was calculated by using root parameters include length, width and numbers of lateral and secondary roots according to the following equation:

$$RSGC = [RL * RW * (LR + SR)] \text{ for treatment} / [RL * RW * (LR + SR)] \text{ for control}$$

Where:

RSGC: Root system growth coefficient, RL: root length (cm) and RW: root width (cm),

LR: number of lateral roots, and SR: number of secondary roots

Determination of bio chemical characteristics of seedling leaves

Leaf pigments

Two discs (0.30 cm^{2}for each) were sampled at the appearance of salinity symptoms from third or fourth leaves avoiding major veins. Chlorophyll was eluted from discs by submerging them in 5 ml of N, N- dimethyl formamide in the dark for at least 72h. The amount of absorbance was read at 470nm, 647nm and 665nm to measure carotenoid, total chlorophyll with UV-vis spectrophotometer and used to calculate leaf a, b and total chlorophyll concentrations according to equations of Moran (1982), also carotenoids (µg/ml) = (1000 x A480 – 0.89 x chl$_a$– 52.02 x chl$_b$)/245 was measured according to Wellburn (1994).

Total phenols component

The phenolic components were extracted as described by (Stabell *et al.*, 1996) with modifications. Weight of 0.25g of leaf fine dry powder was homogenized in 80% ethanol. The homogenate was boiled for 20 min, centrifuged 8,000rpm for 15 min and the supernatant saved. The pellet was re-extracted as above and the two supernatants were collected and evaporated to dryness. The residue was dissolved and completed to a known volume with distilled water and used for the phenols measurement using Folin-Ciocalteau reagent (Sadasivam & Manickam, 1996) with gallic acid as standard. Total phenol contents were expressed as µg gallic acid equivalent (µg GAE)/g dw.

Proline content

Proline concentration was determined according the method of Bates *et al.* (1973). Leaf samples were collected at the end of the experiment. A 0.5 g of fresh weight was mixed with 5 ml aliquot of 3% (w/v) sulfosalicylic acid in glass tubes covered at the top and boiled in a water bath at 100°C. The mixture was centrifuged at 3000 g for 4min at 25°C. A 300 µl aliquot of the extract was mixed with 700 µl distilled water and 14 ml of the reagent mixture (30ml glacial acetic acid, 20ml distilled water and 0.5 g of ninhydrin) and boiled at 100°C for 60 min. After cooling the mixture, we added 5.0ml of toluene. The chromophore containing toluene was separated and absorption was read at 520 nm, using toluene as a blank. Proline concentration was calculated using L-proline for the standard curve and calculated as mg/g dw.

Soluble carbohydrates content (SCC)

The SCC was extracted according to Kerepesi (1996). Weight of 0.1g of leaf dry powder was boiled in 10 ml distilled water under shaking for 50 min and then filtered through qualitative filter paper. An aliquot (0.5 ml) of this filtrate was used for SCC determination following Dubois *et al*., (1956) using D (+)-glucose as standard. The obtained results were recorded as mg/g dw.

Leaf mineral contents

For measurement of macro elements, 0.3g from each sample of dried leaf powder was wet digested with a mixture of concentrated sulphuric and perchloric acids (Peterburgski, 1968) after digestion the cleared solution was quantitavely transferred into 50 ml measuring flask with distilled water and kept for the determinations. Measuring total nitrogen: it was done by using the Micro Kjeldahl apparatus according to Jones *et al.* (1991). Total phosphorus content: it was determined spectrophotometrically according to Jackson (1973). Na^+, K^+ and Ca^{+2} were extracted according to Gavlak *et al*., (1994). Leaf fine dry powder (0.2 g) was microwave digested with nitric/hydrogen peroxide, filtered through qualitative filter paper and used for Na^+, K^+ and Ca^{+2} determinations by flame photometry (Gustav, 1961). For estimation of Mg^{+2}, the method of microwave digestion was used. The concentration of Mg^{+2} was analyzed by electrothermal atomic absorption spectrometry, Perkin Elmer Model 5100 according to Kumpulainen *et al.*, (1983). The concentration of the elements was calculated on a dry weight basis.

DPPH radical scavenging assay

The measurement of the DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical scavenging activity was performed according to method described by (Rekha *et al*., 2012). Leaf sample extract was diluted with DMSO and in each reaction mixture; 1.0 ml of the solution in various concentrations was mixed with 2.0 mL of 100 μM DPPH. The mixture was shaken vigorously and allowed to reach a steady state at room temperature for 30 min. in dark. The changes in color from deep violet (A0) to light yellow (A1) were measured at 517 nm. In addition, ascorbic acid was used as standard sample in the determination of DPPH radical scavenging activity of mango leaf (Fig. 2). Equation of scavenging activity % (IC_{50}%) = $[(A_0 - A_1)/A_0] \times 100$ was used. Where, A_0: is the absorbance of DPPH without leaf mango extract. A_1: is the absorbance in the presence of leaf mango extract or standard sample.

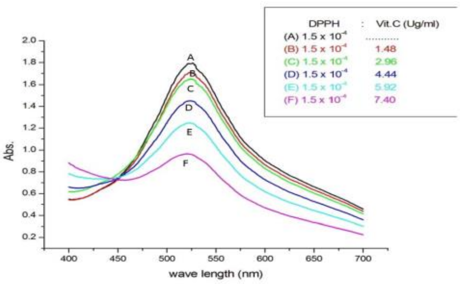

Fig. 2. Effect of Vitamin C concentration on the UV-visible spectra of DPPH in DMSO solvent at25º C

Salinity symptoms parameters

After the salinity symptoms, such as yellowing in the leaf, burning of its edges and fall it, appeared on the leaves of mango seedling, the data represent salinity symptoms including injured seedlings%, injured leaves%, leaf injuring severity and symptoms index as well as re-flushed seedlings% were determined as follow:

Injured seedlings (IS) % = (Number of seedlings have salinity symptoms/Total seedlings number) x 100

Injured leaves (IL) % = (Number of leaves have salinity symptoms/Total leaves number) x 100

Re-flushed seedlings% = (Number Re-flushed seedlings/Total seedlings number) x 100

Salinity symptoms index (SSI) = (IL number x IS number x LIS) / (Total leaves number x Total seedlings number).

Leaf injury severity (LIS)

To record the LIS due to salt stress, scoring was done using a scale of 1-6 with seedlings showing re-flushed with no symptoms being scored as 1 and those with maximum leaf injury as 6 as given below (Lee, 1995) with some modification.

Given score	Leaf injuring severity (LIS)
1	Re-flushed with no symptoms
2	No visible salinity injure on leaves
3	Slight salinity injure on leaves (5-15% yellowing of leaves)
4	Moderate salinity injure on leaves (15-25% yellowing and burning of leaves)
5	High salinity injure on leaves (about 50% yellowing and burning of leaves)
6	Severe salinity injure on leaves (75% yellowing, burning and drying of leaves)

Statistical analysis

The obtained data were statistically analyzed as completely randomized design using SAS (1996) program. Applying the Duncan's new multiple range tests (DMRT) at 5% for the comparison among the treatment means according to Duncan (1955).

RESULTS AND DISCUSSION

Results

Vegetative characteristics of the treated seedlings

The results recorded in Table (1) regarding percentage of seedling height increase (PSHI) indicated that with an increase in the level of salinity up to 3500ppm, the PSHI decreased in the Sukkary cultivar, while a reverse trend with Gahrawy cultivar was fact where the PSHI increased, especially with the level of Salinity 1750ppm.

The application of Nano-silicon at 1 g/l with non-salty water caused an increase in PSHI in Gahrawy cultivar, while the trend was opposite with the Sukkary cultivar. In the case of using Nano silicon spraying under the conditions of irrigation with saline water at the level of 1750ppm, it showed a decrease in the PSHI in both cultivars.

Concerning the increase in stem diameter (SSDI), it was noticed that there is no significant differences between irrigation with non-saline water and saline water at 1750ppm and their combinations with Nano-silicon spraying. However, a significant decrease in SSDI was observed in both cultivars under conditions of irrigation with 3500ppm saline water compared to other treatments and the control.

Generally, the new leaf area (NLA) in both cultivar of Sukkary and Gahrawy did not differ under the studied three levels of salinity, except for irrigation with non-saline water (control) in Sukkary cultivar.

Spraying Nano-silicon on mango Gahrawy seedlings led to a significant increase in the NLA under 3 levels of salinity studied comparing to non-sprayed seedlings, and the

Sukkary cultivar showed the same trend under the irrigating with saline water at 3500ppm.

Root parameters of the treated seedlings

The results shown in Table (2) represent the effect of treating mango seedlings of Sukkary and Gahrawy cultivars with Nano-silicon on the characteristics of the root system under irrigation with three different salinity levels (normal water, 1750 and 3500ppm). Such results showed that irrigation with saline water at either 1750ppm or 3500ppm caused a significant decrease in the NLR and NSR of Gahrawy seedlings compared to irrigation with non-saline water (control). The numbers were as 102 and 83.33 for the LR, and 267.5 and 219.83 for the SR under the influence of salt water at concentrations of 1750 and 3500ppm, respectively, while the numbers were 201 and 745.16 in the seedlings irrigated with non-saline water (control).

As for the Sukkary cultivar, an insignificant increase occurred in the NLR and NSR under the influence of the lower salinity level (1750ppm) compared to the higher salinity level (3500ppm) and the control.

Table 1. Effect of Nano silicon on mango seedlings vegetative growth characteristics of 'Sukkary' and 'Gahrawy' cultivars under salinity stress as average of two seasons

Treatments		Vegetative growth parameters of mango seedling					
Salinity levels	Anti-stress	Seedling height increase % (PSHI)		Seedling stem diameter increase in mm (SSDI)		New leaf area (cm^2) NLA	
		Sukkary	Gahrawy	Sukkary	Gahrawy	Sukkary	Gahrawy
Tap water	------	35.58a	19.76d	3.65a	3.15ab	92.487a	65.06cd
Tap water	N-Si	27.95c	41.45a	3.46a	3.26ab	72.09b	82.52b
1750 ppm	------	32.93b	40.89a	3.09a	3.58a	63.69bc	59.30d
1750 ppm	N-Si	21.12d	37.99ab	3.31a	2.96b	60.11c	115.15a
3500 ppm	------	12.96e	34.67b	2.96a	2.07c	66.59bc	58.59d
3500 ppm	N-Si	23.05d	29.10c	1.72b	1.97c	84.40a	73.46c

Means followed by the same letters are not significantly different at level $P \leq 0.05$ according to DMRT.

Table 2. Effect of Nano silicon on root system parameters in mango seedling of 'Sukkary' and 'Gahrawy' cultivars under salinity stress as average of two seasons

Treatments		Root system parameters of Mango root-stocks					
Salinity levels	Anti-stress	Lateral roots number (NLR)		Secondary roots number (NSR)		Root system growth coefficient (RSGC)	
		Sukkary	Gahrawy	Sukkary	Gahrawy	Sukkary	Gahrawy
Tap water	------	71.3b	201.0a	186.3cd	745.2a	1.00bc	1.00a
Tap water	N-Si	161.5a	132.2b	607.7a	311.7b	1.65ab	0.30b
1750 ppm	------	84.3b	102.0bc	198.0cd	267.5b	1.27bc	0.25b
1750 ppm	N-Si	109.2b	109.2bc	460.7b	209.0b	1.96a	0.09c
3500 ppm	------	68.8b	83.3cd	141.3d	219.8b	0.63c	0.09c
3500 ppm	N-Si	76.7b	61.8d	300.8b	103.5c	0.92c	0.02c

Means followed by the same letters are not significantly different at level $P \leq 0.05$ according to DMRT

Regarding the characteristics of the root system, it was also observed that the response of Sukkary seedlings to the treatment with Nano-silicon differed from that of Gahrawy seedlings. Since treating Sukkary seedlings with Nano-silicon produced a significant increase in the NLR and NSR under irrigation with different levels of salinity compared to non-treated seedlings. While spraying the Gahrawy seedlings with Nano-silicon achieved a reverse trend in that respect. The same comparison was true between two cultivars concerning root distribution coefficient.

All the studied treatments achieved two opposite trends in the root system growth coefficient (RSGC) for the two studied cultivars (Table 2), where a significant increase in the Sukkary cultivar and a significant decrease in the Gahrawy cultivar appeared in this characteristic compared to the control. Also, applying Nano-silicon was more effective in improving the RSGC in the Sukkary cultivar compared to the Gahrawy cultivar under the influence of the studied treatments.

Bio Chemical characteristics of seedling leaves

Leaf pigments

The results in Table (3) represent the effect of saline water irrigation and applying Nano-silicon on the content of total chlorophyll and carotene in the leaves of the mango seedlings of Sukkary and Gahrawy cultivars.

Table 3. Effect of Nano silicon on leaf pigments contents in mango seedling of 'Sukkary' and 'Gahrawy' cultivars under salinity stress as average of two seasons

Treatments		Leaf pigments content of Mango root-stocks			
Salinity levels	Anti-stress	Total chlorophyll (mg/cm^2)		Carotene(mg/cm2)	
		Sukkary	Gahrawy	Sukkary	Gahrawy
Tap water	------	1.38ab	1.48c	0.23ab	0.23c
Tap water	N-Si	1.59a	1.71b	0.34a	0.31b
1750 ppm	------	1.13c	1.38c	0.21ab	0.31b
1750 ppm	N-Si	1.46ab	2.14a	0.13b	0.40a
3500 ppm	------	0.64d	1.38c	0.13b	0.30b
3500 ppm	N-Si	1.25bc	1.84b	0.33a	0.31b

Means followed by the same letters are not significantly different at level $P \leq 0.05$ according to DMRT

The results showed that there was a gradual decrease of total chlorophyll with an increase in the levels of salinity, where the highest levels of total chlorophyll were 1.38 and 1.48 mg/cm^2 in the control (non-salty water irrigation) while the lowest levels were 0.64 and 1.38 mg/cm^2 in the irrigation of 3500ppm saline water for Sukkary and Gahrawy cultivars, respectively.

The results clearly proved that the treatment of seedlings by spraying with Nano-silicon has a highly efficient effect in increasing the leaf content of total chlorophyll compared to non-sprayed seedlings under the three levels of salinity studied.

With regard to the carotene content in the treated seedling leaves, there were usually no significant differences between the tested treatments and the control seedlings in Sukkary cultivar, while it was found a significant increase in the carotene content of seedling leaves in all the studied treatments compared to irrigation with non-saline water (control) in Gahrawy cultivar.

Treating seedlings with Nano-silicon improved the leaf studied pigments content (total chlorophylls and carotene) in seedlings of the two tested mango cultivars under different levels of salinity.

Leaf contents of soluble carbohydrates, proline and total phenols

Data in Table (4) shows the effect of Nano-silicon spraying and saline irrigation at three levels alone or in combinations on the leaf content of soluble carbohydrates contents (SCC), proline and total phenols in Sukkary and Gahrawy mango seedlings.

Table 4. Effect of Nano silicon on bio chemical contents in mango seedling leaves of 'Sukkary' and 'Gahrawy' cultivars under salinity stress as average of two seasons

Treatments		Bio chemical contents in seedling leaves					
Salinity levels	Anti-stress	SCC*(mg/g)		Proline(mg/g)		Total phenols(µg/g)	
		Sukkary	Gahrawy	Sukkary	Gahrawy	Sukkary	Gahrawy
Tap water	------	48.1e	53.1b	1.39e	1.91b	1.44c	1.49cd
Tap water	N-Si	86.4c	51.6b	1.67d	1.83b	1.49bc	1.46d
1750 ppm	------	105.3b	63.6a	2.09a	1.91b	1.57b	1.52b
1750 ppm	N-Si	121.9a	66.6a	1.75cd	1.94b	1.94a	1.63a
3500 ppm	------	44.5e	49.3b	1.89b	2.12a	1.52bc	1.52bc
3500 ppm	N-Si	61.6d	65.7a	1.76c	1.93a	1.44c	1.54b

Means followed by the same letters are not significantly different at level $P \leq 0.05$ according to DMRT
***SCC= Soluble carbohydrates contents**

From the aforementioned results (Table 4), a significant increase in the contents of seedling' leaves of SCC, proline and polyphenols was observed under the influence of irrigation with salty water at 1750ppm compared to irrigation with non-salty water (control). Also, irrigation with a higher level of salinity (3500ppm) caused a significant increase in the proline content of seedling leaves compared to normal water in both cultivars. While, the changes in SCC and phenols contents of leaf were not significant.

Increasing the level of salinity from 1750ppm to 3500ppm led to a significant decrease in the SCC content of leaf, while it did not significantly affect the total phenols content.

Spraying seedlings with Nano-silicon did not affect the proline content of Gahrawy leaves under the three levels of salinity (control, 1750, 3500 ppm) compared to non-sprayed seedlings (Table 4). Whereas the use of Nano-silicon led to a significant decrease in the proline content in Sukkary leaves, and it did not significantly affect Gahrawy cultivar compared to the untreated seedlings under level of salinity irrigation at 1750 or 3500ppm. From the previous results, we concluded that the use of Nano-silicon was more efficient with the lower level of salinity (1750ppm) in both tested cultivars, where it caused a significant increase in the SCC and total phenols contents of the leaves.

The seedlings of the Sukkary cultivar showed the highest level of proline at the low level (1750ppm) of salinity, while the Gahrawy cultivar appeared the same level of proline at the highest level (3500ppm) of salinity (Table 4). This means that there was a difference in the resistance behavior of the two varieties to the effects of salinity.

Also, the Sukkary cultivar gave the highest levels of SCC (121mg/g) and total phenols (1.94µg/g) contents under the influence of the combination treatment between Nano-silicon and irrigation with 1750ppm salt water, and the differences were significant compared to all other results in the two cultivars.

Leaf mineral contents

Sodium, calcium and magnesium contents

The effects of irrigation treatments with salt water in three levels (control, 1750, 3500 ppm) and spray with Nano-silicon at 1g/l on sodium, calcium and magnesium contents in mango seedling leaves of Sukkary and Gahrawy cultivars were recorded in Table (5). The results showed that there was a significant increase in the calcium and magnesium content of leaves when irrigated with a lower level of salinity (1750ppm) compared to irrigation with normal water or a higher level of salinity (3500ppm).

Table 5. Effect of Nano silicon on sodium, calcium and magnesium contents in mango seedling leaves of 'Sukkary' and 'Gahrawy' cultivars under salinity stress as average of two seasons

Treatments		Sodium, Calcium and Magnesium contents in seedling leaves					
Salinity levels	Anti-stress	Sodium(mg/100g dw)		Calcium(g/100g dw)		Magnesium(mg/100g dw)	
		Sukkary	Gahrawy	Sukkary	Gahrawy	Sukkary	Gahrawy
Tap water	------	0.10e	0.16e	1.39d	1.93e	72.00c	64.00c
Tap water	**N-Si**	0.11e	0.15e	2.40a	2.30d	123.99b	154.00a
1750 ppm	------	0.28c	0.57c	1.50d	2.76c	132.00b	77.94b
1750 ppm	**N-Si**	0.19d	0.25d	2.10b	2.95b	169.00a	154.00a
3500 ppm	------	0.63a	0.66a	1.40d	2.36d	59.09c	39.99d
3500 ppm	**N-Si**	0.48b	0.59b	1.86c	3.99a	126.00b	31.99d

Means followed by the same letters are not significantly different at level $P \leq 0.05$ according to DMRT

Irrigation with salinity at a level of 3500ppm led to a significant decrease in the of calcium and magnesium content of leaves in the Gahrawy seedlings, while there was no significant changes in the Sukkary cultivar in both elements.

By gradually increasing the salinity level, the sodium content of the leaves increased in both tested cultivars. Treating the seedlings with Nano-silicon leads to a decrease in their sodium content and thus avoiding the harmful effects of salinity.

The application of Nano-silicon on Sukkary and Gahrawy seedlings irrigated with non-salty water led to a significant increase in the calcium and magnesium contents of leaves, while it had no effect on the sodium content of the leaves for both cultivars.

Using the combination treatment of Nano-silicon spraying with salinity irrigation at 1750ppm gave the highest content of magnesium in the leaves of the Sukkary seedlings (169 mg/100g dw) compared to the other tested treatments in the two cultivars under study, which gave values ranging between (32 to 154 mg/100g dw).

The results in Table (5) proved that, under irrigation with higher salty water at level of 3500ppm, the behavior of the two cultivars of Sukkary and Gahrawy differed in the leaf magnesium content. Where Sukkary cultivar had amounts of Mg (from 59.1 to 169mg/100g dw) considerably higher comparing to the corresponding values in Gahrawy cultivar (from 32 to 154mg/100g dw), and Sukkary also responded to improving the level of magnesium under the influence of spraying with Nano-silicon, while Gahrawy cultivar did not response.

Nitrogen, phosphorous and potassium contents

The data had shown in Table (6) represent the results of the effects of irrigation with three levels of salinity (control, 1750 and 3500ppm) and spraying with Nano-silicon at a 1 g/l, either alone or in combinations on the nitrogen, phosphorus and potassium contents of the leaves of Sukkary and Gahrawy mango seedlings. These results showed that irrigating the seedlings of both two cultivars with saline water at the low level of 1750ppm caused a significant increase in the leaf contents of nitrogen, phosphorus and potassium compared to irrigation with normal water (control) or salt water at a high level (3500ppm). On the other hand, the irrigation of Gahrawy seedlings with the same level of salinity (1750ppm) decreased the nitrogen and potassium contents of the leaves compared to irrigation with normal water (control). By increasing the salinity of irrigation water from 1750ppm to 3500ppm, the decrease in the leaf content of nitrogen, phosphorus and potassium increased in Sukkary cultivar.

In general, it was noticed that the nitrogen, phosphorus and potassium contents of seedlings' leaves in Sukkary seedlings were higher than those of Gahrawy seedlings, especially at the low level (1750 ppm) of salinity irrigation.

Table 6. Effect of Nano silicon on nitrogen, phosphor and potassium contents in mango seedling leaves of 'Sukkary' and 'Gahrawy' cultivars under salinity stress as average of two seasons

Treatments		Nitrogen, phosphorus and Potassium contents of Mango root-stocks					
Salinity	Anti-	Nitrogen(g/100g)		phosphorus(g/100g)		Potassium(g/100g)	
levels	stress	Sukkary	Gahrawy	Sukkary	Gahrawy	Sukkary	Gahrawy
Tap water	------	1.25c	1.13b	0.57c	0.52c	1.11d	1.45a
Tap water	N-Si	1.53a	1.30a	0.69b	0.68a	1.34c	1.44a
1750 ppm	------	1.36b	1.02c	0.74b	0.59b	1.43b	1.01b
1750 ppm	N-Si	1.56a	1.28a	0.84a	0.59b	1.73a	1.38a
3500 ppm	------	1.12d	0.97c	0.47d	0.50c	0.91e	1.07b
3500 ppm	N-Si	1.31bc	1.19b	0.71b	0.59b	1.18d	1.42a

Means followed by the same letters are not significantly different at level *P* ≤ 0.05 according to DMRT

Spraying mango seedlings with Nano-silicon resulted in a significant superiority in nitrogen, phosphorus and potassium content in the leaves under the influence of irrigation with the tested salinity levels (control, 1750, 3500ppm) in both cultivars compared to non-sprayed seedlings that received the same levels of salinity (Table 6). Such superiority was more pronounced with the Sukkary cultivar, under conditions of irrigation with saline water at 1750ppm.

DPPH radical scavenging activity

It should be noted that the low value of IC_{50} is offset by high antioxidant activity, and vice versa. Increasing the salinity level caused an increase of IC_{50}, especially in Gahrawy cultivar (Fig. 3). The highest values of IC_{50} appeared in Sukkary seedlings irrigated with saline water at level of 1750ppm (T_3), while it appeared in the seedlings of Gahrawy when irrigation with saline water level of 3500ppm (T_5). Most of IC_{50} values in Sukkary seedlings were higher than their counterparts in Gahrawy seedlings. The lowest values of IC_{50} were found in leaves of Gahrawy seedlings when sprayed with Nano-silicon under conditions of irrigation with saline water either at 1750ppm (T_4) or at 3500ppm (T_6).

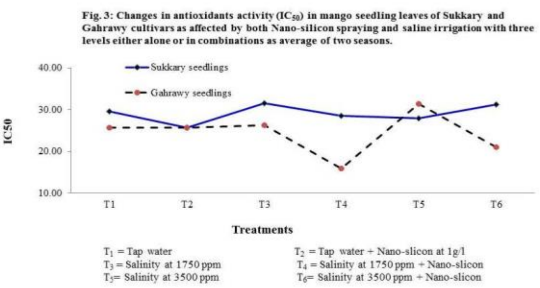

Fig. 3. Changes in antioxidants activity (IC50) in mango seedling leaves of Sukkary and Gahrawy cultivars as affected by both Nano-silicon spraying and saline irrigation with three levels either alone or in combinations as average of two seasons.

Salinity symptoms parameters

The data as an average of the two tested seasons recorded in Table (7) show the results of the percentages of injured leaves (IL %) and injured seedlings (IS %), the percentage of re-flushed seedlings for the growth cycle, leaf injure severity (LIS), and the salinity symptoms index (SSI) on mango seedlings of Sukkary and Gahrawy cultivars under the influence of salinity irrigation with three levels (control, 1750, 3500ppm) and Nano-silicon spraying at 1.0g/l alone or in combinations. The data showed that there were no injured leaves or seedlings under irrigating with normal water, while the percentage of injured leaves and seedlings increased in both cultivars by increasing the salinity levels of irrigation water from 1750ppm to 3500ppm.

Concerning IL%, it was 15.47 and 24.86 at the salinity level of 1750ppm, and 50.05 and 52.91 at the salinity level of 3500ppm for the two cultivars Sukkary and Gahrawy, respectively. Moreover regarding to IS%, it was 9.52% and 28.5% at the level of salinity 1750ppm and 90.5% and 95.2% at the level of salinity 3500ppm for the two cultivars Sukkary and Gahrawy, respectively.

Results in Table (7) cleared that LIS increased with the increase in salinity of irrigation water. Where, it's values were in Sukkary and Gahrawy cultivar, respectively 1.0 and 1.0 when irrigation with normal water, 2.3 and 3.3 when irrigation with a salinity level of 1750 ppm, and 4.6 and 5.7 when irrigation with a salinity level of 3500ppm. It is evident from the aforementioned results that IL % and IS % were much less in Sukkary cultivar compared to Gahrawy cultivar under the low salinity level of 1750ppm. The application of Nano-silicon spraying on Sukkary and Gahrawy mango seedlings had a positive effect by significantly reducing IL % and IS % in both cultivars under study, and the decrease was more evident with Gahrawy cultivar under the influence of salinity irrigation at the high level 3500ppm.

As for the percentage of re-flushed seedlings for the growth cycle, it is clear from the results presented in Table (7) that irrigation with a salinity level of 3500ppm showed the lowest percentages (9.5 and 4.8) compared to irrigation with normal water (71.4 and 81.0) or saline water at 1750ppm (66.7 and 61.9) for each of Sukkary and Gahrawy cultivars, respectively.

In Table (7), concerning SSI , it was observed that there are no significant differences between irrigation treatments with non-saline water (control) and irrigation at the low level salinity of 1750 ppm. Also, the highest values of SSI were 2.10 and 2.77, which appeared when irrigation with saline water at the level of 3500ppm and decreased to 1.39 and 0.89 when spraying seedlings with Nano-silicon at a concentration of 1g/l under the same irrigation of saline water for each of Sukkary and Gahrawy cultivars, respectively.

Table 7. Effect of Nano silicon on salinity symptoms parameters in mango seedlings of 'Sukkary' and 'Gahrawy' cultivars under salinity stress as average of two seasons

Treatments		**Salinity symptoms parameters**									
Salinity levels	**Anti-stress**	**Injured leaves (IL) %**		**Injured seedlings (IS) %**		**Re-flushed seedlings %**		**Leaf injure severity (LIS)**		**Salinity symptoms index (SSI)**	
		Sukkary	**Gahrawy**	**Sukkary**	**Gahrawy**	**Sukkary**	**Gahrawy**	**Sukkary**	**Gahrawy**	**Sukkary**	**Gahrawy**
Tap water	------	0.00d	0.00d	0.00b	0.00e	71.4b	81.0b	1.0c	1.0d	0.00c	0.00c
Tap water	N-Si	0.00d	0.00d	0.00b	0.00e	95.2a	95.2a	1.0c	1.0d	0.00c	0.00c
1750 ppm	------	15.7c	24.9c	09.5b	28.6c	66.7b	61.9c	2.3b	3.3c	0.04c	0.22c
1750 ppm	N-Si	05.7d	19.1c	09.5b	14.3d	81.0ab	81. b	1.6bc	2.7c	0.01c	0.07c
3500 ppm	------	50.0 a	52.9a	90.5a	95.2a	09.5c	04.8e	4.6a	5.7a	2.10a	2.77a
3500 ppm	N-Si	40.0b	39.0b	81.0a	52.4b	14.3c	28.6d	4.3a	4.3b	1.39b	0.89b

Means followed by the same letters are not significantly different at level $P \leq 0.05$ according to DMRT

Discussion

Salinity stress is a critical factor that effect on plant growth. Although there are a lot of references considering interaction between salinity and silicon (Si) in higher plants, there is currently few information available about the possible useful effects of Nano-silicon application to minimize salt stress injuries in mango seedlings. In our study, vegetative parameters have been measured to evaluate effects of salinity stress on seedlings of both 'Sukkary' and 'Gahrawy' mango rootstock (Table 1). In both rootstocks, PSHI decreased with the high salinity (3500ppm), while SSDI reduced gradually with raising salinity concentration from 0 to 3500ppm. Similar results were recognized by Khayyat *et al*., (2014) on pomegranate plants, Rashedy & Abd-Allatif (2017) and Doaa & Shalan (2020) on mango. They indicated that plant height, number of leaves, and stem diameter of plants decreased significantly with increasing salinity. However, PSHI of Gahrawy was enhanced by saline water irrigation at 1750ppm. This was in a good agreement with Rahneshan *et al*., (2018) on pistachio. In the present study, application of Nano silicon enhanced significantly NLA under salinity stress. In addition, there was no variation between sprayed and non-sprayed seedlings by Nano silicon on SSDI. These findings confirmed those of Li *et al*., (2015) on tomato. Moreover, applying Nano-silicon on mango seedlings improved the NLA in two tested cultivars especially with Gahrawy. Similar results were approved by Abou-Baker *et al*., (2012) and Abdul-Qados & Moftah (2015) on bean reported that plants height increased by application of silicon. Such result was strengthened by Coskun *et al*., (2016) who reported that Si has beneficial effects in enhancing the tolerance of plants to biotic and abiotic stresses. Our results regarding percentage of (PSHI) indicated that with an increase in the level of salinity up to 3500ppm, the PSHI decreased in the Sukkary cultivar, while a reverse trend with Gahrawy cultivar was fact. The reduction in plant growth may be attributed to the decrease in mineral uptake, inhibition of photosynthesis and inhibition of cell expansion (Rashedy & Abd-Allatif (2017). Application of silicon improved all plant growth under saline conditions by balancing the decrease of stomatal conductance and potassium. Silicon maintain water status which help in cell expansion and thus caused increment in leaf area and the height of plants which were sprayed with silicon compared to non-spraying (Ali *et al*., 2012). Our results indicated that the content of total chlorophyll gradually decreased significantly with increasing salinity levels in Sukkary and Gahrawy seedlings (Table 2). This trend was in accordance with those were stated in several mango cultivars by Gora *et al*., (2018) and Doaa & Shalan (2020), and in carob seedlings (El-Dengawy *et al*., 2011). Carotene content in Sukkary cultivar unchanged but in Gahrawy cultivar increased under salinity levels compared to the control treatment. Such result was in harmony with those of Ashraf & Harris, (2013) and Rahneshan *et al*., (2018) on pistachio. They suggested that salt tolerant plants have increased or unchanged chlorophyll levels under salinity conditions whereas chlorophyll contents decreased in salt-sensitive plants.

At the high salinity level, salts may build up in the apoplast and dehydrate the cell and inhibit enzymes in cytoplasm or they may exert a direct toxic effect in chloroplast and photosynthetic processes (Munns & Tester, 2008). Also, salinity stress increase of toxic ions (Na^+) in leaf and thus increase ROS and caused oxidative stress and damage chloroplast (Abou-shlell *et al*., 2020). Treating seedlings with Nano-silicon improved the leaf studied pigments content (total chlorophylls and carotene) in seedlings of the two tested mango cultivars under different levels of salinity. These results were in agreement with those of Soylemezoglu *et al*., (2009) on grapevine, and Siddiqui *et al*., (2014) on pepo plants. Si alleviates salt stress with maintenance of cell form through improving permeability of plasma membranes due to the increase of anti-oxidative enzymes SOD and CAT (Al-Aghabary *et al*., 2004) and improvement of plant water status (Haghighi & Pessarakli, 2013).

There are very few studies available on root growth and development and the mechanics of their salt tolerance compared to those of vegetative growth due to limited availability for root observations. In the current result (Table 3), high salinity concentration decreased NLR and NSR in both tested mango root-stocks. This result is in accordance with those of Li *et al*., (2015) and Ozer *et al*., (2019) on tomato who concluded that the root growth reduced by raising salt level which may has a toxic effect on root development. Mostly, root growth is inhibited under salinity due to both osmotic and toxic effects (Franco *et al*., 2011). Osmotic stress caused by low water potential in the growing medium; and ionic stress by the excess amount of specific ion concentration in the root environment.

In this study two opposite trends were observed with root system growth coefficient (RSGC) in Sukkary and Gahrawy where low salinity level considerably enhanced RSGC of Sukkary cultivar and decreased it with Gahrawy. A similar tendency was obtained with Karni *et al*., 2010 who indicated that applying NaCl on tomato plants caused a shorter root with more branched root system and the seedlings had a high root system. The roots play a key role in the salt tolerance of plants as they represent the first organs that control the uptake and translocation of nutrients and salts throughout the plant. In spite of the direct exposure of these organs to saline environment, their growth is less vulnerable to salt than that of the shoots (Munns, 2002). However spraying Nano-silicon on mango seedling increased significantly the NLR and NSR in Sukkary cultivar and on the other side decreased them in Gahrawy cultivar. These current findings confirmed those of Haghighi & Pessarakli (2013) who indicated that root volume decreased with Si application, but the interaction effect showed that adding Si to saline medium improved the root volume. They added that Si was more effective than N-Si especially in low concentrations.

In the present study (Table 4), the seedlings of the Sukkary cultivar exhibited the highest level of proline at the low level (1750ppm) of salinity, while the Gahrawy cultivar appeared the same level of proline at the highest level (3500ppm) of salinity. This means that there was a difference in the resistance behavior of the two varieties to the effects of salinity. This result was in line with many researchers who reported that high salinity levels increased proline content in leaf of mango plant (Omaima *et al*., 2011 & Pandey *et al*., 2014). Proline accumulation could be a protective response, because of the osmoregulation role of proline that prevents water deficit stress under high salinity, and also because of its capability to scavenge the active radicals, produced at salt stress conditions.

Whereas the use of Nano-silicon led to a significant decrease in the proline content in the Sukkary leaves, and it did not significantly affect the Gahrawy cultivar compared to the untreated seedlings under salinity irrigation at concentrations of 1750 and 3500ppm. Our results were in accordance with those of Soylemezoglu *et al*., (2009) in grapevine and Yin *et al*., (2014) in sorghum. They concluded that a lower level of proline in salt-stressed plants following the addition of Si indicates the alleviation of stress damage.

A significant increase in the mango leaf contents of SCC and polyphenols was observed under the effect of salinity irrigation at 1750ppm compared to irrigation with normal water (control). Also, increasing the level of salinity from 1750ppm to 3500ppm led to a significant decrease in the SCC of leaf, while it did not significantly affect the polyphenols content. The present results are in line with Chelli-Chaabouni *et al*., (2010) who reported that under salinity stress plants accumulate compatible solutes such as soluble sugars which are known for their osmo-protection activity. On the contrary, Salt excess resulted in a significant decline of carbohydrate concentration of leaves and/or roots (Khayyat *et al*., 2014).

From our results, we concluded that the use of Nano-silicon was more efficient with the lower level of salinity (1750ppm) in both tested cultivars, where it caused a significant increase in the SCC and polyphenols contents in the leaves of seedlings. Such findings confirmed that Si and Nano- silicon application mitigate the adverse of salinity and increased polyphenol and SCC (Abdel-Haleim *et al*., 2017 & Abou-shlell *et al*., 2020). Phenolic compounds defend plants against a number of biotic and abiotic stresses. Oxidation of phenols produces many defensive compounds that alter the plant physiology and metabolism, which in turn enable it to withstand various stresses either directly or by mediating different plant signaling pathways. ROS such as superoxide anion, hydroxide radicals, H_2O_2, and singlet oxygen produced by oxidation of phenols activate plant defense enzymes (Anaya *et al*., 2017 and El-Shazoly, 2019). Si improves ROS scavenging antioxidant system, which minimizes ROS generation and consequently inhibits lipid peroxidation Karuppanapandian *et al*., (2011).

Raising salinity level caused progressively an increase in sodium concentration of mango leaf in Sukkary and Gahrawy cultivars (Table 5). This result was in accordance with El-Dengawy *et al*., (2011) on carob seedlings, Hafez *et al*., *(*2011) and Abd-Allattif *et al*., (2015) on many mango cultivars. They found that the saline irrigated seedlings contained significantly higher Na concentrations in the leaf than that of the control (normal irrigation) and the Na concentrations were increased significantly in the leaf by increasing salinity level. Overcoming salt stress effects in mango cultivar is associated with effective mechanisms of Toxic ion exclusion (Na^{+}). It is known through ion toxicity, that the accumulation of Na^{+} in the tissues inhibits biochemical process related to photosynthesis. On the other hand, we found that application of Nano silicon reduced significantly sodium content in the leaf, as it was mentioned by Li *et al*., (2015) and Al-Aghabary *et al*., (2004). The explanation is that Nano-silicon protects plants against high uptake of Na^{+} and Cl^{-} via stabled transpiration in constant level even in high level of salinity (Liang, 1999 & Yeo *et al*., 1999). Also, Si maintains cells hydration within the decreasing of transpiration rate rang under stresses (Haghighi & Pessarakli, 2013).

Calcium (Ca) is well known to have regulatory roles in metabolism (Cramer *et al*., 1985) and sodium ions may compete with calcium ions for membrane binding sites. High Ca levels can protect the cell membrane from the adverse effects of salinity. The nature of these responses will vary depending on the plant genotype (Hadi & Karimi, 2012). Magnesium (Mg) is essential atoms of the chlorophyll molecule and has a fundamental influence on the size, structure and function of chloroplast. In this study, low salinity concentration of 1750ppm encouraged significantly accumulation of Ca and Mg contents in leaf of both cultivars (Table 5), while in the high salty water 3500ppm Ca and Mg declined in Gahrawy cultivar and it was not effect in Sukkary cultivar. Similar findings were obtained by EL Sayed *et al*., (2017) and Doaa & shalan (2020). They mentioned that Ca^{+2} and Mg^{+2} decreased with increasing salinity levels. Nano-silicon improved leaf content of calcium and magnesium under the influence of irrigating with normal water in Sukkary and Gahrawy, and it reduced the harmful effects of salinity and significantly increased the two components in Sukkary cultivar only with high salty water. Such result in accordance with that of Li *et al*., (2015) who reported that application of silicon increased the Ca and Mg concentrations in the leaves of tomato.

In the present study (Table 6), low salty water irrigation at 1750ppm enhanced leaf N, P and K contents of Sukkary cultivar and leaf phosphorus content of Gahrawy seedlings. However, High salty water irrigation decreased leaf nitrogen, phosphorus and potassium content of both tested cultivars. In line with our results, a negative effect of salinity on K concentration has been found in mango (Doaa & shalan, 2020). Application Nano- silicon enhanced significantly Nitrogen (N), Phosphorus (P) and Potassium (K) in both cultivars under tested salinity levels. Such result agreed with those of Bukhari *et al*., (2015) in wheat and Tantawy *et al*., (2015) in sweet pepper. Potassium (K^{+}) is the major cation in plants balances the negative charge of anions and play a crucial role in the activation of enzymes in metabolism and synthesis of proteins and carbohydrates and regulation of stomata movement (Rahneshan *et al*., 2018 & Nabati *et al*., 2013). Accordingly, we observed an accumulation of Na accompanied by a decrease in K in the leaf.

In our results, under non salty water irrigation, there weren't any injury symptoms on leaves but with increasing salinity levels of irrigation water from 1750ppm to 3500ppm, the percentage of injured leaves and injured seedlings increased in both cultivars (Table 7). This is in accordance with Roy *et al*., (2015), Rashedy & Abd Allatif (2017) and Deivasigani *et al*., (2018), they reported that survival percentage of seedlings decreased with raising salinity level. With olive seedlings, Kchaou *et al*., (2010) reported that leaf drop started from 60 days after applying high salty water and this phenomenon differed among olive cultivars. The leaf injury could be due to the accumulation of toxic levels of Cl^{-} and Na^{+}, ion imbalance, nutrient deficiencies and water stress. Munns (2002) reported that, ionic stress results in premature senescence of older leaves and toxicity symptoms (chlorosis, necrosis) in mature leaves.

Increasing the salinity level caused an increase of IC_{50}, especially in Gahrawy cultivar (Fig. 3), which means a decrease in the antioxidants activity by increasing the level of salinity. This may be due to more consumption of antioxidant compounds. An opposite behaviors were observed in the two tested cultivars, where increasing the salinity level from 1750ppm to 3500ppm resulted in raising IC_{50} in Gahrawy seedling leaves consequently, the antioxidants activity decreased, but in Sukkary seedlings, IC_{50} decreased and thus antioxidants activity raised. Application of Nano-silicon at a concentration of 1.0 g/L as a spray on the saline-irrigated mango seedlings (from Mediterranean Sea) at a level of 1750 ppm led to IC_{50} reduction, which means enhancing antioxidants activity. The role of antioxidants in mango seedlings is to remove the free radicals (active forms) through donating hydrogen causing their reduction to unreactive forms (Wang *et al*., 2008).

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تأثير معاملة النانوسيليكون على سلوك نمو أصلين مانجو "سكرى وجحراوى" تحت إجهاد الملوحة

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أجريت التجربة في موسمين متتاليين على شتلات أصول مانجو صنفى سكرى وجحراوى وكان الهدف من البحث هو معرفة مدى فاعلية تطبيق النانو سيليكون لتقليل التأثيرات السلبية لمياه الري المالحة على النمو و والخصائص البيوكيميائية والفسيولوجية لأصول المانجو تحت الدراسة وكذلك تحديد مدى ملوحة مياه الري التي يمكن أن تتحملها هذه الأصول. وقد تمت دراسة تأثير ستة معاملات على سلوك شتلات الأصلين كما يلي: الري بمياه الصنبور (كنترول)، ورش ورقى بالنانوسيليكون بتركيز 1جم/لتر، وري بمياه البحر بتركيز 1750 جزء في المليون، وري بمياه البحر بتركيز 1750 جزء في المليون مع رش ورقى بالنانوسيليكون ، وري بمياه البحر بتركيز 3500 جزء في المليون ، و ري بمياه البحر بتركيز 3500 جزء في المليون مع رش ورقى بالنانوسيليكون.وقد تم الرش الورقى 4 مرات عند بداية التجربة وعلى فترات كل 45 يوم. وبعد سنة من بداية التجربة تم 1- قياس الصفات الخضرية المتمثلة فى النسبة المئوية لزيادة ارتفاع الشتلة وزيادة سمك الشتلة والمساحة الورقية وطول وعرض ومعامل نمو المجموع الجذرى وأيضا عدد الجذور الجانبية والثانوية و 2- المكونات البيوكيميائية فى الأوراق (الكلوروفيل الكلى والكاروتين– الفينولات الكلية – البرولين - الكربوهيدرات القابل للذوبان) و3- محتويات الأوراق من العناصر N(فوسفور، بوتاسيوم، نيتروجين، صوديوم، ماغنسيوم، كالسيوم) و4- مضادات الأكسدة غير الأنزيمية، بالإضافة إلى مؤشرات أعراض الملوحة. وكانت أبرز النتائج كما يلي: لوحظ انخفاض في معظم المتغيرات باستثناء محتوى الصوديوم والبرولين وازدادت مؤشرات أعراض الملوحة نتيجة زيادة مستويات ملوحة ماء الرى. كما وجدت تأثيرات إيجابية تضمنت تحسينا في الصبغات الورقية ، والكربوهيدرات القابلة للذوبان ، ومحتوى الفينولات الكلية ، والمغنيسيوم ، والنيتروجين ، والفوسفور ، والبوتاسيوم ، وتقليل مؤشرات أعراض الملوحة نتيجة الري بالمياه المالحة بتركيز 1750 جزء في المليون مع رش الشتلات بالنانوسيليكون (1 جم/لتر). كانت هذه النتائج الإيجابية أكثر وضوحا مع صنف سكري مقارنة بالصنف الجحراوى. وأكدت النتائج أن تأثير النانوسيليكون في سلوك الشتلات يختلف باختلاف الصنف.