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STUDY OF THE EFFECT OF SALINITY STRESS AND MAGNETIZED WATER IRRIGATION ON GROWTH OF WASHINGTON NAVEL ORANGE SEEDLINGS BUDDED ON SOUR ORANGE ROOTSTOCK

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Abstract

This study was conducted during 2016 and 2017 seasons on Washington navel orange seedlings (*Citrus sinenses*) budded on sour orange rootstock (*Citrus aurantium* L.). The study aimed to improve seedling growth under different salinity of water irrigation with using magnetized water under different salinity levels (300, 1000 (control), 2000, 3000 and 4000ppm). The data showed that, Washington navel orange seedlings could use different levels of water salinity reached to 2000 ppm without any harmful effects or any decrease in growth parameters of by using magnetic water irrigation.

***Key words*:** Washington navel orange seedling, citrus, magnetized water, salinity stress, cryptochrome.

Introduction

Citrus is one of the most important fruit crops in the world with an annual production exceeding 124.25 million tons in 2016 (FAO, 2016). In addition, citrus trees are the most important fruit crop in Egypt. The total area under citrus trees in Egypt is 541,723 feddan (Feddan = 0.42 Hectare), out of them 185,892 feddan planted by Washington navel orange trees (Ministry of Agric., 2014).

Citrus is highly sensitive to salinity. The citrus growth is impaired at salinity of about 2 ds/m (1280 ppm) without any concomitant expression of leaf symptoms and about 13 percent decrease of citrus yield per each 1 ds/m (640 ppm) increase in salinity above 1.4 ds/m (896 ppm) (Murkute *et al.*, 2005). Salinity is a major abiotic stress factor reducing the yield of wide varieties of crops all over the world. Worldwide, 100 million ha or 5% of the Arab land is adversely affected by high salt concentration which reduces growth and yield (Ashraf and Foolad, 2007; Ali *et al.*, 2011). Continuous use of saline irrigation water leads to soil salinization. High contents of soluble salts accumulated in the soil can significantly depresses plant growth and development at different physiological levels and decrease the productivity of soils. Using poor quality irrigation water with high salinity is one of the main problems of agriculture in Egypt and many countries in the world. To reclaim soil and water, and to reduce soil salinity, magnetized water irrigation can be used (Amer *et al.*, 2014).

Magnetized water irrigation reduce the Na toxicity at cell level by detoxification of Na, either by restricting the entry of Na at membrane level, decrease of soil alkalinity or by reduced absorption of Na by plant roots. Also, magnetic treatments improved availability, uptake, assimilation and mobilization of these nutrients within the plant system, increase in photosynthetic pigments, endogenous promoters, which lead to improved plant growth characteristics, root function, influenced the chemical composition of plants (Ali *et al.*, 2011; Amer *et al.*, 2014; Aly*et al.*, 2015; Mostafa *et al.*, 2016). It is so important to focus on the results of Bondarenko *et al.*,1999, who cleared that the main effects of magnetic irrigation water were the products of high-energy reactions such as free radicals, atomic oxygen, and nitrogen-containing compounds, which were found in the treated water.I n addition, magnetic water has a relationship with cryptochromes which are photolyase-like blue light receptors originally discovered in arabidopsis but later found in other plants, microbes and animals. Arabidopsis has two cryptochromes, CRY1 and CRY2, which mediate primarily blue light inhibition of hypocotyl elongation and photoperiodic control of floral initiation, respectively. In addition, cryptochromes regulate over a dozen other light responses, including circadian rhythms, tropic growth, stomata opening, guard cell development, root development, abiotic stress responses, cell cycles, programmed cell death, apical dominance, fruit and ovule development (Yu *et al.*, 2010). It is highly important to refer to results confirmed by Maffei, 2014, who stated that the cryptochromes responded to the magnetic field, which may be the link between the magnetized water and cryptochromes.

This study aimed to improve seedling growth under different salinity of water irrigation with using magnetized water under different salinity levels (300, 1000, 2000, 3000 and 4000 ppm).

Material and Methods

The present investigation carried out during two successive seasons (2016 and 2017) to improve Washington navel orange seedling (*Citrus sinenses,* Osbeck*)* growth, budded on sour orange (*Citrus aurantium* L.) rootstock, under different salinity of water irrigation with using magnetized water. The experimental seedling were one year old and have the same volume. The seedling grown in plastic pots (30 cm diameter) were filled up with 20 kg of air-dried silty clay soil under Plastic greenhouse condition in a private orchard at Belbeis region – El Sharkia Governorate, Egypt. All seedling under this study received the same applied horticultural practices except those of the experimental treatments. The experimental design was a split plot arrangements of randomized complete block with three replicates and five seedling for each replicate. The main plot (first factor) comprised magnetized or non-magnetized water and the diameter of magnetic device was 2.5 inches, 12000 gauss and with output of 40 m^3 /hr. The sub-plot (second factor) had five salinity levels of water irrigation (300, 1000 (control), 2000, 3000 and 4000 ppm).

According to Murkute *et al*., 2005 citrus growth is impaired at salinity of about 2 ds/m (1280 ppm) without any concomitant expression of leaf symptoms. Thus, the control will be non-magnetized water with 1000 ppm of water irrigation salinity for explaining all experimental results in this study.

Table 1: Main chemical constituents of the used irrigation water.

pH	TDS ppm	Soluble cations meq /L				Soluble anions meq /L				Boron (ppm)
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co_3^{-}	HCo_3^{-}	Cl^{-}	SO_4^{--}	
7.12	300	1.40	1.00	1.35	0.94	0.09	2.40	0.90	1.30	0.02
7.26	1000	1.18	0.95	7.30	6.23	0.24	2.59	1.10	11.72	0.04
7.46	2000	0.87	0.89	15.79	13.78	0.46	2.86	1.39	26.62	0.06
7.67	3000	0.56	0.82	24.29	21.33	0.68	3.13	1.67	41.51	0.08
7.87	4000	0.25	0.75	32.78	28.88	0.90	3.40	1.96	56.40	0.10

The tested treatments were evaluated throw the following parameters:

Growth parameters

The measurements of the seedling was the same at the start of every experimental season as followed: plant height was about 70 cm, the diameter was about 0.70 cm and the plant has one shoot. At the end of every experimental season plant height, number of laterals shoots, number of leaves per shoot and leaf area were determined and recorded.

Stomatal behavior and Leaf Water Relations

The total numbers of stomata and the number of opened stomata /cm^2 of leaf area were determined using the method of Stino *et al*., 1974; the percentage of opened stomata was calculated according the following equation:

$$\text{Opened stomata} = \frac{\text{Number of opened stomata}}{\text{Number of total stomata}} \times 100$$

The following indices were considered for water relations: 1) the total leaf water content (%) was determined according the follow equation (water content (%) = $\frac{\text{Leaf fresh weight} - \text{Leaf dry weight}}{\text{Leaf fresh weight}} \times 100$). 2)the leaf bound water content (%) was estimated following the method stated by Gosov (1960). 3) the leaf free water content was calculated (=total leaf water content- leaf bound water content).

Leaf photosynthetic pigments, cell sap osmotic pressure and proline contents

The photosynthetic pigments contents (mg/ 100 g of fresh weight) were determined in fresh samples of leaf blades collected in August according to Von-Wettestein, 1957. Moreover, the proline content of fresh leaves (µ moles/g fresh weight) was determined following the method adopted by Bates *et al*., 1973. Leaf osmotic pressure of the cell sap of leaf blades was determined following the method of Gosov, 1960.

Leaf chemical composition

The dried leaves were finely grinded and digested using micro-keildahl unit. The percentage of nitrogen content was determined according to Naguib, 1969. Phosphorus percentage was determined according to AOAC, 1985. Potassium percentage was determined according to Brown and Lilliland, 1964. The leaf Cl was determined according to Higinbothan *et al*., 1967, while leaf Na content was determined following the method described by Brown and Lilliland, 1964.

Root behavior

The following indices were studied at the end of every season after plant root has been washed and cleaned. The studied parameters were: 1) root length by measure vertical root penetration, 2) root size by measure of horizontal extension, 3) root fresh weight and 4) fibrous root length.

Statistical Analysis

The experimental design was split plot arrangement of complete randomized block design (factorial experiment -split plot design) with three replicates and five seedling for each replicate. The main plot contained magnetized or non-magnetized water, the sub-plot comprised five salinity levels of water irrigation (300, 1000 (control), 2000, 3000 and 4000 ppm).The data obtained were statistically analyzed using the analysis of variance method as reported by Snedecor and Cochran, 1980. The differences between means were differentiated by using Duncan's range test (Duncan, 1955).

Results

Growth Parameters

The data in Table (2) showed that, magnetized water had a great positive effect on growth parameters in both seasons. Plant height reached to 99.73 cm compared to the non-magnetized water, which was 91.70 cm. In addition, using irrigation water with low salinity (300 ppm) gained the highest values, which reached to 112.57 cm for plant height. Also, applying magnetized water with low salinity of water irrigation (300 ppm) gained the heights value for plant height, which was 116.72 cm. At the same time, using magnetized water with 1000 or 2000 ppm of salinity gained 105.35 and 98.27cm, which were statistically better than or equal to (control) non-magnetized water combined with 1000 ppm of salinity (97.25 cm). The other parameters have the same trend in both seasons.

Table 2: Effect of salinity stress and magnetized water irrigation on some growth parameters of Washington navel orange seedlings budded on sour orange rootstock(2016-2017 seasons).

Treatments	Plant height (cm)		Number of laterals shoots per transplant		Number of leaves per shoot		Leaf area (cm^2)	
	First season (2016)							
Non-M.W.	91.70	B	6.35	B	12.03	B	37.84	B
M.W.	99.73	A	6.83	A	12.35	A	40.65	A
W.S.300ppm	112.57	A	8.26	A	13.29	A	45.33	A
W.S.1000ppm	101.30	B	7.36	B	12.32	B	41.63	B
W.S.2000ppm	96.11	B	7.05	C	12.08	B	39.56	C
W.S.3000ppm	88.08	C	5.25	D	11.77	C	35.96	D
W.S.4000ppm	80.51	D	5.01	E	11.48	D	33.76	E
Non-M.W. ×W.S.300ppm	108.42	b	7.84	b	13.17	b	43.95	b
Non-M.W. ×W.S.1000ppm (control)	97.25	d	7.19	d	12.19	d	40.64	d
Non-M.W. ×W.S.2000ppm	93.94	e	6.91	e	11.98	e	38.44	e
Non-M.W. ×W.S.3000ppm	82.95	g	5.03	h	11.63	h	34.19	g
Non-M.W. ×W.S.4000ppm	75.93	h	4.76	i	11.18	i	32.00	h
M.W. ×W.S.300ppm	116.72	a	8.68	a	13.41	a	46.71	a
M.W. ×W.S.1000ppm	105.35	c	7.53	c	12.46	c	42.63	c
M.W. ×W.S.2000ppm	98.27	d	7.19	d	12.18	d	40.68	d
M.W. ×W.S.3000ppm	93.20	e	5.47	f	11.92	f	37.73	e
M.W. ×W.S.4000ppm	85.09	f	5.27	g	11.79	g	35.53	f
	Second season (2017)							
Non-M.W.	93.00	B	6.52	B	10.48	B	37.97	B
M.W.	99.37	A	7.15	A	11.22	A	41.32	A
W.S.300ppm	112.72	A	8.35	A	12.62	A	46.15	A
W.S.1000ppm	102.10	B	7.68	B	11.42	B	42.60	B
W.S.2000ppm	96.80	B	7.37	C	10.72	B	40.33	C
W.S.3000ppm	86.34	C	5.62	D	9.88	C	35.62	D
W.S.4000ppm	82.95	D	5.15	E	9.63	D	33.53	E
Non-M.W. ×W.S.300ppm	111.27	b	8.19	b	12.22	b	44.63	b
Non-M.W. ×W.S.1000ppm (control)	98.03	d	7.46	d	11.08	c	41.56	c
Non-M.W. ×W.S.2000ppm	93.93	e	7.22	e	10.34	d	39.38	d
Non-M.W. ×W.S.3000ppm	82.60	h	5.06	h	9.55	e	33.21	g
Non-M.W. ×W.S.4000ppm	79.16	i	4.69	i	9.21	e	31.09	h
M.W. ×W.S.300ppm	114.18	a	8.51	a	13.03	a	47.67	a
M.W. ×W.S.1000ppm	106.18	c	7.91	c	11.77	b	43.64	b
M.W. ×W.S.2000ppm	99.67	d	7.52	d	11.09	c	41.28	c
M.W. ×W.S.3000ppm	90.08	f	6.18	f	10.20	d	38.03	e
M.W. ×W.S.4000ppm	86.74	g	5.61	g	10.04	d	35.96	f

Non-M.W. = non magnetized water; M.W. = magnetized water; W.S. = Water salinity.
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Stomatal behaviors and water relation

Table (3) cleared that, opened stomata percentage reached to 45.81% by using magnetized water compared to the non-magnetized, which was 41.90%. Regarding, water irrigation with low salinity (300 ppm) reached to 53.46% for opened stomata percentage. Additionally, magnetized water application with low salinity of water irrigation (300 ppm) gained the heights value for opened stomata percentage, which was 55.79%. Also, using magnetized water with 1000 or 2000 ppm of salinity gained 48.59% and 45.46%, which were statistically better than or equal to (control) non-magnetized water combined with 1000 ppm of salinity (45.26%). The other parameters (bound and free water percentage) have the same trend in both seasons except closed stomata percentage, which has opposite direction.

Table 3: Effect of salinity stress and magnetized water irrigation on stomatal behaviors and water relation of Washington navel orange seedlings budded on sour orange rootstock (2016-2017 seasons).

Treatments	Opened stomata %		Closed stomata %		Bound water (%)		Free water (%)	
	First season (2016)							
Non-M.W.	41.90	B	58.10	A	40.22	B	22.57	B
M.W.	45.81	A	54.19	B	40.85	A	23.21	A
W.S.300ppm	53.46	A	46.54	D	42.20	A	24.37	A
W.S.1000ppm	46.93	B	53.07	C	42.12	B	23.37	B
W.S.2000ppm	43.90	C	56.10	B	40.53	C	22.99	C
W.S.3000ppm	38.68	D	61.32	A	38.91	D	22.07	D
W.S.4000ppm	36.32	D	63.68	A	38.90	D	21.65	E
Non-M.W. ×W.S.300ppm	51.13	b	48.87	h	42.27	a	24.07	b
Non-M.W. ×W.S.1000ppm (control)	45.26	d	54.74	f	41.96	c	23.14	d
Non-M.W. ×W.S.2000ppm	42.33	e	57.67	e	39.10	d	22.76	e
Non-M.W. ×W.S.3000ppm	36.88	h	63.12	b	38.80	e	21.75	g
Non-M.W. ×W.S.4000ppm	33.89	i	66.11	a	38.95	e	21.15	h
M.W. ×W.S.300ppm	55.79	a	44.21	i	42.13	b	24.68	a
M.W. ×W.S.1000ppm	48.59	c	51.41	g	42.28	a	23.59	c
M.W. ×W.S.2000ppm	45.46	d	54.54	f	41.97	c	23.22	d
M.W. ×W.S.3000ppm	40.47	f	59.53	d	39.03	d	22.40	f
M.W. ×W.S.4000ppm	38.74	g	61.26	c	38.84	e	22.14	f
	Second season (2017)							
Non-M.W.	42.88	B	57.12	A	40.24	B	22.59	B
M.W.	46.89	A	53.11	B	40.87	A	23.22	A
W.S.300ppm	54.71	B	45.29	D	42.23	A	24.39	A
W.S.1000ppm	48.03	A	51.97	C	42.14	B	23.38	B
W.S.2000ppm	44.93	A	55.07	B	40.56	C	23.01	C
W.S.3000ppm	39.59	B	60.41	A	38.94	D	22.09	D
W.S.4000ppm	37.17	C	62.83	A	38.92	D	21.66	E
Non-M.W. ×W.S.300ppm	52.33	b	47.67	h	42.30	a	24.08	b
Non-M.W. ×W.S.1000ppm (control)	46.32	d	53.68	f	41.99	c	23.16	d
Non-M.W. ×W.S.2000ppm	43.32	e	56.68	e	39.12	d	22.77	e
Non-M.W. ×W.S.3000ppm	37.75	h	62.25	b	38.82	e	21.76	g
Non-M.W. ×W.S.4000ppm	34.69	i	65.31	a	38.97	e	21.16	h
M.W. ×W.S.300ppm	57.10	a	42.90	i	42.15	b	24.69	a
M.W. ×W.S.1000ppm	49.73	c	50.27	g	42.30	a	23.60	c
M.W. ×W.S.2000ppm	46.53	d	53.47	f	41.99	c	23.24	d
M.W. ×W.S.3000ppm	41.42	f	58.58	d	39.05	d	22.41	f
M.W. ×W.S.4000ppm	39.65	g	60.35	c	38.87	e	22.16	f

Non-M.W. = non magnetized water; M.W. = magnetized water; W.S. = Water salinity.
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Leaf pigments, osmotic pressure and proline content

Regarding Table (4), leaf pigments have affected by magnetized water application, which reached to 0.197, 0.092 and 0.147 mg/ 100 g of leaf fresh weight compared to the non-magnetized, which reached to 0.178, 0.083 and 0.133 mg/ 100 g of leaf fresh weight for leaf chlorophyll a, chlorophyll b and carotenoids contents, respectively. In addition, leaf pigments have affected by water irrigation with low salinity (300 ppm), which reached to 0.235, 0.109 and 0.178 mg/ 100 g of leaf fresh for leaf chlorophyll a, chlorophyll b and carotenoids contents, respectively. It is clear that the magnetized water application with low salinity of water irrigation (300 ppm) gained the heights value for chlorophyll a, chlorophyll b and carotenoids contents, which were 0.240, 0.112 and 0.183 mg/ 100 g of leaf fresh, respectively. Also, using magnetized water with 1000 or 2000 ppm of salinity gained 0.218, 0.102, 0.165, 0.205, 0.096 and 0.156 mg/ 100 g of leaf fresh, which were statistically better than or equal to (control) non-magnetized water combined with 1000 ppm of salinity, which were 0.205, 0.095 and 0.155 mg/ 100 g of leaf fresh for chlorophyll a, chlorophyll b and carotenoids contents, respectively. This was true in both seasons.

On the opposite direction, leaf cell sap osmotic pressure and proline content get low values with magnetized water reached to 20.06 atm. and 57.49 µ g / moles of leaf fresh compared to 21.06 atm. and 65.50 µ g / moles of leaf fresh for the non-magnetized, respectively. Also, Leaf cell sap osmotic pressure and proline content get low values with low salinity water irrigation (300 ppm), which reached to 18.43 atm. and 44.47µ g / moles of leaf fresh, respectively. Thus, magnetized water application with low salinity of water irrigation (300 ppm) gained the lowest values for leaf cell sap osmotic pressure and proline content, which were 18.03 atm. and 42.56 µ g / moles of leaf fresh, respectively. Also, using magnetized water with 1000 or 2000 ppm of salinity gained 19.12 atm., 50.18 µ g / moles of leaf fresh, 19.98 atm. And 55.54 18 µ g / moles of leaf fresh, which were statistically better than or equal to (control) non-magnetized water combined with 1000 ppm of salinity, which were 19.98atm. and 56.23µ g / moles of leaffresh for leaf cell sap osmotic pressure and proline content, respectively. This was true in both seasons.

Table 4: Effect of salinity stress and magnetized water irrigation on leaf pigments, osmotic pressure and proline content of Washington navel orange seedlings budded on sour orange rootstock (2016-2017 seasons).

Treatments	Leaf chlorophyll a content (mg/100 g of leaf F. W.)		Leaf chlorophyll b content (mg/ 100 g of leaf F. W.)		Leaf carotenoids content (mg/ 100 g of leaf F. W.)		Leaf cell sap osmotic pressure (atm.)		Leaf proline content (µ g / moles of leaf F. W.)	
	First season (2016)									
Non-M.W.	0.178	B	0.083	B	0.133	B	21.06	A	65.50	A
M.W.	0.197	A	0.092	A	0.147	A	20.06	B	57.49	B
W.S.300ppm	0.235	A	0.109	A	0.178	A	18.43	E	44.47	C
W.S.1000ppm	0.211	B	0.099	B	0.160	B	19.55	DX	53.20	B
W.S.2000ppm	0.200	B	0.094	B	0.151	B	20.43	C	58.85	B
W.S.3000ppm	0.153	C	0.072	C	0.111	C	21.74	B	72.54	A
W.S.4000ppm	0.137	D	0.064	D	0.099	D	22.64	A	78.43	A
Non-M.W. ×W.S.300ppm	0.229	b	0.107	b	0.173	b	18.84	h	46.38	h
Non-M.W. ×W.S.1000ppm (control)	0.205	d	0.095	d	0.155	d	19.98	f	56.23	f
Non-M.W. ×W.S.2000ppm	0.196	e	0.091	e	0.147	e	20.87	e	62.15	e
Non-M.W. ×W.S.3000ppm	0.138	h	0.065	h	0.100	h	22.30	b	77.84	b
Non-M.W. ×W.S.4000ppm	0.122	i	0.057	i	0.088	i	23.30	a	84.92	a
M.W. ×W.S.300ppm	0.240	a	0.112	a	0.183	a	18.03	i	42.56	i
M.W. ×W.S.1000ppm	0.218	c	0.102	c	0.165	c	19.12	g	50.18	g
M.W. ×W.S.2000ppm	0.205	d	0.096	d	0.156	d	19.98	f	55.54	f
M.W. ×W.S.3000ppm	0.168	f	0.079	f	0.122	f	21.18	d	67.24	d
M.W. ×W.S.4000ppm	0.151	g	0.071	g	0.110	g	21.97	c	71.95	c
	Second season (2017)									
Non-M.W.	0.180	B	0.084	B	0.134	B	20.63	A	66.07	A
M.W.	0.198	A	0.093	A	0.148	A	20.03	B	57.99	B
W.S.300ppm	0.235	A	0.109	A	0.178	A	19.06	E	44.85	C
W.S.1000ppm	0.214	B	0.100	B	0.162	B	19.73	DX	53.66	B
W.S.2000ppm	0.203	B	0.095	B	0.153	B	20.26	C	59.36	B
W.S.3000ppm	0.154	C	0.073	C	0.113	C	21.04	B	73.17	A

W.S.4000ppm	0.137	D	0.065	D	0.100	D	21.58	A	79.11	A
Non-M.W. ×W.S.300ppm	0.231	b	0.107	b	0.175	b	19.30	h	46.78	h
Non-M.W. ×W.S.1000ppm (control)	0.208	d	0.096	d	0.158	d	19.99	f	56.72	f
Non-M.W. ×W.S.2000ppm	0.198	e	0.092	e	0.149	e	20.52	e	62.69	e
Non-M.W. ×W.S.3000ppm	0.138	h	0.065	h	0.101	h	21.38	b	78.51	b
Non-M.W. ×W.S.4000ppm	0.123	i	0.058	i	0.090	i	21.98	a	85.66	a
M.W. ×W.S.300ppm	0.239	a	0.111	a	0.181	a	18.82	i	42.93	i
M.W. ×W.S.1000ppm	0.221	c	0.103	c	0.167	c	19.47	g	50.61	g
M.W. ×W.S.2000ppm	0.208	d	0.097	d	0.158	d	19.99	f	56.02	f
M.W. ×W.S.3000ppm	0.170	f	0.080	f	0.124	f	20.71	d	67.82	d
M.W. ×W.S.4000ppm	0.152	g	0.072	g	0.111	g	21.18	c	72.57	c

Non-M.W. = non magnetized water; M.W. = magnetized water; W.S. = Water salinity.
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Leaf chemical composition

As shown in Table (5), leaf chemical compositions were affected by magnetized in both seasons. Nitrogen percentage reached to 2.39% compared to the non-magnetized water, which was 2.28%. In addition, using irrigation water with low salinity (300 ppm) gained the highest values, which reached to 2.61% cm for nitrogen percentage. Also, applying magnetized water with low salinity of water irrigation (300 ppm) gained the heights value for nitrogen percentage, which was 2.64%. At the same time, using magnetized water with 1000 or 2000 ppm of salinity gained 2.53% and 2.43%, which were statistically better than or equal to (control) non-magnetized water combined with 1000 ppm of salinity (2.42%). The phosphorus percentage and potassium percentage have the same trend in both seasons.

Table 5: Effect of salinity stress and magnetized water irrigation on leaf chemical composition of Washington navel orange seedlings budded on sour orange rootstock (2016-2017 seasons).

Treatments	N (%)		P (%)		K (%)		Na (%)		Cl (%)	
	First season (2016)									
Non-M.W.	2.28	B	0.132	B	1.26	B	0.190	A	0.78	A
M.W.	2.39	A	0.136	A	1.32	A	0.182	B	0.72	B
W.S.300ppm	2.61	A	0.145	A	1.44	A	0.163	D	0.56	D
W.S.1000ppm	2.47	B	0.139	B	1.35	B	0.180	C	0.70	C
W.S.2000ppm	2.40	B	0.135	C	1.32	B	0.189	B	0.77	B
W.S.3000ppm	2.14	C	0.127	D	1.20	C	0.197	A	0.84	A
W.S.4000ppm	2.04	D	0.124	E	1.15	D	0.201	A	0.86	A
Non-M.W. ×W.S.300ppm	2.59	b	0.144	b	1.42	b	0.166	h	0.59	h
Non-M.W. ×W.S.1000ppm (control)	2.42	d	0.136	d	1.33	d	0.186	f	0.74	f
Non-M.W. ×W.S.2000ppm	2.37	e	0.134	e	1.31	e	0.193	e	0.80	e
Non-M.W. ×W.S.3000ppm	2.04	h	0.126	h	1.15	h	0.199	b	0.86	b
Non-M.W. ×W.S.4000ppm	1.96	i	0.119	i	1.12	i	0.204	a	0.89	a
M.W. ×W.S.300ppm	2.64	a	0.146	a	1.45	a	0.160	i	0.54	i
M.W. ×W.S.1000ppm	2.53	c	0.142	c	1.37	c	0.174	g	0.65	g
M.W. ×W.S.2000ppm	2.43	d	0.136	d	1.33	d	0.184	f	0.73	f
M.W. ×W.S.3000ppm	2.25	f	0.129	f	1.24	f	0.195	d	0.82	d
M.W. ×W.S.4000ppm	2.12	g	0.128	g	1.19	g	0.197	c	0.84	c
	Second season (2017)									
Non-M.W.	2.15	B	0.131	B	1.28	B	0.183	A	0.79	A
M.W.	2.28	A	0.138	A	1.34	A	0.175	B	0.72	B
W.S.300ppm	2.51	A	0.155	A	1.45	A	0.157	D	0.55	D
W.S.1000ppm	2.23	B	0.141	B	1.38	B	0.170	C	0.67	C
W.S.2000ppm	2.19	B	0.135	C	1.34	B	0.182	B	0.77	B
W.S.3000ppm	2.09	C	0.123	D	1.22	C	0.192	A	0.86	A
W.S.4000ppm	2.04	D	0.118	E	1.17	D	0.195	A	0.89	A
Non-M.W. ×W.S.300ppm	2.30	b	0.154	b	1.43	b	0.159	h	0.57	h

Non-M.W. ×W.S.1000ppm (control)	2.20	d	0.136	d	1.35	d	0.176	f	0.72	f
Non-M.W. ×W.S.2000ppm	2.18	e	0.133	e	1.33	e	0.187	e	0.82	e
Non-M.W. ×W.S.3000ppm	2.05	h	0.121	h	1.17	h	0.194	b	0.88	b
Non-M.W. ×W.S.4000ppm	2.01	i	0.113	i	1.13	i	0.198	a	0.93	a
M.W. ×W.S.300ppm	2.73	a	0.157	a	1.46	a	0.155	i	0.53	i
M.W. ×W.S.1000ppm	2.25	c	0.147	c	1.40	c	0.165	g	0.62	g
M.W. ×W.S.2000ppm	2.21	d	0.136	d	1.36	d	0.176	f	0.73	f
M.W. ×W.S.3000ppm	2.13	f	0.126	f	1.26	f	0.189	d	0.84	d
M.W. ×W.S.4000ppm	2.08	g	0.124	g	1.21	g	0.192	c	0.86	c

Non-M.W. = non magnetized water; M.W. = magnetized water; W.S. = Water salinity.
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

On the other hand, leaf Na percentage and Cl percentage get low values with magnetized water reached to 0.182% and 0.72% compared to 0.190% and 0.78% for the non-magnetized, respectively. Also, leaf Na percentage and Cl percentage get low values with low salinity water irrigation (300 ppm), which reached to 0.163% and 0.56%, respectively. Thus, magnetized water application with low salinity of water irrigation (300 ppm) gained the lowest values for leaf Na percentage and Cl percentage, which were 1.66% and 0.59%, respectively. Also, using magnetized water with 1000 or 2000 ppm of salinity gained 0.174%, 0.65%, 0.0184 and 0.73%, which were statistically better than or equal to (control) non-magnetized water combined with 1000 ppm of salinity which were 0.186% and 0.74 for leaf Na percentage and Cl percentage, respectively. This was true in both seasons.

Root Behavior

The results in Table (6) revealed that, root extension have increased by using magnetized water in both seasons. Root length reached to 45.73 cm compared to the non-magnetized water, which was 39.13 cm. Also, using irrigation water with low salinity (300 ppm) gained the highest values, which reached to 55.00 cm for root length. In addition, applying magnetized water with low salinity of water irrigation (300 ppm) gained the heights value for plant height, which was 57.33 cm. At the same time, using magnetized water with 1000 or 2000 ppm of salinity gained 50.67 and 45.33 cm, which were statistically better than or equal to (control) non-magnetized water combined with 1000 ppm of salinity (45.33 cm). The other parameters for root extension have the same trend in both seasons.

Table 6: Effect of salinity stress and magnetized water irrigation on root behavior of Washington navel orange seedlings budded on sour orange rootstock (2016-2017 seasons).

Treatments	Root length (cm)		Root size (cm^3)		Root fresh weight (g)		Fibrous root length (cm)	
	First season (2016)							
Non-M.W.	39.13	B	40.53	B	38.36	B	289.56	B
M.W.	45.73	A	50.53	A	47.82	A	384.19	A
W.S.300ppm	55.00	A	58.83	A	55.67	A	462.74	A
W.S.1000ppm	48.00	B	51.50	B	48.73	B	393.34	B
W.S.2000ppm	43.83	B	46.83	C	44.32	B	349.18	C
W.S.3000ppm	35.33	C	38.17	D	36.12	C	267.17	D
W.S.4000ppm	30.00	D	32.33	E	30.60	D	211.97	E
Non-M.W. ×W.S.300ppm	52.67	b	54.67	b	51.73	b	423.31	b
Non-M.W. ×W.S.1000ppm (control)	45.33	c	47.00	c	44.48	c	350.76	c
Non-M.W. ×W.S.2000ppm	42.33	c	43.67	c	41.32	c	319.21	c
Non-M.W. ×W.S.3000ppm	30.33	d	31.33	d	29.65	d	202.51	d
Non-M.W. ×W.S.4000ppm	25.00	e	26.00	e	24.60	e	152.04	e
M.W. ×W.S.300ppm	57.33	a	63.00	a	59.62	a	502.17	a
M.W. ×W.S.1000ppm	50.67	b	56.00	b	52.99	b	435.92	b
M.W. ×W.S.2000ppm	45.33	c	50.00	c	47.31	c	379.15	c
M.W. ×W.S.3000ppm	40.33	c	45.00	c	42.58	c	331.83	c
M.W. ×W.S.4000ppm	35.00	d	38.67	d	36.59	d	271.90	d

	Second season (2017)							
Non-M.W.	35.67	B	36.87	B	34.89	B	254.87	B
M.W.	43.20	A	47.67	A	45.11	A	357.07	A
W.S.300ppm	55.67	A	59.67	A	56.46	A	470.62	A
W.S.1000ppm	41.67	B	45.00	B	42.58	B	331.83	B
W.S.2000ppm	38.50	C	40.83	C	38.64	C	292.40	C
W.S.3000ppm	32.50	C	34.67	D	32.80	C	234.05	D
W.S.4000ppm	28.83	D	31.17	E	29.49	D	200.93	E
Non-M.W. ×W.S.300ppm	48.00	b	49.33	b	46.68	b	372.84	b
Non-M.W. ×W.S.1000ppm (control)	39.00	c	40.67	c	38.48	c	290.83	c
Non-M.W. ×W.S.2000ppm	37.00	c	38.00	c	35.96	c	265.59	c
Non-M.W. ×W.S.3000ppm	29.00	d	30.00	d	28.39	d	189.89	d
Non-M.W. ×W.S.4000ppm	25.33	e	26.33	e	24.92	e	155.19	e
M.W. ×W.S.300ppm	63.33	a	70.00	a	66.24	a	568.41	a
M.W. ×W.S.1000ppm	44.33	b	49.33	b	46.68	b	372.84	b
M.W. ×W.S.2000ppm	40.00	c	43.67	c	41.32	c	319.21	c
M.W. ×W.S.3000ppm	36.00	c	39.33	c	37.22	c	278.21	c
M.W. ×W.S.4000ppm	32.33	c	36.00	c	34.07	c	246.67	c

Non-M.W. = non magnetized water; M.W. = magnetized water; W.S. = Water salinity.
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Discussion

Magnetic water is one of several physical factors affects plant growth. It has positive effect on the growth parameters, opened stomatal percentage, free water percentage, bound water percentage, leaf pigments content, nitrogen percentage, phosphorus percentage, potassium percentage and root extension.

Regarding, the results obtained in Tables (2, 3, 4, 5 and 6) showed that, plants irrigated with magnetic water with 2000 ppm of water salinity were in the same rank with the plants irrigated with 1000 ppm of water salinity with non-magnetized water (control). The stimulatory effect of the application of magnetic water on the growth parameters reported in this study may be attributed to the increase in photosynthetic pigments (Table 4), increase N, P, K percentage (Table 5) and root extension (Table 6). The increasing in those parameters may be due to that, the magnetic water effect on phyto-hormone production leading to improving cell activity, increased mobile forms of fertilizers, increased water absorption, enhanced moisture content, increased photosynthetic pigments, increased endogenous IAA and increased activated the bio-enzyme systems which leads to the growth improvement (Hozayn and Abdul-Qados, 2010; Ali *et al*., 2011; Mostafazadeh-Fard *et al*., 2011; Aly*et al*., 2015).

However, the plant did not have to close stomata, increase proline content or increase osmotic pressure (Table 3 and 4)in magnetized water with 2000 ppm of water salinity treatment, which were equal to (control) non-magnetized water combined with 1000 ppm of salinity treatment without any significant differences. This trend was in both two seasons, which means the plant were not affected by 2000 ppm of water salinity to the point of feeling threatened and forced to increase those parameters.

According to Aly *et al*., 2015; Falivene *et al*., 2016; Mostafa *et al*., 2016 magnetic water may be responsible of increasing leaching of excess soluble salts, lowering soil alkalinity, dissolving slightly soluble salts (carbonates, phosphates and sulfates), increasing water absorption and enhancing moisture content, which explain the low values of Na and Cl by using 2000 ppm of water salinity with magnetized water (Table 5).

At the same time, latest research reports makes us suggest the role of cryptochrome in this process. Cryptochromes (CRY) are photosensory receptors that regulate growth and development in plants and the circadian clock and controlling photomorphogenesis in response to blue or ultraviolet (UV-A) light in plants. Cryptochromes are probably the evolutionary descendents of DNA photolyases, which are light-activated DNA-repair enzymes, so we suggest that the H_2O magnetized molecule which is magnetic energy carrier in somehow and by some cellular mechanisms succeeded to transfer this energy to cryptochromes molecule, which led to this apparent improvement in the studied parameters. This hypothesis has been enhanced by the results of the researches which confirmed that the cryptochromes is affected and responded to the magnetic field (Maffei, 2014), in addition to many other researches which clarified and affirmed the cryptochromes role in blue light regulation , photoperiodic and flowering control (Ahmed and Cashmore, 1993; Guo *et al*., 1998).

Additionally, the cryptochrome has its powerful link noticing that the increment of leaf chlorophyll content under magnetized water treatment especially if reconnecting our results with the data obtained by (Figueroa and Niell, 1988) who mentioned that, the amount of chlorophyll accumulated is greater in blue light, which implies the action of cryptochrome, according to the criteria for the specific blue light photoreceptor involvement and this supports our suggestion which had mentioned before.

Finally it is likely to suggest that the magnetic water which is loaded with magnetic energy affects and activates the cryptochromes so all characters regulated by cryptochromes had also been activated which led to the improvement of these parameters. This information will be so helpful not only to explain currant results but also to answer many questions related to the relationship of magnetism and plant performance under stress (biotic and abaiotic), salinity, efficiency of fertilization ,plant defense system,……. etc.

In this respect, Our results are in agreement with those obtained by other researchers Hozayn and Abdul-Qados, 2010 on wheat; Sadeghipour and Aghaei, 2013 on cowpea; Hassan, 2014 on *Calendula officinalis* L; Aghamir *et al*., 2015 on bean; Aly *et al*., 2015 on Valencia orange; El-Shokali *et al*., 2015 on tomato and sunflower; Jogi *et al*., 2015 on brassica plants; Hozayn *et al*., 2016 on Canola; Mostafa *et al*., 2016 and Mahmoud *et al.,* 2018 on Washington orange trees.

Conclusion

The results of the present investigation revealed that, using magnetized water technique even under salinity condition had a high positive effect on Washington orange seedling. Regarding, the highest values for growth parameters, opened stomatal percentage, free water percentage, bound water percentage, leaf pigments content, nitrogen percentage, phosphorus percentage, potassium percentage and root extension were obtained by magnetized water combined with water salinity (300 ppm). However, the effect of magnetized water combined with 1000 or 2000 ppm of water salinity for the above parameters have statistically values over than or equal to (control) non-magnetized water combined with 1000 ppm of salinity. On the contrary, closed stomata percentage, cell sap osmotic pressure, proline, sodium percentage and chloride percentage as a salinity indicators in plant gained low values with magnetized water combined with 1000 or 2000 ppm of water salinity, which have statistically values lower than or equal to (control) non-magnetized water combined with 1000 ppm of salinity. Those indicators levels in plant did not effect by 2000 ppm of water salinity under magnetized water compared to (control) non-magnetized water combined with 1000 ppm of salinity. Lastly, these results showed that, it could use water salinity reached to 2000 ppm without any harmful effects or any decrease in growth parameters by using magnetic water irrigation.

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