Effect of Saline Water Irrigation on Sour Orange and Volkamer Lemon Seedling Rootstocks

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Abstract: This study was carried out during the two consecutive seasons of 2012 and 2013 in shade house for Plant Production Dept. Fac. Environ. Agri. Sci. Suez Canal Univ. Egypt. Two citrus six-month-old uniform seedling citrus rootstocks namely: Sour orange and Volkamer lemon transferred into black plastic tube PVC (15 cm diameter x 40 cm depth) filled with 2kg growth media mixture of sand soil and peat moss (4:1 by volume) and irrigated using the tap water at 14 days before run treatments. These seedlings were subjected to three different irrigation saline water levels (tap water 700 "control", 2000, and 3000 ppm) to determine the effects of water salt level on growth parameters, chemical compositions, leaf total pigments and proline. The results obtained showed that Volkamer lemon seedlings had the greatest leaf and root biomass, photosynthetic pigments, proline, leaf k content and area of root vascular bundle and had the lowest values leaf N, Cl and Na content, thickness of root cortex, thickness of mesophyll tissue and leaf blade, while Sour orange seedlings were on the contrary. On the other hand, irrigation with the saline water caused decrease the all vegetative growth parameters, plant photosynthetic pigments and area of root vascular cylinder, while increased the leaf N, Cl and Na content, leaf proline concentration and thickness of root cortex, thickness of mesophyll tissue and leaf blade. Finally, vegetative growth parameters, leaf mineral and leaf total pigments analysis and anatomy features for root and leaf blade indicated that Volkamer lemon rootstock is more tolerant to salinity of irrigation water.

***Keywords*:** Sour orange, Volkamer lemon, proline, salinity stress, saline water.

INTRODUCTION

Citrus are among the most widespread fruit crops throughout the world, being their global production around 122 million of tonnes per year (FAO, 2012), of which Egypt produces 4 million tonnes with rate 3.27 % of the total global production from 518.7 thousand feddans according to Yearly of Statistic and Agricultural Economic Dept., (2012). Citrus is produced in arid and semiarid climates (Ruiz, 1997 and Ferguson and Grattan, 2005), therefore can be cultivate in new reclamation area but limited water resources in this regions and water salinity is a major problem due to its negative influence on the yields and growth of many crops especially citrus plant (Chapman, 1968a; Al-Yassin, 2005 and Ferguson and Grattan, 2005). Citrus trees have been classified as a salt-sensitive crop (Maas, 1993 and Storey and Walker, 1999). Saline irrigation water reduces citrus tree growth and fruit yield (Garcia-Sanchez *et al.,* 2006 and Grieve *et al.,* 2007). In this respect, the high salinity levels increase proline content in leaves of citrus rootstocks and it was concluded that these osmolytes play a key role in generating tolerance against salt stress (Arbona *et al.,* 2003 and Balal *et al.,* 2011). Salinity affects citrus in three ways (Levy and Syvertsen, 2003 and Al-Yassin, 2005): (i) osmotic stress; occurs when the concentration of salts in the soil water are high enough to reduce crop growth (Lauchli and Epstein, 1990), (ii) toxic ion stress, such as Na^+ and Cl^- (Grattan and Grieve, 1999), where chloride toxicity manifests as slight leaf bronzing and leaf tip yellowing followed by tip burn and necrosis (Maas and Grattan, 1999), while sodium toxicity starts as a marginal yellowing followed by a progressive necrosis beginning at the leaf margin (Bernstein, 1965), (iii) nutritional imbalance caused by these ion-toxicity effects; in citrus, nutritional imbalance has been also attributed to depressed absorption of some nutrients. A decrease in the concentration of calcium, magnesium, and sometimes potassium was found when salt concentration in the irrigation water was increased (Zekri and Parsons, 1992). On this line, three mechanisms of salt tolerance in citrus: chloride exclusion, water saving and accumulation of soluble solids (Garcia-Sanchez *et al.,* 2002). Though, the ability of citrus trees to tolerate salinity varies among species and depends on the rootstocks (Maas, 1993 and Storey and Walker, 1999). Citrus tolerance to salinity can be correlated with its ability to restrict the entry of ions into the shoots (Greenway and Munns, 1980). Exclusion of certain ions has been demonstrated in some citrus rootstocks. Rangpur lime (*C.limonia*) and Cleopatra mandarin (*C. reshnii*) appear to be Cl^- excluders (Walker *et al.,* 1983 and Zekri and Parsons, 1992). Trifoliate orange (*Poncirus trifoliata*) and its hybrids appear to be Na excluders (Grieve and Walker, 1983 and Zekri and Parsons, 1992). With addition to, Cleopatra mandarin which is one of the best Cl^- excluding rootstocks, was recognized as a salt-tolerant rootstock even though it was never selected intentionally because of its salt tolerance, but rather as an ornamental (Chapman, 1968b).

MATERIALS AND METHODS

The experiment was conducted in two consecutive seasons of 2012 and 2013 during the late summer from end August until beginning May in shade house for Plant Production Dept. Fac. Environ. Agric. Sci., Suez Canal Univ., Egypt. The main objective of this study was to evaluate salinity tolerance for two citrus seedling rootstocks namely: Sour orange (*Citrus aurantium* L.) and Volkamer lemon (*C. volkameriana* Ten. & Pasq.). These seedlings transferred to black plastic tube (15 cm diameter x 40 cm depth) each containing two kg of growth media mixture of sand soil and peat moss (4:1 by volume) and irrigated using the tap water at 14 days before run treatments. Then irrigation with three saline levels (tap water 700 "control" – 2000 and 3000 ppm). Saline water treatments (2000 ppm and 3000 ppm) preparing with using water 5000 ppm from underground water well at the Faculty Environmental Agri. Sci., El-Arish, North Sinai Governorate, Egypt, and mixed it with different rate of tap water. The chemical analysis properties of saline water treatments and tap water as shown in table 1.

Table (1): Chemical analysis of underground water well and saline water treatments:

Water treatments	EC ($dS.m^{-1}$)	Cations ($meq.l^{-1}$)				Anions ($meq.l^{-1}$)				S.A.R
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{-}	
W_0	7.70	6.00	6.00	63.00	0.60	-	5.4	60.6	9.6	25.72
W_1	1.10	5.40	1.60	3.28	0.42	-	4.0	3.0	3.7	1.754
W_2	3.20	6.60	5.50	19.67	0.21	-	4.5	20.0	7.2	7.999
W_3	4.60	10.80	6.00	29.20	0.29	-	2.5	33.0	10.8	10.07

- Soils, Water & Environment Res. Ins., Agri. Res. Center, Ismailia, Egypt.
- W_0= underground water well, W_1= tap water treatment "control", W_2= irrigation treat.2000 ppm, W_3= irrigation treat.3000 ppm.

Growth measurements:

Fresh weight of leaf and root was recorded by weighing on electrical balance. They were placed in an oven at 70ºC until constant dry weight then recorded.

Chemical analysis:

Nitrogen content (%): determined by Neslar method as described by (Bremner and Mulvaney, 1982).

Total chloride content (%): determined in leaf tissue by $AgNO_3$ titration (Chapman and Pratt, 1961)

Potassium (%) and Sodium content (%): estimated in the original digestion solution using an atomic absorption spectrophotometer [Type: perklin-Elmer Model 2380].

Biochemical analysis:

Total pigments: Chlorophyll a & b and carotenoids contents were estimated according to the method described by Arnon, (1949). Fresh leaves extracted with 85 % acetone and absorbance of the supernatant was measured at 662, 644 and 440.5 nm, using Spectrophotometer (Model 6300 Jenway Co.). Concentration of total pigments as mg g^{-1} F.W was calculated.

Proline: The proline in citrus rootstocks was estimated according to the method used by Bates *et al.,* (1973). A homogenized fresh leaf tissue (0.5 g) was added in 10 mL of 3% sulfo-salicylic acid. Homogenates of citrus rootstock fresh leaf samples were filtered through Whatman No. 2 filter paper. Two mL of the filterate was taken in a test tube containing 2 mL of acid ninhydrin solution (1.25 g ninhydrin in 30 mL glacial acetic acid and 20 mL of 6 *M* orthophosphoric acid). Then, 2 mL of glacial acetic acid was added in a test tube containing filtrate and heated for 1 h at 100ºC. The reaction was arrested in an iced bath and the cromophore was extracted with 4 ml toluene and its absorbance at wave length 520 nm was determined in spectrophotometer while toluene was used as a blank. Proline concentration was determined from a standard curve and calculated on fresh weight basis.

Anatomical structure:

Anatomical studies were done to shed light on the changes in the structure of leaves and roots. In the second season, samples from leaves and roots (3 mm in diameter) were taken when the experiment was ended. Thereafter, all samples were cleaned from dust, then cut into suitable parts and immediately killed and fixed in F.A.A. solution (Formalin - acetic acid - alcohol 70%) 5:5:90V/V. For dehydration, the samples were dipped in graded series of ethanol up to absolute concentration, followed by series of mixture of xylene and absolute ethanol up to pure xylene. Infiltration and embedding were followed by paraffin wax of 56-58 ^{o}C melting point. Cross sections of 12 microns in thickness were made at the middle portion of the sample using a rotary microtome then double stained with safranin and light green, cleared in xylene combination was followed as described by (Johansen, 1940). The cross sections were mounted in canada balsam, air dried, examined and microscopically photographed. Section areas were calculated and statistically analyzed.

Statistical analysis:

Data were statistically analyzed with a complete randomized design (CRD) by using Co-STAT software, V.6.13 (CoHort software, Berkeley, CA 94701) on 6 treatments (2 citrus species x 3 saline irrigation water) and three replicates. Mean values of treatments were differentiated by using least significant range (Duncan's multiple range tests) at 0.01% level probability (Duncan, 1955)

RESULTS

Results in (table 2&3) and (fig. 1-b) indicate that irrigation with saline water significantly decrease fresh and dry weight of leaf and root, chlorophyll a (mg g^{-1} f.w), chlorophyll b (mg g^{-1} f.w), carotenoids (mg g^{-1} f.w) and leaf K (ppm) content as compared with control of all tested rootstock seedlings whereas in most cases, the higher level of salinity (3000 ppm) is more effective than the lower level (2000 ppm) in both seasons. The data did not show a specific trend for concentration proline (g $100g^{-1}$ w.) in leaves. In most cases the lower level of salinity (2000 ppm) is more effective than the higher level (3000 ppm).

While, a gradually increase in leaf N (ppm), Cl (%) and Na (%) content as affected by salinity stress showed fig (1-a and 2-a &b). In this respect, the high value of concentration leaf N (ppm), Cl (%) and Na (%) 1.558, 2.276 and 0.399 came from irrigation with level of salinity (3000 ppm) and tap water took an opposite trend which had 1.317, 1.386 and 0.144 averages respectively.

Concerning citrus species rootstocks, Volkamer lemon exhibited the highest fresh and dry weight of leaf and root, chlorophyll a (mg g^{-1} f.w), carotenoids (mg g^{-1} f.w), proline (g $100g^{-1}$ w.), leaf K (ppm) content as compared with the Sour orange. Non-significant difference showed between Volkamer lemon and Sour orange in respect to chlorophyll b (mg g^{-1} f.w). Sour orange came in the first rank and Volkamer lemon in the second one for N (ppm), Cl (%) and Na (%) content.

The interaction between citrus species rootstocks and irrigation saline water was significant in the two considered seasons (table 2&3). The highest leaf fresh weight, root fresh and dry weight, total pigments and leaf K content came from Volkamer lemon irrigated by tap water (control). While, the least values was record by Sour orange irrigated by saline water at 3000 ppm**.** But, the highest leaf dry weight came from Volkamer lemon irrigated by tap water (control) or/and irrigated by saline water at 2000 ppm. While, the least values was record by Sour orange irrigated by saline water at 3000 ppm.

In the two seasons the highest proline (g $100g^{-1}$ d.w) in leaves came by Volkamer lemon irrigated by saline water at 2000 ppm, while the lowest value record by Sour orange irrigated by tap water (control).

The highest concentration of N, Cl and Na in leaves came from Sour orange irrigated by saline water at 3000 ppm (1.514, 2.258 and 0.645), but Volkamer lemon irrigated by tap water (control) gave the lowest value which had 1.363, 1.328 and 0.130 averages during 2012 1nd 2013 seasons, respectively (fig. 1-a and 2-a&b).

Table (4) and plates 1, 2, 3 and 4 (a, b and c) show the effect of saline irrigation water on the anatomical structure of root of the two studies citrus species namely: Sour orange and Volkamer. Data show that the specific effect of citrus rootstock species indicated that Sour orange the largest thickness of cortex, mesophyll tissue and leaf blade but, it's gave the lowest area of root vascular cylinder. While, Volkamer lemon species was took an opposite trend in 2013 seasons. On the other contrary, no significant differences in thickness of upper and lower epidermal between them.

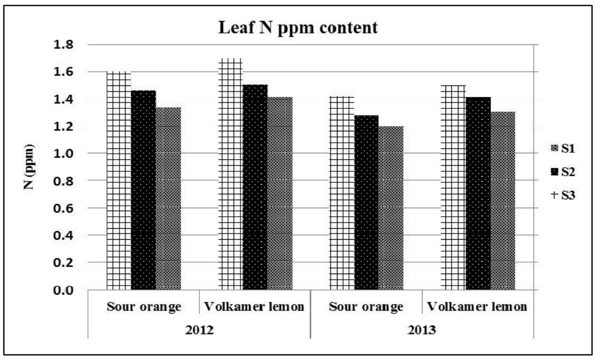

Fig. (1-a)

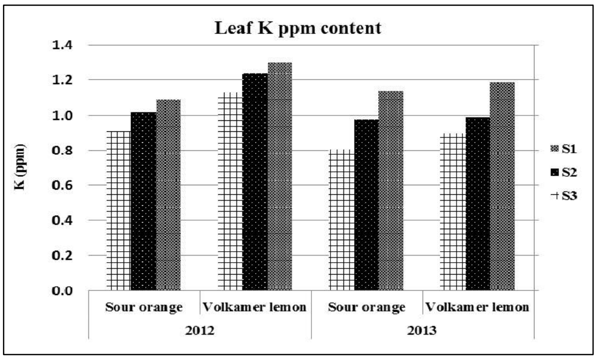

Fig. (1-b)

* S_1, S_2 and S_3 refer to irrigation water salinity at 700, 2000, 3000 ppm respectively.

Fig (1): Effect of saline irrigation water on leaf N and K content in citrus species rootstocks.

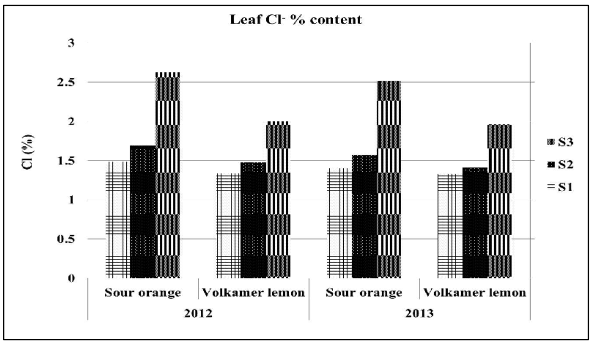

Fig. (2-a)

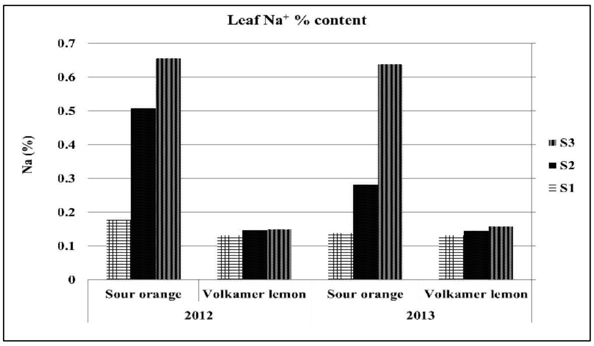

Fig. (2-b)

* S_1, S_2 and S_3 refer to irrigation water salinity at 700, 2000, 3000 ppm respectively.

Fig (2): Effect of saline irrigation water on leaf Cl and Na content in citrus species rootstocks.

Regarding to irrigation with saline water data indicate that thickness of cortex, mesophyll tissue and thickness of leaf blade significantly increases by increased salinity levels. The greatest values came from high saline irrigation water 3000 ppm compared with tap water (control). But, irrigation with high saline water 3000 ppm decrease area of root vascular cylinder compared with tap water (control). But, irrigation with saline water especially saline water 3000 ppm decrease thickness of upper and lower epidermal.

The interaction effect between varietal differences of citrus rootstock and irrigation saline water treatments of root and leaf anatomy features indicated that Volkamer lemon species irrigation by tap water (control) gave the highest area of root vascular cylinder, thickness of upper and lower epidermal. While, Sour orange species irrigated by saline water at 3000 ppm gave the highest thickness of cortex, mesophyll tissue and thickness of leaf blade.

Table (2): Effect of saline irrigation water on fresh and dry weight of leaf (g) and root (g) in citrus species rootstocks under during 2012 and 2013 seasons:

Treatments	Leaf fresh weight (g)			Root fresh weight (g)			Leaf dry weight (g)			Root dry weight (g)		
	Sour	**Volka**	**Overall mean**	**Sour**	**Volka**	**Overall mean**	**Sour**	**Volka**	**Overall mean**	**Sour**	**Volka**	**Overall mean**
2012 Season												
Tap water Control	22.68 b	23.69 a	23.18 A	12.99 ab	13.51 a	13.25 A	10.89 b	11.57 a	11.23 A	8.68 c	11.02 a	9.85 A
Saline water 2000 ppm	20.66 c	22.59 b	21.63 B	11.92 b	12.88 ab	12.40 A	9.99 c	10.76 b	10.38 B	7.90 d	10.14 b	9.02 B
Saline water 3000 ppm	16.97 d	20.73 c	18.85 C	9.98 c	11.89 b	10.93 B	9.00 e	9.67 d	9.33 C	6.67 e	7.70 d	7.19 C
Overall mean	20.10 *b*	22.33 *a*		11.63 *b*	12.76 *a*		9.96 *b*	10.67 *a*		7.75 *b*	9.62 *a*	
2013 Season												
Tap water Control	18.47 b	19.51 a	18.99 A	10.89 ab	11.29 a	11.09 A	8.90 b	9.31 a	9.10 A	5.41 c	6.22 a	5.82 A
Saline water 2000 ppm	16.30 d	18.03 c	17.17 B	9.85 ab	10.65 ab	10.25 A	8.23 c	8.71 b	8.47 B	4.85 e	6.00 b	5.43 B
Saline water 3000 ppm	12.95 f	15.42 e	14.18 C	8.09 c	9.38 bc	8.74 B	6.75 e	7.52 d	7.14 C	4.17 f	5.33 d	4.75 C
Overall mean	15.91 *b*	17.65 *a*		9.61 *b*	10.44 *a*		7.96 *b*	8.51 *a*		4.81 *b*	5.85 *a*	

*** Sour= Sour orange rootstock & Volka= Volkamer lemon rootstock**

Table (3): Effect of saline irrigation water on leaf pigments and proline in citrus species rootstocks during 2012 and 2013 seasons:

Treatments	Chlorophyll A (mg g^{-1} f.w)			Chlorophyll B (mg g^{-1} f.w)			Carotenoids (mg g^{-1} f.w)			Proline (g 100g^{-1} w)		
	Sour	**Volka**	**Overall mean**	**Sour**	**Volka**	**Overall mean**	**Sour**	**Volka**	**Overall mean**	**Sour**	**Volka**	**Overall mean**
2012 Season												
Tap water Control	3.343 b	3.450 a	3.397 A	2.630 a	2.684 a	2.657 A	1.779 b	1.913 a	1.846 A	0.134 e	0.140 d	0.137 C
Saline water 2000 ppm	2.755 d	2.889 c	2.822 B	2.400 b	2.582 a	2.491 B	1.665 c	1.705bc	1.685 B	0.301 b	0.312 a	0.306 A
Saline water 3000 ppm	2.071 f	2.278 e	2.175 C	1.903 c	2.356 b	2.130 C	1.496 d	1.331 e	1.414 C	0.287 c	0.301 b	0.294 B
Overall mean	2.723 *b*	2.872 *a*		2.311 *b*	2.541 *a*		1.647 *a*	1.650 *a*		0.240 *b*	0.251 *a*	
2013 Season												
Tap water Control	2.765 b	2.958 a	2.861 A	2.122 b	2.261 a	2.192 A	1.188 b	1.299 a	1.244 A	0.122 f	0.127 e	0.125 C
Saline water 2000 ppm	2.553 d	2.760 b	2.656 B	2.019 c	1.979 c	1.999 B	1.083 c	1.184 b	1.134 B	0.290 b	0.293 a	0.292 A
Saline water 3000 ppm	2.380 e	2.638 c	2.509 C	1.590 d	1.604 d	1.597 C	0.890 d	1.069 c	0.979 C	0.277 d	0.282 c	0.280 B
Overall mean	2.566 *b*	2.785 *a*		1.910 *a*	1.948 *a*		1.053 *b*	1.184 *a*		0.230 *b*	0.234 *a*	

*** Sour= Sour orange rootstock & Volka= Volkamer lemon rootstock**

Table (4): The interaction effect between varietal differences of citrus rootstock and saline irrigation water on root and leaf anatomy.

	Treatments	Root anatomy features		leaf anatomy features			
		Thickness of cortex (µm)	Area of vascular cylinder (µm²)	Upper epidermis (µm)	Lower epidermis (µm)	Mesophyll (µm)	Blade (µm)
Sour orange	Tap water (Control)	59.86	1.57239	1.82	1.51	27.35	30.68
	Saline water 2000 ppm	61.15	0.85535	1.78	1.45	31.97	35.20
	Saline water 3000 ppm	61.37	0.62500	1.42	1.15	34.14	36.71
Volkamer lemon	Tap water (Control)	30.18	3.16653	1.85	1.51	26.78	30.14
	Saline water 2000 ppm	41.50	1.38423	1.72	1.48	27.35	30.55
	Saline water 3000 ppm	49.05	0.80509	1.53	1.17	28.27	30.97

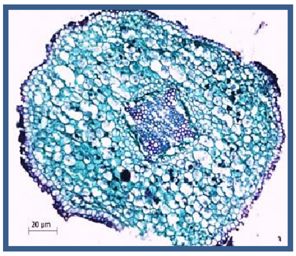

Plate (1-a)

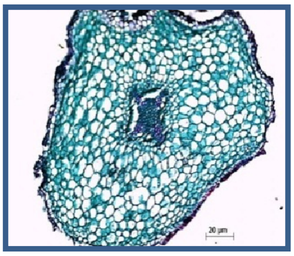

Plate (1-b)

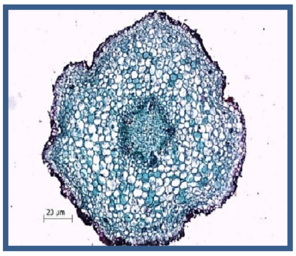

Plate (1-c)

* S_1, S_2 and S_3 refer to irrigation water salinity at 700, 2000, 3000 ppm respectively.

Plates (1): Cross section of root in Sour orange showed different tissues as affected by saline irrigation water (X=100).

Plate (2-a)

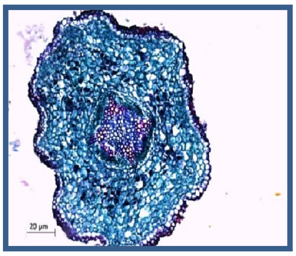

Plate (2-b)

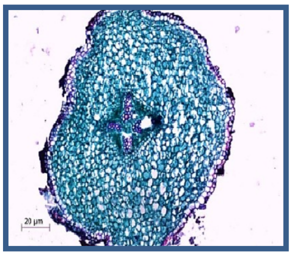

Plate (2-c)

* S_1, S_2 and S_3 refer to irrigation water salinity at 700, 2000, 3000 ppm respectively.

Plates (2): Cross section of root in Volkamer lemon showed different tissues as affected by saline irrigation water (X=100).

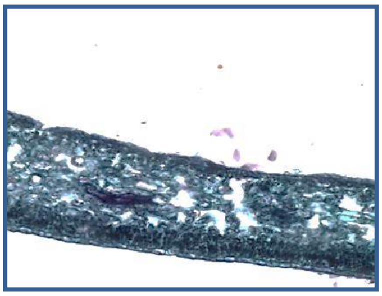

Plate (3-a)

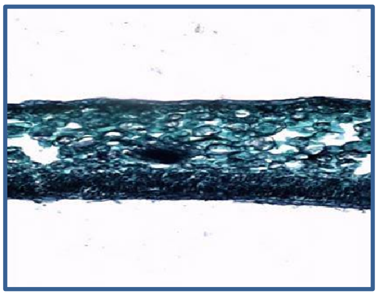

Plate (3-b)

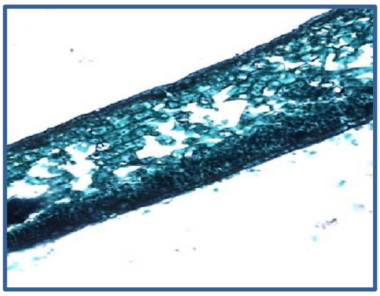

Plate (3-c)

* S_1, S_2 and S_3 refer to irrigation water salinity at 700, 2000, 3000 ppm respectively.

Plates (3): Cross section of leaf blade in Sour orange showed different tissues as affected by saline irrigation water (X=100).

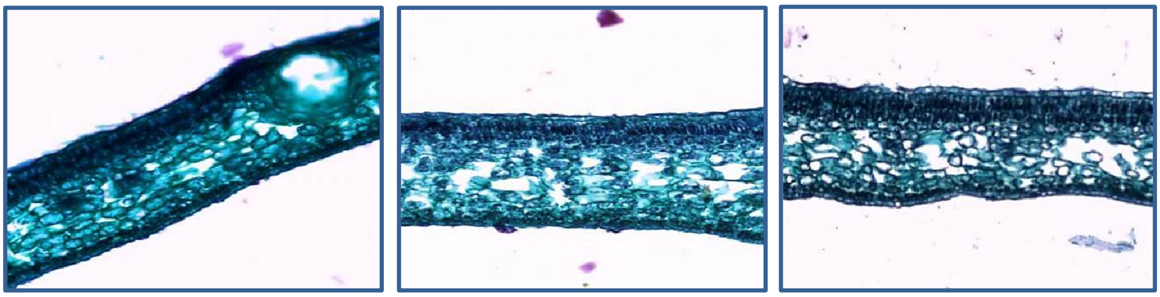

Plate (4-a) **Plate (4-b)** **Plate (4-c)**

* S_1, S_2 and S_3 refer to irrigation water salinity at 700, 2000, 3000 ppm respectively.

Plates (4): Cross section of leaf blade in Volkamer lemon showed different tissues as affected by saline irrigation water (X=100).

DISCUSSION

Previous results showed that saline water decrease plant biomass and photosynthetic pigments due to the osmotic stress; one of the salinity effects on citrus rootstock seedlings caused by the total concentration of salt dissolved in the soil solution due to irrigation water quality, which affects the availability of free water (unbound) through physical processes (Starck and Karwowska, 1978). In the same line, salt tolerance in citrus is usually based on Cl^- toxicity than to Na^+ toxicity (Maas, 1993 and Romero-Aranda *et al.,* 1998). Hence, all these effects could be reflected on lowering different citrus rootstocks growth.

And also, salinity caused loss the chlorophyll contents and reduced photosynthetic ability over destruction of chlorophyll biosynthesis, stomata closure and suppression of specific enzymes that are responsible for the synthesis of photosynthetic pigments and decrease in the uptake of minerals needed for chlorophyll biosynthesis i.e., iron and manganese. All this is due to increased salinity of the accumulation of chlorine ion in tissue plant (Strognova *et al.,* 1970; Mayber and Gale, 1975; El-Lawendy, 1990; Zekri, 1991 and El-Desouky and Atawia, 1998)

Moreover, Volkamer lemon seedlings proved that to be more tolerant to salinity irrigation water than Sour orange (El-Desouky and Atawia, 1998; Levy *et al.,* 1999a, 1999 b and Levy and Syvertsen, 2004), these result may be cause increased ability Volkamer lemon organs to growth under salinity damage. And also, these results may explain that citrus seedlings tended to increase the osmotic pressure in their cell sap through increasing dry matter content or decreasing water content in their tissues as a step for tolerating the salts stress addition to, increased ability Volkamer lemon to restrict uptake and/or transport of Cl^- and Na^+ between roots and shoots compared with Sour orange.

Many of studies indicated that irrigation with saline water data indicate that thickness of root cortex, mesophyll tissue and thickness of leaf blade significantly increases by increased salinity levels, while decrease area of root vascular bundle (Sourial *et al.,* 1978; Basal, 1978 ;Draz, 1986 and El-Hamady *et al.,* 1986)

These result of increased the thickness of leaf blade could be attributed to that increasing salinity level affected the leaf growth in two directions. Firstly it decreases the metabolic processes which induced less leaf area/plant. Secondary it increased the osmotic pressure inside the cells which permit more into the cell and increased the thickness of leaf blade (Basal, 1978). In the same line, salinity also reduces intercellular spaces in leaves so data showed increased of the mesophyll tissue with increasing salinity levels (Delphine *et al.,* 1998).

CONCLUSIONS

Finally, vegetative growth parameters, mineral content and total pigments analysis indicated that Volkamer lemon rootstock is more tolerant to salinity of irrigation water.

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تأثير الري بالماء المالح على شتلات أصول النارنج والفولكامريانا

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أجريت هذه الدراسة خلال موسمي ٢٠١٢ و ٢٠١٣ على شتلات بعض أصول الموالح وهي: النارنج والفولكامارينا عمر ٦ أشهر بصوبة مظللة بقسم الإنتاج النباتي - كلية العلوم الزراعية البيئية، جامعة قناة السويس – مصر. وذلك بهدف دراسة تأثير الري بالماء المالح على شتلات أصلين من الموالح هما: النارنج والفولكامريانا. وتمت زراعة الشتلات فى أنابيب بلاستيكية سوداء PVC بقطر ١٥سم وارتفاع ٤٠ سم فى بيئة رمل : بيتموس بنسبة ٤: ١ على التوالي، وتم ري جميع شتلات التجربة بماء الصنبور (معاملة المقارنة) لمدة ١٤ يوم قبل بدء معاملات التجربة. تضمنت هذه التجربة ٢ معاملة أصول موالح (النارنج والفولكامريانا) والري بثلاث مستويات ملوحة (ماء الصنبور ٧٠٠ جزء فى المليون "معاملة المقارنة"- ٢٠٠٠ جزء فى المليون – ٣٠٠٠ جزء فى المليون). وأظهرت النتائج تفوق أصل الفولكامريانا على أصل النارنج حيث أعطي أعلى قيمة للقياسات الخضرية للأوراق والجذور والمحتوي الكلي للصبغات والبرولين وتركيز عنصر البوتاسيوم بالأوراق بالإضافة الى أكبر سمك للحزم الوعائية للجذر والبشرة العليا والسفلي للورقة، بينما أعطت أقل القيم لتركيز الأوراق من عنصر النيتروجين والكلوريد والصوديوم وسمك القشرة للجذور وسمك الطبقة الوسطى للورقة وسمك الورقة. كما أن الري بمعاملات المياه المالحة أدت الى خفض جميع القياسات الخضرية والمحتوي الكلي للصبغات وعلى العكس أدت الى زيادة محتوي الأوراق من النيتروجين والكلوريد والصوديوم والبرولين وسمك طبقة القشرة للجذور وسمك الطبقة الوسطى للورقة وسمك الورقة. وعموماً تشير النتائج من خلال قياسات النمو الخضرية ومحتوي الأوراق من العناصر والصبغات وخصائص الورقة التشريحية الى أن أصل الفولكامريانا اكثر تحملاً للري بالمياه المالحة.