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Effect of Magnetized Water and Different Levels of Water Supply on Growth and Yield of Navel Orange Trees

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Abstract: Water deficiency is a global dilemma that limits sustainable development plans in many countries, particularly in arid and semi-arid regions such as Egypt. Citrus is classified as one of the crops that are sensitive to water stress and low water quality, since exposing it to stress, leads to reducing its productivity. Therefore, the need arose for this study, which was carried out during 2016 and 2017 seasons on ten-years-old Washington navel orange trees (*Citrus sinenses*) budded on sour orange rootstock (*Citrus aurantium* L.) under sandy loam soil conditions at Belbeis region – El Sharkia Governorate, Egypt. The study aimed to improve water use efficiency and maximize water utilization by using magnetized water technique at different levels of water supply (100, 80 and 60% of ETc i.e. evapotranspiration) under drip irrigation system with high quality River Nile water to determine the most effective treatment. The data revealed that, the irrigation water quantity can be reduced by 20% while maintaining the production and the possibility of increasing it by using magnetic water technique. Additionally, the water use efficiency and the water unit economic return were higher even with the reduction of water quantity by 40%. The most effective treatment in the first season was achieved by magnetized water at 100% or 80% ETc that produced 2.54 and 2.57kg fruit for each cubic meter of irrigation water, respectively. In the second season, magnetized water at 100% ETc produced 3.22 kg fruit for each cubic meter of irrigation. Using magnetic water technique can maximize the utilization of high quality water and reduce the amount of irrigation water consumed.

Key words: Washington navel orange · Citrus · Magnetized water · Water supply · Water stress · Evapotranspiration · Cryptochrome

INTRODUCTION

Citrus is classified as a sensitive crop to water scarcity, which is one of the major causes of low productivity and decline of citrus orchards. Water deficit in citrus diminishes vegetative growth, yield and sometimes quality, causing important economic losses [1].

Previous studies under Egyptian conditions exhibited a wide range of irrigation rate needed for orange orchards that could reach sometimes 8000 m^3 / fed./ year or more [2, 3]. The general trend in those studies showed that increasing irrigation rate caused promotions in many characteristics, which leads to an increment in both vegetative growth and fruiting and finally profitable yield [3-5].

High water consumption is not consistent with the adoption of the Egyptian agricultural policy to reducing water consumption , in the same time increasing water unit return for citrus (EGP/ cubic meter of irrigation water) to reach 7.14 EGP by the year 2030 (SADS: Sustainable Agricultural Development Strategy towards 2030).

The River Nile as a major source of water in Egypt, puts it under enormous pressure especially in view of the competitive situation with neighboring countries, many steps need to be taken to conserve both the quantity and quality of water and appropriate strategies will have to be developed to avoid risk to future water supplies. Water irrigation accounted for over 81.5 % of the total water use in Egypt according to statistics of Central Agency for Public Mobilization and Statistics (2016) then the main efficiency gains must come from reducing the amount of water used for irrigation.

One of the ways, which can reduce the total water used for irrigation, is to employ practices that improve crop yield per unit volume of water used (i.e., water productivity or water use efficiency). Magnetized water

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could be one of these practices [6]. In addition, magnetized water is an inexpensive and environmentally friendly, has small installation fees and no energy requirements. So it is possible to say that magnetic field and magnetized water irrigation improved the plant growth characteristics, root function, influenced the chemical composition of plants, affected soil nutrient availability, activated plant enzymes and thereby increased the yield according to Hozayn and Abdul-Qados [7], Alikamanoglu and Sen [8], Mostafazadeh-Fard *et al.* [9] and Radhakrishnan and Kumari [10]. In the meantime, it is so important to focus on the results of Bondarenko *et al.* [11]. They mentioned that the main effects of magnetic treatment of irrigation water were the products of high-energy reactions such as free radicals, atomic oxygen and nitrogen-containing compounds, which found in the treated water, also, a magnetic field causes redistribution of flow energy due to the momentum change of charged particles.

Cryptochromes 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 also regulate over a dozen other light responses, including circadian rhythms, tropic growth, stomata opening, guard cell development, root development, bacterial and viral pathogen responses, a biotic stress responses, cell cycles, programmed cell death, apical dominance, fruit and ovule development, seed dormancy and magneto reception. Cryptochromes have two domains, the N-terminal PHR (Photolyase-Homologous Region) domain that bind the chromophore FAD (flavin adenine dinucleotide) and the CCE (CRY C-terminal Extension) domain that appears intrinsically unstructured but critical to the function and regulation of cryptochromes. Most cryptochromes accumulate in the nucleus and they undergo blue light-dependent phosphorylation or ubiquitination. It is hypothesized that photons excite electrons of the flavin molecule, resulting in redox reaction or circular electron shuttle and conformational changes of the photoreceptors. The photo excited cryptochromes phosphorylated to adopt an open conformation, which interacts with signaling partner proteins to alter gene expression at both transcriptional and posttranslational levels and consequently the metabolic and developmental programs of plants [12]. It is highly important to refer to what had been confirmed by Maffei [13], who stated that the cryptochromes are affected and responded to the magnetic field, the importance of the previous remark due to it may be the link between the magnetized water and cryptochromes.

The aim of this study was of prime importance to improve water use efficiency and increase the water unit return for citrus to reach the target of SADS 2030 (Sustainable Agricultural Development Strategy towards 2030, i.e 7.14 EGP / one cubic meter of irrigation water for citrus crop) by using magnetized water combined with different levels of water supply (100, 80 and 60% of ETc) under drip irrigation system and to provide further physiological understanding about the magnetization of water and its impact on citrus plants.

MATERIALS AND METHODS

The present investigation has been carried out during two successive seasons (2016 and 2017) to improve water use efficiency and increase water unit return for citrus by studying the effect of magnetized water and different levels of water supply (100, 80 and 60% of ETc) on growth, flowering, fruit set and yield of Washington navel orange trees (*Citrus sinenses (L.) Osbeck)* budded on sour orange (*Citrus aurantium L.*) rootstock. The experimental trees were ten years old and grown at 4×5 meters, in sandy loam soil under drip irrigation system using River Nile water in a private orchard at Belbeis region, El Sharkia Governorate, Egypt.

All the trees of this study received the same horticultural practices except experimental treatments. The experimental design was split plot arrangements of randomized complete block design with three replicates and two trees for each replicate. The main plot (first factor) comprised magnetized or non-magnetized water (control), the sub-plot (second factor) had three irrigation levels (100, 80 and 60% of ETc). The main plot (first factor) included water types:1- magnetized water (diameter of magnetic device was 2.5 inches, 12000 gauss and with output of 40 m^3 /hr.) and 2-normal water (control). The sub-plot (second factor) was irrigation levels, the tested irrigation levels are based on different rates of irrigation water i. e. 4509.02, 3608.30 and 2705.48 m^3 /fed./year. These values resulted from the FAO – Penman - Moteith equation, evapotranspiration rat (ETo) calculated with CROPWAT v.8.00 computer program using meteorological data of the region and characteristics of the experimental trees.

The Tested Treatments Were Evaluated Through the Following Parameters

Tree Volume and Roots Behavior (Length of Fibrous Roots): Tree height (m), tree diameter (m), tree circumference (m) and tree canopy volume (m^3) were determined in both of seasons study. The tree canopy volume was calculated according to the following equation: Canopy volume (m^3) =1.33 x 0.5 x circumference (m) x 3.14 x 0.5 x height (m) [14]. Tree volume increment had been calculated by subtracting tree volume at the beginning and at the end of each season, In addition, the total length of fibrous roots in 500 cm^3 soil samples were taken from the layers of 0-30cm from soil surface at the beginning of the experiment then at the end of each season (December).

Flowering and Fruit Set: Sixteen twigs per tree (four twigs in each side) had been chosen to collect the data. The number of leafy and leafless inflorescences per twig were counted and recorded then leafy inflorescences percentages were calculated according to the following equation:

$$\text{Leafy inflorescences (\%)} = \frac{\text{Leafy inflorescences}}{\text{Total inflorescences}} \times 100$$

In addition, the total number of flowers per twig was counted and recorded at full bloom. In the same time, the number of set fruitlets per twig was counted and recorded after fruit set stage. Finally, the fruit set percentage was calculated according to the following equation:

$$\text{Fruit set (\%)} = \frac{\text{Number of set fruitlet}}{\text{Number of total flowers}} \times 100$$

Leaf Photosynthetic Pigments, Proline, Cell Sap Osmotic Pressure and Opened Stomata Percentage: 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 [15]. Moreover, the proline content of fresh leaves (µ moles/g fresh weight) was determined following the method adopted by Bates *et al.* [16]. Leaf osmotic pressure of the cell sap of leaf blades was determined following the method of Gosov [17]. The total number of stomata and the number of opened stomata /cm^2 of leaf area was determined using the method of Stino *et al.* [18] the percentage of opened stomata was calculated according the following equation:

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

Fruit Physical Properties: Samples of 32 fruits per each replicate (16 fruits per each tree) were randomly taken, the studied parameters involved: fruit weight (g), fruit height (cm), fruit diameter, (cm) fruit shape index (height / diameter) and juice volume cm^3.

Chemical Constituents of the Fruit Juice: The following parameters were considered: total soluble solids percentage (TSS) was determined using a hand refractometer, total titratable acidity as g citric acid / 100 ml of juice was determined by titration against 0.1 N sodium hydroxide in presence of phenol phthalin as an indicator, values of the TSS /acid ratio were calculated, ascorbic acid content (mg / 100 ml of juice) was determined by titration against 2, 6- dichlorophenol indophenols pigment (mg/ 100 ml) following the method illustrated in the A.O.A.C. [19].

Yield, Water Use Efficiency and Water Unit Return: At harvesting (December), the numbers of harvested fruits per tree were counted, the total weight of all fruits per tree (the yield/tree, in kg) was determined and recorded and the hypothetic yield/ fed. [on basis of 210 trees/fed. (4x5m apart)] was calculated.

Water use efficiency (WUE) values were calculated according to the following equation [20],

$$\text{WUE} = \frac{Yield\ (kg\ per\ feddan)}{Seasonal\ ET\ (m3\ per\ feddan)}$$

Water unit returns (WUR) were calculated according to the following equation: Water unit return = WUE × price of 1kg orange (4 EGP).

Statistical Analysis: The experimental design was split plot arrangement of complete randomized block design (factorial experiment -split plot design) with three replicates and two trees for each replicate. The main plot contained magnetized or non-magnetized water (control), the sub-plot comprised three water irrigation levels (100, 80 and 60% of ETc). The data obtained were statistically analyzed using the analysis of variance method reported by Snedecor and Cochran [21]. The differences between means were differentiated by using Duncan's range test [22].

RESULTS AND DISCUSSION

The obtained data disclosed significant increments in magnetized water treatments for all morpho-phenological parameters displayed in Table (1) starting

Table 1: Effect of water type and water supply levels on morpho-phenological parameters of fruits per tree and tree yield of Washington navel orange trees (2016 & 2017 seasons)

Treatments	Tree canopy volume increment (m^3)		Total length of fibrous roots (cm) / 500 cm^3 soil in 0-30 cm soil layer		Percentage of leafy inflorescences		Overall fruit set percentage per twig		Number of fruits per tree		Tree yield (kg)	
	First season (2016)											
Control	4.74	B	115.73	B	57.82	B	6.08	B	84.36	B	24.99	B
Magnetized water (M. w.)	6.93	A	158.56	A	71.22	A	7.31	A	126.77	A	40.94	A
100% ETc	7.87	A	162.44	A	73.62	A	9.06	A	132.67	A	42.40	A
80% ETc	6.14	B	141.41	B	62.83	B	6.33	B	114.08	B	35.08	B
60% ETc	3.50	C	107.59	C	54.21	C	4.70	C	69.94	C	21.10	C
Control×100%ETc	5.83	c	132.61	c	64.28	c	8.24	b	102.87	c	31.25	c
Control×80%ETc	5.10	d	119.93	d	55.47	d	5.57	d	88.94	d	26.52	d
Control×60%ETc	3.31	e	94.67	e	50.64	e	4.41	f	61.28	f	17.56	e
M. w.×100%ETc	9.92	a	192.28	a	81.03	a	9.87	a	162.48	a	54.48	a
M. w.×80%ETc	7.18	b	162.89	b	68.80	b	7.08	c	139.21	b	44.09	b
M. w.×60%ETc	3.70	e	120.52	d	57.36	d	4.99	e	78.61	e	24.91	d
	Second season (2017)											
Control	6.86	B	117.06	B	59.53	B	8.23	B	92.63	B	26.93	B
Magnetized water (M. w.)	10.37	A	158.19	A	75.28	A	10.09	A	138.94	A	43.86	A
100% ETc	12.16	A	167.75	A	72.88	A	11.24	A	159.79	A	50.86	A
80% ETc	8.76	B	140.65	B	70.68	A	9.32	B	114.09	B	34.15	B
60% ETc	4.93	C	104.48	C	57.48	B	6.93	C	73.47	C	21.45	C
Control×100%ETc	8.72	c	133.93	c	56.61	e	10.00	c	115.32	c	34.39	c
Control×80%ETc	7.40	d	121.25	d	67.87	c	8.21	d	98.23	d	28.75	d
Control×60%ETc	4.46	f	95.99	f	53.70	f	6.50	f	64.34	f	18.09	e
M. w.×100%ETc	15.60	a	201.57	a	85.93	a	12.49	a	204.26	a	69.13	a
M. w.×80%ETc	10.13	b	160.05	b	72.96	b	10.42	b	129.96	b	39.76	b
M. w.×60%ETc	5.40	e	112.96	e	60.83	d	7.35	e	82.61	e	25.01	d

M.w. = magnetized water, control = non-magnetized water, ETc = evapotranspiration.
Means followed by the same letter\s within each column are not significantly different from each other at 0.5% level

with an increment in tree volume rate, leafy inflorescences percentage which is considered as a preliminary predictor of yield status, fruit set and length of fibrous roots which were also reflected in the increase of tree yield and hypothetic yield per feddan. Actually, it is too difficult to extend logical explanation for obvious improvement in the current parameters or the following parameters that will be discussed later (chlorophylls, stomata…. act) under magnetized water effect without considering them as one package under a central control unit that influenced in these parameters together.

From the latest and sophisticated research reports it could be deduced and strongly point out to 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 are affected and responded to the magnetic field, in addition to many other researches which clarified and affirmed the cryptochromes role in blue light regulation, photoperiodic and flowering control [13, 23, 24]. Likewise, they regulate other aspects of plant growth and development, including entrainment of the circadian clock, guard cell development and stomatal opening, root growth, plant height, fruit and ovule size, tropic growth, apical dominance, apical meristem activity, programmed cell death, the high-light stress response, osmotic stress response, shade avoidance and responses to bacterial and viral pathogens [25-43].

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 current results but also to answer many questions related to the relationship of magnetism and plant performance under stress (biotic and abiotic), salinity, efficiency of fertilization , plant defense system, ……. etc.

Results regarding conserving magnetized water were in agreement with those mentioned by Hassan [44] on *Calendula officinalis* L, Mohammed [45] on cucumber, Aly *et al.* [46] on Valencia orange and Mostafa *et al.* [47] on Washington orange trees. At the same time, the magnetic treatment effect on phyto-hormone production leading to improving cell activity, increased mobile forms of fertilizers, increased water absorption, enhanced moisture content, increased photosynthetic pigments and endogenous IAA [9, 46, 48]. Also, magnetic treatment 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 [46-50]. As well as increased mobile forms of fertilizers, increased photosynthetic pigments, activated phytohormones such as gibberellic acid-equivalents, indole-3-acetic acid (leading to improved cell activity) and activated the bio-enzyme systems which leads to the growth improvement and increase the crop yield [7, 48].

As for water supply levels, the obtained results revealed that plant volume and roots behavior were affected significantly by water supply levels our results are in harmony with results found by Koshita and Takahara [51] on Satsuma mandarin, Mahmoud [3] on navel orange and Melgar *et al.* [52], Mahmoud and Youssef [50] on Valencia oranges, Falivene *et al.* [49] and Dorji *et al.* [53] on citrus trees. The increase in plant volume and root behavior might be due to the effect of water on some metabolic processes in the plant cell. Besides the increasing soil moisture might have increased soil available N, K and P in root zone and its uptake [54, 55].

The data in Table (2) demonstrated clearly the ability of the cellular system to deal with the quantitative deficiency of water by different mechanisms, despite the increased amount of proline, which is one of the indicators of plant exposure to stress, as shown in 60 % ETc whatever it was control or magnetized treatment. However, the plant did not have to close the stomata in M.W 60% ETc treatment and the opening stomata percentage in this treatment was equal to control 100% ETc treatment without any significant differences. This trend held true in both two seasons, which means that plant cells were not affected or witnessed this deficiency of water quantity to the point of feeling threatened and forced to close their stomata. In other words, it may be possible to say that the presence of magnetism protecting biochemical and biological processes inside the cell from being affected by water deficiency , also water molecule (as quantum) which is essential for all cell biochemical reactions and responsible for cell vitality was not effective as magnetized water molecule (energy carrier) in activating cellular reactions and this fact confirms that plant cell may have numerous mechanisms during water deficiency in the same time the leaf cell sap osmotic pressure had the same trend of proline to maintain the continuous flow of water to cells.

Additionally, the cryptochrome has its powerful link assuming the increment of leaf chlorophyll content under magnetized water treatment and by binding our results with those obtained by Figueroa and Niell [56], 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 which supports our suggestion mentioned earlier.

On the contrary the previous studies showed that , water stress effect on stomatal closure, which lowers or prevents water loss and reduces CO_2 availability for the chloroplast and reduction in photosynthesis as well as a massive and irreversible expansion of small daughter cells produced by less meristematic divisions and inhibition of cell expansion [55, 57, 58].

For magnetized water, the results were in harmony with those reported by Sadeghipour and Aghaeion [59] on cowpea, Hassan [44] on *Calendula officinalis* L, Aghamir *et al.* [60] on bean, Jogi *et al.* [61] on brassica plants and Hozayn *et al.* [62] on Canola.

Regarding water supply levels, the obtained results reveal that leaf photosynthetic pigments were affected significantly by water supply levels. Such finding is in harmony with the results found by XiaoLi *et al.* [63] on citrus trees, Malik *et al.* [64] on Satsuma mandarin trees, ShenXi *et al.* [65] on citrus trees and Mahmoud and Youssef [50] on Valencia orange trees.

Data presented in Table (3) showed sovereignty and superiority of magnetized water treatments in all physical and chemical fruit parameters, except juice acidity, with significant differences in both seasons of the study. This refers to the clear improvement in intracellular processes, which was reflected in the improvement of these apparent qualities and treatment with magnetized

Table 2: Effect of water type and water supply levels on leaf photosynthetic pigments and proline contents, cell sap osmotic pressure and opened stomata percentage of Washington navel orange leaves (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 proline content (µ g / moles of leaf F. W.)		Leaf cell sap osmotic pressure(atm.)		Opened stomata percentage	
	First season (2016)									
Control	169.15	B	79.12	B	87.91	A	21.70	A	77.01	B
Magnetized water (M. w.)	186.84	A	87.40	A	79.05	B	21.28	B	85.07	A
100% ETc	184.26	A	85.81	A	27.04	C	18.86	C	83.41	A
80% ETc	181.64	A	84.87	A	82.82	B	21.46	B	82.58	A
60% ETc	168.08	B	79.10	B	140.58	A	24.15	A	77.13	B
Control×100%ETc	176.75	b	82.31	b	27.72	e	18.89	e	80.01	b
Control×80%ETc	171.11	b	79.95	b	86.60	c	21.64	c	77.79	c
Control×60%ETc	159.60	c	75.10	c	149.41	a	24.56	a	73.24	d
M. w.×100%ETc	191.78	a	89.31	a	26.35	e	18.83	e	86.82	a
M. w.×80%ETc	192.17	a	89.79	a	79.05	d	21.28	d	87.37	a
M. w.×60%ETc	176.57	b	83.09	b	131.75	b	23.74	b	81.03	b
	Second season (2017)									
Control	171.35	B	79.98	B	85.43	A	21.58	A	79.03	B
Magnetized water (M. w.)	185.70	A	86.68	A	77.53	B	21.21	B	85.65	A
100% ETc	186.19	A	86.35	A	25.75	C	18.80	C	85.75	A
80% ETc	180.23	B	83.99	B	80.07	B	21.33	B	83.10	B
60% ETc	169.16	C	79.66	C	138.62	A	24.06	A	78.17	C
Control×100%ETc	179.35	b	83.18	b	26.76	e	18.85	e	82.60	b
Control×80%ETc	173.41	b	80.81	b	83.24	c	21.48	c	79.95	c
Control×60%ETc	161.30	c	75.96	c	146.30	a	24.42	a	74.54	d
M. w.×100%ETc	193.04	a	89.52	a	24.74	f	18.75	f	88.91	a
M. w.×80%ETc	187.06	a	87.17	a	76.90	d	21.18	d	86.24	a
M. w.×60%ETc	177.01	b	83.36	b	130.94	b	23.70	b	81.80	b

M.w. = magnetized water, control = non-magnetized water, ETc = evapotranspiration.
Means followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Table 3: Effect of water type and water supply levels on fruit weight, fruit shape index, juice volume, juice TSS, juice acidity, TSS/acid ratio and ascorbic acid of Washington navel orange fruits (2016 & 2017 seasons)

Treatments	Fruit weight (g)		Fruit shape index (length/diameter)		Juice volume/ fruit (cm^3)		Juice TSS (%)		Juice acidity (%)		TSS/acid ratio		Ascorbic acid (mg/100 ml)	
	First season (2016)													
Control	296.19	B	1.1126	A	167.21	B	11.07	B	0.76	A	14.58	B	39.05	B
Magnetized water (M. w.)	322.98	A	1.1126	A	182.34	A	12.27	A	0.71	A	17.32	A	43.31	A
100% ETc	319.57	A	1.1130	A	180.41	A	11.04	C	0.71	A	15.06	C	44.82	A
80% ETc	307.48	B	1.1127	A	173.59	B	11.70	B	0.75	A	15.81	B	41.75	B
60% ETc	301.69	B	1.1119	A	170.33	B	12.27	A	0.73	A	16.98	A	36.98	C
Control×100%ETc	303.81	c	1.1130	a	171.51	c	10.61	e	0.76	a	13.75	f	41.86	c
Control×80%ETc	298.23	c	1.1127	a	168.37	c	11.05	d	0.76	a	14.64	e	39.76	d
Control×60%ETc	286.53	d	1.1119	a	161.76	d	11.56	c	0.76	a	15.36	d	35.53	e
M. w.×100%ETc	335.34	a	1.1130	a	189.31	a	11.47	c	0.67	a	16.37	c	47.77	a
M. w.×80%ETc	316.73	b	1.1127	a	178.81	b	12.35	b	0.74	a	16.99	b	43.74	b
M. w.×60%ETc	316.86	b	1.1119	a	178.89	b	12.98	a	0.71	a	18.60	a	38.43	d
	Second season (2017)													
Control	290.70	B	1.1132	A	164.12	B	11.20	B	0.78	A	14.38	B	39.65	B
Magnetized water (M. w.)	315.71	A	1.1132	A	178.24	A	12.67	A	0.73	A	17.13	A	44.90	A
100% ETc	318.31	A	1.1137	A	179.71	A	11.33	C	0.75	A	14.96	C	47.09	A
80% ETc	299.32	B	1.1134	A	168.99	B	11.82	B	0.76	A	15.68	B	42.35	B
60% ETc	291.97	B	1.1126	A	164.84	B	12.66	A	0.77	A	16.64	A	37.39	C
Control×100%ETc	298.19	bc	1.1137	a	168.35	b	10.88	d	0.78	a	13.73	f	42.71	c
Control×80%ETc	292.70	c	1.1134	a	165.25	c	11.15	c	0.78	a	14.42	e	40.42	d
Control×60%ETc	281.19	d	1.1126	a	158.75	d	11.57	c	0.78	a	14.99	d	35.82	e
M. w.×100%ETc	338.43	a	1.1137	a	191.07	a	11.77	c	0.71	a	16.18	c	51.47	a
M. w.×80%ETc	305.94	b	1.1134	a	172.72	b	12.50	b	0.73	a	16.94	b	44.28	b
M. w.×60%ETc	302.75	bc	1.1126	a	170.92	b	13.75	a	0.76	a	18.28	a	38.95	d

M.w. = magnetized water, control = non-magnetized water, ETc = evapotranspiration.
Means followed by the same letter\s within each column are not significantly different from each other at 0.5% level

water that rendered the plant to be tolerant to water deficiency. This obvious effect is clearly shown in fruit juice volume character which was increased by water magnetized treatment, which means that the abundance of water in the fruits and the plant did not have to retention water in the leaves or its vascular system, because water quantity is completely sufficient for biochemical and biological processes, even with M. w. ×60%ETc the fruit juice volume was higher than it in treatment with control×100%ETc. Moreover, it could be mentioned that the genetic characteristic traits of the species as Washington navel orange have not changed by magnetized water as it was evident in fruit shape index parameter.

For magnetized water, the obtained results were in the same line with Al-Shrouf [66] on cucumber, Aly *et al.* [46] on Valencia orange and Mostafa *et al.* [47] on Washington orange. In the same time, it is important to refer to researches that exhibit the role of cryptochrome to explain our data such as those obtained by El-Assal *et al.* [33] and Fruhwirth *et al.* [67] who stated that CryB does not only influence photosynthesis gene expression but also genes for the non-photosynthetic energy metabolism like Krebs cycle and oxidative phosphorylation. These results are in harmony with our data, which exhibit a significant increasing in TSS % and ascorbic acid with magnetized water treatments despite the approximate stability in Juice acidity with insignificant values.

Regarding water supply levels, the results of the present investigation confirmed those obtained by Treeby *et al.* [68] on Bellamy navel orange.

Results in Table (4) summarize the benefits of our study. The highest significant increment in hypothetic yield per feddan (ton / feddan) was gained by using a magnetized water treatment which recorded 8.60 tons / feddan while non-magnetized water treatment (control) produced only 5.25 tons / feddan. In addition, the interaction between magnetized water and water supply levels showed that M.w.×80%ETc recorded 9.26 tons / feddan and control × 100%ETc produced 6.56 tons / feddan, which means that magnetized water treatment increased yield by 29.1 % , while reducing water consuming by 20 % (900.72 m^3 water), this trend held true in both seasons. With a more comprehensive view, these results can not be evaluated without reference to WUE (Water use efficiency - kg fruit /m^3 water) and WUR (water unit return - EGP/m^3 water) to express them economically as a monetary product of the water unit, so, if the results have generally shown superiority of magnetized water treatment in WUE and WUR but the interaction clarified that the magnetized water treatment combined with 60%ETc was better than the control combined with 100% ETc where the values recorded for M. w.× 60%ETc were 1.93 for WUE and 7.72 for WUR while control×100%ETc recorded 1.46 for WUE and 5.84 for WUR with obvious and high significant differences , even if it was less in yield (5.23 T/F) but it was better in water use efficiency and the economic return from using the water unit. A parallel trend was also observed in the second season.

Finally, it could be possible to state that magnetized water treatments achieved what is targeted for citrus in SADS (Sustainable Agricultural Development Strategy towards 2030) by reducing the amount of water used to irrigate citrus orchards by a rate ranging from 20 to 40 %, in the same time increased the water unit return(WUR) to reach 7.72 EGP / one cubic meter of irrigation water, at 40 % saved water and could reach 9.24 EGP / one cubic meter of irrigation water at 20 % saved water.

Results of the present investigation revealed that yield characteristics were affected significantly by water magnetization. They are in harmony with those observed by Mohammed [45] on cucumber, Aly *et al.* [46] on Valencia orange, El-Shokali *et al.* [69] on tomato and sunflower, Hozayn *et al.* [62] on canola [62] and Mostafa *et al.* [47] on Washington orange trees. In view of the preceding results, it appears that magnetic treatment might have increased leaching of excess soluble salts, lowering soil alkalinity, dissolving slightly soluble salts (carbonates , phosphates and sulfates) increasing water absorption and enhancing moisture content [9, 46, 47]. The increased mobile forms of fertilizers, also might have increased photosynthetic pigments, activated phytohormones such as gibberellic acid-equivalents, indole-3-acetic acid (leading to improved cell activity) and activated the bio-enzyme systems which leads to growth improvement and increase the crop yield [7, 48].

Regarding water supply levels, the present investigation agree with the finding mentioned earlier by Mahmoud [3] on Washington navel orange trees, Melgar *et al.* [52] on Valencia oranges, as well as Dorji *et al.* [53] and Falivene *et al.* [49] on citrus trees. This result may be due to that using high water irrigation supply possibly due to the increase in soil moisture availability [49, 50, 51]. This increase in yield might be due to the effect of water on some metabolic processes in the plant cell. Besides the increase in soil moisture might have increased soil available N, K and P and their uptake in zone of roots as well as enhanced photosynthetic processes, carbohydrates production and yield [54, 55].

Table 4: Effect of water type and water supply levels on hypothetic yield per feddan, water use efficiency and water unit return of Washington navel orange trees (2016 & 2017 seasons).

Treatments	Hypothetic yield per feddan (ton)		Water use efficiency (kg fruit /m^3 water)		Water unit return (EGP/m^3 of water)	
	First season (2016)					
Control	5.25	B	1.45	B	5.80	B
Magnetized water (M. w.)	8.60	A	2.35	A	9.40	A
100% ETc	8.90	A	2.00	A	8.00	A
80% ETc	7.37	B	2.06	A	8.24	A
60% ETc	4.43	C	1.65	B	6.60	B
Control×100%ETc	6.56	c	1.46	d	5.84	d
Control×80%ETc	5.57	d	1.54	c	6.16	c
Control×60%ETc	3.69	e	1.36	e	5.44	e
M. w.×100%ETc	11.44	a	2.54	a	10.16	a
M. w.×80%ETc	9.26	b	2.57	a	10.28	a
M. w.×60%ETc	5.23	d	1.93	b	7.72	b
	Second season (2017)					
Control	5.65	B	1.56	B	6.24	B
Magnetized water (M. w.)	9.21	A	2.49	A	9.96	A
100% ETc	10.68	A	2.41	A	9.64	A
80% ETc	7.17	B	1.99	B	7.96	B
60% ETc	4.50	C	1.67	C	6.68	C
Control×100%ETc	7.22	c	1.60	d	6.40	d
Control×80%ETc	6.04	d	1.67	d	6.68	d
Control×60%ETc	3.80	f	1.40	e	5.60	e
M. w.×100%ETc	14.52	a	3.22	a	12.88	a
M. w.×80%ETc	8.35	b	2.31	b	9.24	b
M. w.×60%ETc	5.25	e	1.94	c	7.76	c

M.w. = magnetized water, control = non-magnetized water, ETc = evapotranspiration.

Means followed by the same letter\s within each column are not significantly different from each other at 0.5% level

CONCLUSION

It could be mentioned on the basis of the obtained results that, using magnetized water technique had a high economic return through increasing total yield, water use efficiency and water unit return (WUR) which reached to 12.88 EGP / one cubic meter of irrigation water with the same usual amount of water (M. w.×100%ETc).

In addition, the amount of water used to irrigate citrus orchards could be decreased by 20% simultaneously with increasing yield by 29.1 % , WUR to 9.24 EGP / one cubic meter of irrigation water, or saving about 40 % of used water, achieving WUR 7.72 EGP / one cubic meter of irrigation water as well fulfillment the target of SADA in year 2030 (Sustainable Agricultural Development Strategy towards 2030) which should be 7.14 EGP / one cubic meter of irrigation water for citrus.

Even though reducing of water quantity in some treatments reached 40% yet, the magnetism might have protected cell biochemical and biological processes from being affected by water deficiency. Thus, water molecule (as quantum) which is essential for all cell biochemical reactions and responsible for cell vitality was not effected as water molecule loaded by magnetic energy in activating cellular reactions.

Moreover, it is possible to introduce cryptochrome as a key providing better and deeper physiological understanding for plant intercellular system response to magnetic energy and magnetized water effect and further investigations are also needed to clarify this relationship.

Finally, it could be pointed out that biophysics could be a distinguished and safe alternative tool to solve many problems in agriculture and far from chemicals and their serious health effects.

REFERENCES

1. Romero, P., J.M. Navarro, J. Perez-Perez, F. Garcia-Sanchez, A. Gomez-Gomez, I. Por-ras, V. Martinez and P. Botia, 2006. Deficit irrigation and rootstock: their effects on water relations, vegetative development, yield, fruit quality and mineral nutrition of *Clemenules mandarin*. Tree Physiology, 26: 1537-1548.
2. Abd-El Aziz, R.A., 2004. Effect of some irrigation treatments on the physiological activities of Balady orange trees. Ph. D. Thesis, Faculty of Agriculture, Zagazig University, Egypt, pp: 206.

3. Mahmoud, T.A., 2012. Effect of some irrigation and growth regulator treatments on growth and fruiting of Washington navel orange trees. Ph. D. thesis, Faculty of Agriculture, Zagazig University, Egypt, 208.
4. Wassel, A.H., F.F. Ahmed, M.A. Ragab and M.M. Ragab, 2007. Response of Balady mandarin trees to drip irrigation and nitrogen fertigation. 8th African Crop Science Society Conference, El-Minia, Egypt, 27(31): 503-511.
5. Panigrahi, P. and A.K. Strivastava, 2011. Deficit irrigation (DI) scheduling for mature Nagpur mandarin (*Citrus reticulata* Blanco) trees of central India. Indian Journal of Soil Conservation, 39(2): 149-154.
6. Diaz, D.C.E., J.A. Riquenes, B. Sotolongo, M.A. Portuondo, E.O. Quintana and R. Perez, 1997. Effects of magnetic treatment of irrigation water on the tomato crop. Horticultural Science Abstracts, 69: 494.
7. Hozayn, M. and A.M.S.A. Abdul-Qados, 2010. Magnetic water application for improving wheat (*Triticum aestivum* L.) crop production. Agriculture and Biology Journal of North America, 1(4): 677-682.
8. Alikamanoglu, S. and A. Sen, 2011. Stimulation of growth and some biochemical parameters by magnetic field in wheat (*Triticum sativum* L.) tissue cultures. African Journal of Biotechnology, 10: 10957-10963.
9. Mostafazadeh-Fard, B., M. Khoshravesh, S.F. Mousavi and A.R. Kiani, 2011. Effects of magnetized water and irrigation water salinity on soil moisture distribution in trickle irrigation. Journal of Irrigation and Drainage Engineering, 137(6): 398-403.
10. Radhakrishnan, R. and B.D.R. Kumari, 2012. Pulsed magnetic field: A contemporary approach offers to enhance plant growth and yield of soybean. Plant Physiology and Biochemistry, 51: 139-144.
11. Bondarenko, N.P.H., E.Z. Gak, E.E. Rokhinson and I.P. Ananyev, 1999. Magnetic treatment of irrigation water: experimental results and application conditions. Environmental Science Technology, 33: 1280-1285.
12. Yu, X., H. Liu, J. Klejnot and C. Lina, 2010. The Cryptochrome Blue Light Receptors. The Arabidopsis Book, American Society of Plant Biologists, First published on September 23, 10.1199/tab.0135
13. Maffei, M.E., 2014. Magnetic field effects on plant growth, development and evolution. Plant Science, 04(5): 445-460.
14. Turell, F.M., 1965. Comparative nocturnal thermal budgets of large and small citrus trees. Ecology, 46: 25-34.
15. Von-Wettestein, D., 1957. Chlorophyll Lethal und Submikroskopischefromivechsel der Plastiden Exptl. Cell Research, 12: 427-433.
16. Bates, L.S., R.R. Walren and I.D. Tears, 1973. Rapid determination of proline for water stress studies. Plant and Soil, 39: 205-207.
17. Gosov, N.A., 1960. Some Methods in Studying Plant Water Relations. Leningrad. Acad. Of Science, USSR.
18. Stino, G.R., M.M. El- Azzouni, K.M. Abdalla and A.M. Mohsen, 1974. Varietal studies in relation to zone of plantation in ARE. Egypt. Journal Horticulture, 1(2): 145-156.
19. A.O.A.C., 1985. Official Methods of Analysis of the Association of Official Agric. Chemists. 13th Ed. Benjamin Franklin Station, Washington, D. C., B. O. Box450, USA.
20. Jensen, M.E., 1983. Design and Operation of Farm Irrigation Systems. American Society Agriculture Engineers, Michigan, U.S.A.
21. Snedecor, G.W. and W.G. Corchran, 1980. Statistical Methods. Oxford and J.B.H. Publishing Co. 7th Ed. Iowa State University, Press, Am., Iowa, USA.
22. Duncan, D.B., 1955. Multiple range and multiple "F" test. Biometrics, 11: 1- 42.
23. Ahmed, M. and A.R. Cashmore, 1993. HY4 gene of A. thaliana encodes a protein with characteristics of a blue-light photoreceptor. Nature., 366: 162-166.
24. Guo, H., H. Yang, T.C. Mockler and C. Lin, 1998. Regulation of flowering time by *Arabidopsis* photoreceptors. Science, 279: 1360-1363.
25. Somers, D.E., P.F. Devlin and S.A. Kay, 1998. Phytochromes and cryptochromes in the entrainment of the arabidopsis circadian clock. Science, 282: 1488-1490.
26. Yanovsky, M.J., M.A. Mazzella, G.C. Whitelam and J.J. Casal, 2001. Resetting of the circadian clock by phytochromes and cryptochromes in arabidopsis. Journal of Biological Rhythms, 16(6): 523-530.
27. Mao, J., Y.C. Zhang, Y. Sang, Q.H. Li and H.Q. Yang, 2005. A role for arabidopsis cryptochromes and COP1 in the regulation of stomatal opening. Proceedings National Academy of Sciences of the United States of America, 102(34): 12270-12275.
28. Kang, C.Y., H.L. Lian, F.F. Wang, J.R. Huang and H.Q. Yang, 2009. Cryptochromes, phytochromes and COP1 Regulate Light-Controlled stomatal development in arabidopsis. The Plant Cell, 21(9): 2624-2641.

29. Canamero, R.C., Nadia Bakrim, J.P. Bouly, A. Garay, E. E. Dudkin, Y. Habricot and Margaret Ahmad, 2006. Cryptochrome photoreceptors cry1 and cry2 antagonistically regulate primary root elongation in *Arabidopsis thaliana.* Planta, 224: 995-1003.
30. Zeng, J., Q. Wang, J. Lin, K. Deng, X. Zhao, D. Tang and X. Liu, 2010. Arabidopsis cryptochrome-1 restrains lateral roots growth by inhibiting auxin transport. Journal of Plant Physiology, 167(8): 670-673.
31. Weller, J.L., G. Perrotta, M.E.L. Schreuder, A.V. Tuinen, M. Koornneef, G. Giuliano and R.E. Kendrick, 2001. Genetic dissection of blue-light sensing in tomato using mutants deficient in cryptochrome 1 and phytochromes A, B1 and B2. The Plant Journal, 25(4): 427-440.
32. Platten, J.D., E. Foo, R.C. Elliott, V. Hecht, J.B. Reid and J.L. Weller, 2005. Cryptochrome 1 Contributes to Blue-Light Sensing in Pea. Plant Physiology, 139: 1472–1482.
33. El-Assal, S.E.D., C.A. Blanco, C.J. Hanhart and M. Koornneef, 2004. Pleiotropic effects of the arabidopsis cryptochrome 2 allelic variation underlie fruit trait-related QTL. Plant Biology, 6(4): 370-374.
34. Whippo, C.W. and R.P. Hangarter, 2003. Second Positive Phototropism Results from Coordinated Co-Action of the phototropins and cryptochromes. Plant Physiol., 132(3): 1499-1507.
35. Mayama, T.T., T. Sakai, A. Hanada, Y. Uehara, T. Asami and S. Yamaguchi, 2010. Role of the phytochrome and cryptochrome signaling pathways in hypocotyl phototropism. The Plant Journal, 62: 653-662.
36. Giliberto, L., G. Perrotta, P. Pallara, J.L. Weller, P.D. Fraser, P.M. Bramley, A. Fiore, M. Tavazza and G. Giuliano, 2005. Manipulation of the blue light photoreceptor cryptochrome 2 in tomato affects vegetative development, flowering time and fruit antioxidant content. Plant Physiology, 137: 199-208.
37. Juez, E.L., E. Dillon, Z. Magyar, S. Khan, S. Hazeldine, S.M. Jager, J.A.H. Murray, G.T.S. Beemster, L. Bögre and H. Shanahan, 2008. Distinct light-initiated gene expression and cell cycle programs in the shoot apex and cotyledons of arabidopsis. Plant Cell, 20(4): 947-968.
38. Danon, A., N.S. Coll and K. Apel, 2006. Cryptochrome-1-dependent execution of programmed cell death induced by singlet oxygen in *Arabidopsis thaliana*. Proceedings National Academy of Sciences of the United States of America, 103(45): 17036-17041.
39. Weston, E., K. Thorogood, G. Vinti and E.L. Juez, 2001. Light quantity controls leaf-cell and chloroplast development in *Arabidopsis thaliana* wild type and blue-light-perception mutants. Planta, 211: 807-815.
40. Kleine, T., P. Kindgren, C. Benedict, L. Hendrickson and A. Strand, 2007. Genome-wide gene expression analysis reveals a critical Role for cryptochrome1 in the response of arabidopsis to high irradiance. Plant Physiology, 144: 1391-1406.
41. Xu, P., Y. Xiang, H. Zhu, H. Xu, Z. Zhang, C. Zhang, L. Zhang and Z. Ma, 2009. Wheat cryptochromes: subcellular localization and involvement in photomorphogenesis and osmotic stress responses. Plant Physiol., 149(2): 760-774.
42. Keller, M.M., Y. Jaillais, U.V. Pedmale, J.E. Moreno, J. Chory and C.L. Ballaré, 2001. Cryptochrome 1 and phytochrome B control shade-avoidanceresponses in arabidopsis via partially independent hormonal cascades. Plant Journal, 67(2): 195-207.
43. Jeong, R.D., C.C. Shekara, S.R. Barman, D. Navarre, D.F. Klessig, A. Kachroo and P. Kachroo, 2010. Cryptochrome 2 and phototropin 2 regulate resistance protein-mediated viral defense by negatively regulating an E3 ubiquitin ligase. Proceedings National Academy of Sciences of the United States of America, 107(30): 13538-13543.
44. Hassan, A.Z., 2014. Effect of magnetized irrigation water with different gausses on the growth and mucilage percentage on two varieties of *Calendula officinalis* L. Journal of Biotechnology Research Center, 8(3): 5-10.
45. Mohammed, D.A., 2014. Effect of magnetic water and depth of drip irrigation water and yield of cucumber in green houses. Diyala Agricultural Sciences Journal, 6(1): 79-86.
46. Aly, M.A., M.E. Thanaa, S.M. Osman and A.A.M. Abdelhamed, 2015. Effect of magnetic irrigation water and some anti-salinity substances on the growth and production of Valencia orange. Middle East Journal of Agriculture Res., 4: 88-98.
47. Mostafa, M.F.M., M.S.S. El-Boray, A.M.N. Shalan and A.H. Ghaffar, 2016. Effect of magnetized irrigation water levels and compost on vegetative growth, leaf mineral content and water use efficiency of Washington navel orange trees. Journal Plant Production, Mansoura University, 7(2): 249-255.
48. Ali, T.B., Soha E. Khalil and A.M. Khalil, 2011. Magnetic treatments of *Capsicum Annuum* L. grown under saline irrigation conditions. Journal of Applied Sciences Research, 7(11): 1558-1568.

49. Falivene, S., J. Giddings and M. Skewes, 2016. Managing Citrus Orchards With Less Water. June 2016 Primefact 427 Second edition.
50. Mahmoud, T.A. and Ebtessam A. Youssef, 2016. Water deficiency and mulching effects on Valencia orange trees. Agricultural Science, Moshtohor, 55(1): 113-127.
51. Koshita, Y. and T. Takahara, 2004. Effect of water stress on flower-bud formation and plant hormone content of satsuma mandarin (*Citrus unshiu Marc*). Science Horticulture, 99: 301-307.
52. Melgar, J.C., L.G. Albrigo and J.P. Syvertsen, 2012. Winter drought stress can delay flowering and avoid immature fruit loss during late-season mechanical harvesting of Valencia oranges. Acta. Horticulture, 965: 55-60.
53. Dorji, K., L. Lakey, S. Chophel, S.D. Dorji and B. Tamang, 2016. Adoption of improved citrus orchard management practices: a micro study from Drujegang growers, Dagana, Bhutan. Agriculture and Food Security, 5(3): 1-8.
54. Ghosh, S.G., K. Asanuma, A. Kusutani and M. Toyota, 2000. Effect of moisture stress at different growth stages on the amount of total nonstructural carbohydrate, nitrate reeducates activity and yield of potato. Japanese Journal of Tropical Agriculture, 44(3): 158-166.
55. Ahmed, M.E.M. and N.I. Abd El-Kader, 2016. The influence of magnetic water and water regimes on soil salinity, growth, yield and tubers quality of potato plants. Middle East Journal Agriculture Research, 5(2): 132-143.
56. Figueroa, F.L. and F.X. Niell, 1998. Control of chlorophyll a synthesis by phytochrome and cryptochrome in the red alga Corallina elongata Ellis et Soland. Revista española de fisiología, 44(3): 287-294.
57. Flexas, J., J. Bota, F. Loreto, G. Coranic and T.D. Sharkey, 2004. Diffusive and metabolic limitation to photosynthesis under drought and salinity in C3 plants. Journal Plant Biology, 6: 269-279.
58. Erice, G., J. Irigoyen, M. Sanchez-Diaz, J. Avice and A. Ourry, 2007. Effect of drought, elevated CO_2 and temperature on accumulation of N and vegetative storage proteins (VSP) in tap root of nodulated alfalfa before and after cutting. Plant Science Journal, 172: 903-912.
59. Sadeghipour, O. and P. Aghaei, 2013. Improving the growth of cowpea (*Vigna unguiculata* L. Walp.) by magnetized water. Journal of Biodiversity and Environmental Sciences (JBES), 3(1): 37-43.
60. Aghamir, F., H. Bahrami, M.J. Malakouti, S. Eshghi and F. Sharifi, 2015. Seed germination and seedling growth of bean (*Phaseolus vulgaris*) as influenced by magnetized saline water. Eurasian Journal of Soil Science, 5(1): 39-46.
61. Jogi, P.D., R.D. Dharmale, M.S. Dudhare and A.A. Aware, 2015. Magnetic water: a plant growth stimulator improve mustard (*Brassica nigra* L.) crop production. Asian Journal of Bio- Science, 10(2): 183-185.
62. Hozayn, M., M.M. Abdallha, A.A.A. El-Monem, A.A. El-Saady and M.A. Darwish, 2016. Applications of magnetic technology in agriculture: a novel tool for improving crop productivity (1): canola. African Journal of Agricultural Research, 11(5): 441-449.
63. Xiao Li, Z., L. XiaoPeng, N. Qiong, H. Cheng Neng, X. Yu Ming and X. Shen Xi, 2013. Effect of water stress on physiological characteristics, JA biosynthesis and correlative genes expression in citrus. Acta Agriculture Universitatis Jiangxiensis, 35(3): 530-535.
64. Malik, N.S.A., J.L. Perez, M. Kunta, J.M. Patt and R.L. Mangan, 2014. Changes in free amino acids and polyamine levels in Satsuma leaves in response to Asian citrus psyllid infestation and water stress. Insect Science, 21(6): 707-716.
65. Shen Xi, X., Z. XiaoLi: L. Xiao Peng, H. Cheng Neng, X. Yu Ming and L. Jing, 2016. Effect of water stress on citrus physiological characteristics, jasmine acid biosynthesis and correlative gene expression. Acta Horticulture, 11(12): 247-253.
66. Al-Shrouf, A.M., 2014. The effect of magnetic treatment of irrigation water on cucumber production and water productivity. Acta Horticulturae, 1054: 111-117.
67. Fruhwirth, S., K. Teich and G. Klug, 2012. Effects of the cryptochrome cryb from *Rhodobacter sphaeroides* on global gene expression in the dark or blue light or in the presence of singlet oxygen. PLoS One, 7(4): 33791.
68. Treeby, M .T., R.E. Henriod, K.B. Bevington, D.J. Milne and R. Storey, 2007. Irrigation management and rootstock effects on navel orange [Citrus sinensis (L.) Osbeck] fruit quality. Agricultural Water Management, 91 (1-3):24-32.
69. El-Shokali, A.A.M., A.M. Abdelbagi and M.D. Abdallah, 2015. Enhancing the mineral elements of exposure to magnetic field in plants leave. Journal of Basic and Applied Sciences, 11: 440-444.