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EFFECT OF IRRIGATION WITH MAGNETIC WATER ON NITROGEN FERTILIZATION EFFICIENCY OF NAVEL ORANGE TREES

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Abstract

This investigation was conducted during 2016 and 2017 seasons on ten years old of Washington navel orange trees (*Citrus sinenses)* budded on sour orange rootstock (*Citrus aurantium* L.). The study aimed to enhance nitrogen fertilization efficiency by using magnetized water irrigation combined with different levels of nitrogen fertilization (400, 600, 800 and 1000 g N per tree/ year). The data revealed that, the nitrogen fertilization doses can be reduced by 20% while maintaining the production and the possibility of increasing it by using magnetic water irrigation. The nitrogen fertilization efficiency and the nitrogen fertilization unit economic return were higher even with the reduction of nitrogen fertilization doses.

***Key words*:** Washington orange trees, citrus, magnetized water, nitrogen fertilization, 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). Also, citrus trees are the most important fruit crop in Egypt, particularly for exportation. The total area under citrus trees in Egypt is 541,723 feddan (Feddan = (0.42 Hectare), out of them 439,024 feddan are fruitful producing 4,098,590 tons (43.00% of the total production of fruit trees) with an average of 9.34 tons per feddan. The total area planted by Washington navel orange trees is 185,892 feddan out of them 157,793 feddan are fruitful producing 1,531,952 tons with an average of 9.71 tons per feddan (Ministry of Agric., 2014).

One of the key players in modern industrial agriculture is fertilizer derived from nitrogen fixation, responsible in some cases for up to 75% of crop yield increases. Global supply of nitrogen has doubled since World War II. It is estimated that 1% of the world's energy consumption goes toward fertilizer manufacture. That energy, of course, requires the burning of fossil fuels. On average, 5.5 gallons of fossil fuels per acre, per year are needed to fertilize soil for farming. In addition, nitrogen is an essential element for all amino acids in plant structures which are the building blocks of plant proteins, important in the growth and development of vital plant tissues and cells like the cell membranes and chlorophyll. Moreover, N is a component of nucleic acid that forms DNA a genetic material significant in the transfer of certain crop traits and characteristics that aid in plant survival. It also helps hold the genetic code in the plant nucleus. According to Parameshwar and Srivastava, 2013; Srivastava and Singh, 2016; AboEid, 2017 studies on nitrogen fertilization for citrus trees included various rates between 400 and 1500gN / tree / year. The general trend in those studies was that increasing nitrogen fertilization rate caused promotions in both vegetative growth and fruiting of orange trees.

According to Hozayn and Abdul-Qados, 2010; Alikamanoglu and Sen, 2011; Mostafazadeh-Fard *et al.*, 2011; Radhakrishnan and Kumari, 2012 magnetic field and magnetized water irrigation improved plant growth characteristics, root function, influenced the chemical composition of plants, affected soil nutrient availability, activated plant enzymes and thereby increased the yield. In the meantime, it is so important to focus on the results of Bondarenko *et al.*, 1999, who mentioned 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. Also, a magnetic field causes redistribution of energy flow due to the momentum change of charged particles. In 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 what had been 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 enhance nitrogen efficiency and determine the most effective treatment by using magnetized water combined with different levels of nitrogen fertilization (400, 600, 800 and 1000 g N per tree / year) under drip irrigation system.

Material and Methods

The present investigation has been carried out during two successive seasons (2016 and 2017) to enhance nitrogen efficiency by assessing the effect of magnetized water combined with different levels of nitrogen fertilization (400, 600, 800 and 1000 g N per tree / year) on flowering, fruit set and yield of Washington navel orange trees (*Citrus sinenses,* 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 by Nile River water in a private orchard at Belbeis region – El Sharkia Governorate, Egypt.

All trees under this study received the same applied horticultural practices except those of the experimental treatments. The experiment was arranged in five treatments as follows: 1) non- magnetized water combined with 1000 g N per tree / year (control), 2) magnetized water combined with 1000 g N per tree / year, 3) magnetized water combined with 800 g N per tree / year, 4) magnetized water combined with 600 g N per tree / year and 5) magnetized water combined with 400 g N per tree / year). Each treatment comprised three replicates and two trees for each replicate, in a complete randomized design.

The tested treatments were evaluated throw the following parameters:

Flowering and fruit set

Sixteen twigs per tree have been chosen, four twigs in each of the four sides to collect the data. The total number of inflorescences, number of leafy and leafless inflorescences and their percentages per twig were counted and recorded. In addition, the number of flowers on each inflorescence type was recorded. Leafy inflorescences percentages were calculated according to the following equation:

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

while leafless inflorescences percentages were calculated according to the following equation (leafless inflorescences % = 100 - leafy inflorescences percentages). The numbers of set fruitlets on leafy and leafless inflorescences per twig were counted and recorded. Finally, the fruit set percentage in each case was calculated according to the following equation:

$$\text{Fruit set \% per inflorescences} = \frac{\begin{array}{c}\text{Number of set fruitlets}\\ \text{on inflorescence type}\end{array}}{\begin{array}{c}\text{Number of flowers}\\ \text{on inflorescence type}\end{array}} \times 100$$

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

$$\text{Fruit set}\left(\%\right) = \frac{\text{Number of set fruitlet}}{\text{Total number of flowers}} \times 100\,.$$

Yield, nitrogen use efficiency and nitrogen unit return

At harvesting (December), the number of harvested fruits per tree was 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.

Nitrogen use efficiency (NUE) values were calculated according to the following equation

$$\text{NUE} = \frac{\text{Yield}\left(\text{kg per tree}\right)}{\text{Nitrogen}\left(\text{kg per tree}\right)}$$

Nitrogen unit returns (NUR) were calculated according to the following equation: Nitrogen unit return = NUE × price of 1kg orange (4 EGP).

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 volume (cm^3), fruit height (cm), fruit diameter (cm), fruit shape index (height / diameter), fruit pulp weight (g), juice volume / fruit (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 phenolphthalin 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 indophenol (mg/ 100 ml) following the method illustrated in the AOAC, 1985.

Leaf photosynthetic pigments and leaf dry matter 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,1957. The leaf dry matter percentage (%) was determined according the following equation

$$= \frac{\text{leaf dry weight}}{\text{leaf fresh weight}} \times 100.$$

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. In addition, calcium (%), magnesium (%), zinc (ppm), manganese (ppm) and iron (ppm) were determined by the Atomic Absorption apparatus (Jackson, 1967).

Statistical analysis

The experiment was arranged in five treatments as follows: 1) non- magnetized water combined with 1000 g N per tree (control), 2) magnetized water combined with 1000 g N per tree, 3) magnetized water combined with 800 g N per tree, 4) magnetized water combined with 600 g N per tree and 5) magnetized water combined with 400 g N per tree. Each treatment comprised three replicates and two trees for each replicate, in a complete randomized design. 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 multiple range test (Duncan, 1955).

Results and Discussion

Flowering and fruit set

The results in Table (1) showed the effect of magnetized water combined with different doses of nitrogen on flowering and fruit set characteristics of Washington naval orange trees, which recorded significant differences especially with magnetized water combined with 1000 g N per tree. The highest values in both seasons were obtained from the second treatment (magnetized water combined with 1000 g N per tree).However, the third treatment (magnetized water combined with 800 g N per tree) achieved values statistically equal to the control (non-magnetized water combined with 1000 g N per tree), which save20 percent of the used nitrogen, this trend was also in the second season.

Concerning the effect of magnetized water, the obtained results are in agreement with Aly *et al.* (2015) on Valencia orange, which might be due to a positive effect of magnetic treatment on phyto-hormone production leading to improved cell activity. Also, the increased mobile forms of fertilizers might increase water absorption, enhancing moisture content, as well as photosynthetic pigments and endogenous promoters (IAA) (Reina *et al*., 2001; Maheshwari and Grewal, 2009; Aly *et al.,* 2015; Mahmoud *et al.,* 2018). Lastly, Maffei, 2014 stated that the blue light photoreceptors cryptochromes (cry1 and cry2) are responded to the magnetic field. Also, it has been suggested that cry2 is the predominant photoreceptor in perception of the long-day photoperiod signal in the control of flowering (Guo *et al*., 1998). In addition, many other researches clarified the cryptochromes role in blue light regulation, photoperiodic and flowering control (Ahmed and Cashmore, 1993; Guo *et al*., 1998).

As for the effect of nitrogen doses, our results were in the same line with Sharawy *et al*., 2003; Wassel *et al*., 2007 on citrus.

Yield, nitrogen use efficiency (NUE) and nitrogen unit returns (NUR)

Results in Table (2) summarize the outcomes of this study. The highest significant increment in hypothetic yield per feddan (ton / feddan) was gained by using the second treatment (magnetized water with 1000 g N per tree), which recorded 11.81 ton per feddan, while corresponding value for the control (non-magnetized water treatment with 1000 g N per tree) was 8.73 ton per feddan. In addition, magnetized water with 800 g N per tree treatment gained 9.26 ton per feddan, which was statistically equal to the control. In Addition, this treatment reduced nitrogen fertilization by 20%, this trend was obtained in the two seasons.

With a more comprehensive view, these results cannot be evaluated individually without reference to NUE (Nitrogen use efficiency - kg fruit /1 kg Nitrogen) and NUR (Nitrogen unit return - EGP/1 kg nitrogen) to interpret these results economically as a monetary product of the nitrogen unit, so, if the results have generally shown superiority of magnetized water treatment in NUE and NUR but the treatments clarified that magnetized water with 1000 g N per tree was better than the control where the values were recorded for magnetized water with 800 g N per tree 55.14 for NUE and 220.56 for WUR while control recorded 41.56 for NUE and 166.24 for NUR with obvious and high significant differences, even if it was less in yield (8.73

ton per feddan) but it was better in nitrogen use efficiency and the economic return from using the nitrogen unit. This trend was also held true in the second season.

Regarding the results of magnetized water, the present investigation revealed that yield characteristics were affected significantly; which confirmed the results by Mohammed, 2014 on cucumber; Aly *et al*., 2015 on Valencia orange; El-Shokali *et al*., 2015 on tomato and sunflower and Mostafa *et al*., 2016 and Mahmoud *et al.,* 2018 on Washington orange trees.Such results may due to that magnetic treatment has increased leaching power of excess soluble salts, lowering soil alkalinity, dissolving lower soluble salts (carbonates , phosphates and sulfates), increased water absorption and enhancing moisture content(Amer *et al*., 2014; Aly *et al*., 2015; Mostafa *et al*., 2016) and as such 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 growth improvement and increase the crop yield (Hozayn and Abdul-Qados, 2010; Ali *et al*., 2011).

With regard to nitrogen doses, results were in agreement with those of Wassel *et al*., 2007 on Balady mandarin trees; Sheikh *et al*., 2013 on citrus trees and Srivastava and Singh, 2016 on Nagpur mandarin.

Fruit weight, fruit volume, fruit height, fruit diameter, fruit shape index, pulp weight and Juice volume:

Data in Table (3) show the effect of magnetized water combined with different doses of nitrogen on fruit weight, fruit volume, fruit height, fruit diameter, fruit shape index, peel weight, pulp weight and juice volume of Washington navel orange fruits. All the tested treatments recorded significant differences in fruit weight, volume, height as well as peel weight and pulp weight characteristics especially with magnetized water combined with 1000 g N per tree.

Regarding, the differences between magnetized water combined with different doses nitrogen for fruit weight, fruit volume, fruit height, fruit diameter, peel weight, pulp weight and juice volume were significant and have similar trend, except fruit shape index, in the two seasons. For fruit weight, the highest values were 340.69 and 343.84 g for magnetized water combined with 1000 g N per tree which gained increments reached 10.35 and 13.47 % over the control in the 1st and the 2nd seasons, respectively. With, pulp weight, the highest values were 276.41 and 278.95 g for magnetized water combined with 1000 g N per tree which gained10.35 and 13.46 % over the control in the 1st and the 2nd seasons, respectively. In the meantime, the magnetized water combined with 800 or 600 g N per tree gained values statistically equal to the control, which saved 20 percent of nitrogen used in fertilization. This trend held true in the second season.

For magnetized water, the obtained results were in the same line with Al-Shrouf, 2014 on cucumber; Aly *et al*., 2015 on Valencia orange and Mostafa *et al*., 2016 and Mahmoud *et al.,* 2018 on Washington orange. In the same time, it is important to refer to researches on the role of cryptochrome (El-Assal *et al*., 2004; Fruhwirth *et al*., 2012) who stated that CryB influenced not only photosynthesis gene expression but also genes of the non-photosynthetic energy metabolism like Krebs cycle and oxidative phosphorylation.

For nitrogen doses, our results were in harmony with those of Wassel *et al*., 2007 on Balady mandarin trees; Anwar 2013 on citrus trees and Sheikh *et al*., 2013 on citrus trees.

TSS, acidity, TSS / acid ratio and ascorbic acid contents:

Data in Table (4) show the effect of magnetized water combined with different doses of nitrogen on TSS, acidity, TSS / acid ratio and ascorbic acid contents which were significant in the two seasons.

As for TSS and TSS / acid ratio, all the tested treatments achieved statistically better values than the control, which can save from 20 to 60 % of nitrogen used in fertilization. This trend was also true in second season. On the contrary, juice acidity was not affected with all used doses of nitrogen.

As for magnetized water, the obtained results were in the same line with Al-Shrouf, 2014 on cucumber; Aly *et al*., 2015 on Valencia orange and Mostafa *et al*., 2016 and Mahmoud *et al.,* 2018 on Washington orange. In the same time, researches on the role of cryptochrome (El-Assal *et al*., 2004; Fruhwirth *et al*., 2012) cleared that CryB does not only influence photosynthesis gene expression but also genes for the non-photosynthetic energy metabolism like Krebs cycle and oxidative phosphorylation, which 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.

As for nitrogen doses, our results are in agreement with those mentioned by Wassel *et al*., 2007 on Balady mandarin trees; Anwar 2013 and Sheikh *et al*., 2013 on citrus trees.

Leaf photosynthetic pigments and leaf dry matter percentage:

Data in Table (5) show the effect of magnetized water combined with different doses of nitrogen fertilization on photosynthetic pigments and dry matter percentage of Washington navel orange leaves. All the tested treatments revealed significant differences in leaf photosynthetic pigments and dry matter percentage. The highest values were recorded with magnetized water combined with 1000 or 800 g N per tree, while magnetized water combined with 600 g N per tree achieved, in most cases values statistically equal to the control, this can save 40 percent of nitrogen used in fertilization. This trend was also in second season.

Also, the leaf dry matter percentage reached 30.63 and 31.12 for magnetized water combined with 1000 g N per tree which gained increment reached 5.88 and 5.23% over the control in the 1st and the 2nd seasons, respectively. The other treatments were better than the control or gained values statically equal to the control.

As for magnetized water, the obtained results confirmed those by Aghamir *et al*., 2015 on bean; Jogi *et al*., 2015 on brassica; Hozayn *et al*., 2016 on canolaand Mahmoud *et al.,* 2018 on Washington orange.

For nitrogen doses, the obtained results were in the same line with Rattanpal, 2014 on rough lemon and Bernardi *et al*., 2015 on sweet orange trees.

Leaf Chemical Composition

Data in Table (6) show the effect of magnetized water combined with different doses of nitrogen on leaf chemical composition of Washington navel orange trees. Most of tested treatments recorded significant increment in leaf chemical composition characteristics especially with magnetized water combined with 1000 or 800 g N per tree, this came true in both seasons.

Regarding leaf nitrogen content, magnetized water combined with 1000, 800 or 600 g N per tree gained statistical increments over the control in both seasons. The same trend were obtained with other leaf chemical composition components except Mg, which was not affected by all treatments.

For magnetized water, the obtained results were in agreement with Hozayn and Abdul-Qados, 2010 on wheat; El-Shokali *et al*., 2015 on tomato and sunflower and Jogi *et al*., 2015 on brassica.

For nitrogen doses, the obtained results were in the same line with Wassel *et al*., 2007 on citrus, Rattanpal, 2014 on rough lemon and Bernardi *et al*., 2015 on Valencia orange

Table 1: Effect of magnetized water combined with different levels of nitrogen fertilization on leafy inflorescence characteristics of Washington navel orange trees (2016-2017 seasons).

Treatments	Percentage of leafy inflorescences	Fruit set percentage on leafy inflorescence	Percentage of leafless inflorescences	Fruit set percentage on leafless inflorescence	Total number of flowers per twig	Overall fruit set percentage per twig
	First season (2016)					
Control	65.30 C	8.97 B	34.70 C	4.71 B	220.14 B	7.80 B
M. w. × 1000 g N / tree	82.30 A	12.03 A	17.70 E	5.64 A	289.94 A	10.02 A
M. w. × 800 g N / tree	68.78 B	9.18 B	31.22 D	3.63 C	199.73 C	7.83 B
M. w. × 600 g N / tree	62.91 D	5.18 C	37.09 B	3.09 D	157.67 D	6.03 C
M. w. × 400 g N / tree	51.59 E	4.13 D	48.41 A	2.46 E	95.45 E	4.80 D
	Second season (2017)					
Control	57.51 D	11.00 B	42.49 A	5.10 B	237.06 B	10.16 B
M. w. × 1000 g N / tree	87.28 A	13.91 A	12.72 D	6.33 A	342.45 A	12.69 A
M. w. × 800 g N / tree	72.94 B	10.90 B	27.06 C	5.13 B	245.07 B	10.42 B
M. w. × 600 g N / tree	68.30 C	8.71 C	31.70 B	4.37 C	197.79 C	8.87 C
M. w. × 400 g N / tree	58.46 D	6.94 D	41.54 A	3.48 D	119.41 D	7.07 D

M.w. = magnetized water; control = non-magnetized water combined with 1000 g N /tree.
Means followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Table 2: Effect of magnetized water combined with different levels of nitrogen fertilization on yield and water use efficiency of Washington navel orange trees (2016-2017 seasons).

Treatments	Number of fruits per tree	Tree yield (kg)	Hypothetic yield per feddan (Ton)	Nitrogen use efficiency (kg fruits per Kg nitrogen)	Nitrogen unit returns (NUR)
	First season (2016)				
Control	134.54 B	41.56 B	8.73 B	41.56 B	166.24 B
M. w. × 1000 g N / tree	165.07 A	56.25 A	11.81 A	56.25 A	225.00 A
M. w. × 800 g N / tree	139.21 B	44.11 B	9.26 B	55.14 A	220.56 A
M. w. × 600 g N / tree	107.80 C	34.96 C	7.34 C	58.26 A	233.04 A
M. w. × 400 g N / tree	79.47 D	23.34 D	4.90 D	58.35 A	233.40 A
	Second season (2017)				
Control	123.86 B	37.52 B	7.88 B	37.52 D	150.08 D
M. w. × 1000 g N / tree	177.52 A	61.06 A	12.82 A	61.06 A	244.24 A
M. w. × 800 g N / tree	129.96 B	39.77 B	8.35 B	49.72 C	198.88 C
M. w. × 600 g N / tree	107.39 C	33.09 C	6.95 C	55.15 B	220.60 B
M. w. × 400 g N / tree	86.66 D	24.98 D	5.24 D	62.44 A	249.76 A

M.w. = magnetized water; control = non-magnetized water combined with 1000 g N /tree.
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 magnetized water combined with different levels of nitrogen fertilization on fruit volume, fruit height, fruit diameter, fruit shape index, peel weight and pulp weight of Washington navel orange fruits (2016-2017 seasons).

Treatments	Fruit weight (g)	Fruit volume (cm^3)	Fruit height (L) (cm)	Fruit diameter (D) (cm)	Fruit shape index (L/D)	Pulp weight (g)	Juice volume/ fruit (cm^3)
	First season (2016)						
Control	308.74 C	332.88 C	8.11 C	7.28 B	1.1130 A	250.49 B	181.63 B
M. w. × 1000 g N / tree	340.69 A	367.32 A	8.95 A	8.04 A	1.1130 A	276.41 A	200.42 A
M. w. × 800 g N / tree	316.73 BC	341.49 BC	8.32 BC	7.47 B	1.1127 A	256.96 B	186.33 B
M. w. × 600 g N / tree	324.10 B	349.44 B	8.51 B	7.65 B	1.1124 A	262.95 B	190.67 B
M. w. × 400 g N / tree	293.63 D	316.59 D	7.71 D	6.93 C	1.1124 A	238.23 C	172.74 C
	Second season (2017)						
Control	303.03 B	326.72 B	7.96 B	7.15 B	1.1137 A	245.85 B	178.28 B
M. w. × 1000 g N / tree	343.84 A	370.71 A	9.03 A	8.11 A	1.1137 A	278.95 A	202.28 A
M. w. × 800 g N / tree	305.94 B	329.85 B	8.04 B	7.22 B	1.1134 A	248.21 B	179.99 B
M. w. × 600 g N / tree	308.00 B	332.08 B	8.09 B	7.27 B	1.1131 A	249.88 B	181.20 B
M. w. × 400 g N / tree	288.18 C	310.71 C	7.57 C	6.80 C	1.1131 A	233.81 C	169.54 C

M.w. = magnetized water; control = non-magnetized water combined with 1000 g N /tree.
Means followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Table 4: Effect of magnetized water combined with different levels of nitrogen fertilization on juice volume, weight, TSS, acidity, TSS / acid ratio and ascorbic acid content of Washington navel orange fruits (2016-2017 seasons).

Treatments	Juice TSS (%)	Juice acidity (%)	TSS/acid ratio	Ascorbic acid (mg/100 ml)
	First season (2016)			
Control	10.50 C	0.77 A	13.62 D	42.54 B
M. w. × 1000 g N / tree	11.56 B	0.68 A	16.38 B	48.53 A
M. w. × 800 g N / tree	12.35 A	0.74 A	16.99 B	43.74 B
M. w. × 600 g N / tree	12.53 A	0.73 A	17.54 A	42.89 B
M. w. × 400 g N / tree	11.29 B	0.76 A	14.94 C	38.26 C
	Second season (2017)			
Control	10.80 C	0.79 A	13.64 D	43.40 B
M. w. × 1000 g N / tree	11.91 B	0.72 A	16.11 B	52.29 A
M. w. × 800 g N / tree	12.50 A	0.73 A	16.94 B	44.28 B
M. w. × 600 g N / tree	13.19 A	0.77 A	17.43 A	42.95 B
M. w. × 400 g N / tree	11.37 B	0.78 A	14.64 C	38.79 C

M.w. = magnetized water; control = non-magnetized water combined with 1000 g N /tree.
Means followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Table 5: Effect of magnetized water combined with different levels of nitrogen fertilization on leaf photosynthetic pigments and leaf dry matter percentage of Washington navel orange trees(2016-2017 seasons).

Treatments	Leaf chlorophyll a content (mg/100 g F. W.)	Leaf chlorophyll b content (mg/ 100 g F. W.)	Leaf carotenoids content (mg/ 100 F. W.)	Leaf dry matter percentage (%)
	First season (2016)			
Control	170.05 B	69.29 B	65.02 B	24.75 B
M. w. × 1000 g N / tree	184.47 A	75.17 A	70.53 A	30.63 A
M. w. × 800 g N / tree	181.93 A	74.38 A	68.49 A	25.46 B
M. w. × 600 g N / tree	174.30 B	71.42 B	64.90 B	26.71 B
M. w. × 400 g N / tree	157.98 C	64.73 C	58.82 C	25.08 B
	Second season (2017)			
Control	172.56 B	70.02 C	65.85 B	25.89 C
M. w. × 1000 g N / tree	185.67 A	75.35 A	70.86 A	31.12 A
M. w. × 800 g N / tree	177.10 B	72.21 B	66.67 B	28.95 B
M. w. × 600 g N / tree	179.24 B	73.33 B	66.82 B	27.83 B
M. w. × 400 g N / tree	159.96 C	65.44 D	59.64 C	25.59 C

M.w. = magnetized water; control = non-magnetized water combined with 1000 g N /tree.
Means followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Table 6: Effect of magnetized water combined with different levels of nitrogen fertilization on leaf chemical composition of Washington navel orange trees (2016-2017 seasons).

Treatments	N %	P %	K %	Ca %	Mg %	Fe ppm	Mn ppm	Zn ppm
	First season (2016)							
Control	2.39 C	0.106 C	1.37 C	3.53 B	0.39 A	71.64 B	26.76 B	30.53 B
M. w. × 1000 g N / tree	2.72 A	0.127 A	1.62 A	4.19 A	0.44 A	85.44 A	30.52 A	36.18 A
M. w. × 800 g N / tree	2.54 B	0.120 B	1.51 B	4.24 A	0.44 A	90.83 A	29.26 A	33.34 A
M. w. × 600 g N / tree	2.56 B	0.120 B	1.41 C	4.18 A	0.45 A	98.27 A	29.93 A	30.90 B
M. w. × 400 g N / tree	2.28 D	0.099 C	1.29 D	3.80 B	0.41 A	81.09 A	26.70 B	28.09 B
	Second season (2017)							
Control	2.45 C	0.117 C	1.44 C	3.30 B	0.37 A	64.16 D	29.93 C	33.59 B
M. w. × 1000 g N / tree	2.77 A	0.152 A	1.63 A	3.74 A	0.43 A	83.44 B	39.93 A	38.00 A
M. w. × 800 g N / tree	2.60 B	0.144 B	1.59 B	3.99 A	0.41 A	90.57 A	32.14 B	36.54 A
M. w. × 600 g N / tree	2.59 B	0.132 B	1.48 C	3.94 A	0.43 A	90.97 A	32.30 B	33.60 B
M. w. × 400 g N / tree	2.34 D	0.107 D	1.34 D	3.57 B	0.39 A	73.68 C	29.17 C	30.45 C

M.w. = magnetized water; control = non-magnetized water combined with 1000 g N /tree.
Means followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Conclusion

The results of the present study showed that, all the tested treatments revealed significant differences over the control. Regarding, the highest values for flowering, fruit set, fruit weight and hypothetic yield per feddan were obtained from magnetized water combined with 1000 g N per tree. However, magnetized water combined with 800 g N per tree achieved values statistically equal to the control, which save 20 percent of the used nitrogen, this trend was also in the second season. As for TSS and TSS / acid ratio, all the tested treatments achieved statistically better values than the control, which can save from 20 to 60 % of nitrogen used in fertilization. This trend was also true in second season. On the contrary, juice acidity was not affected with all used doses of nitrogen.

In addition, most of tested treatments for leaf chemical composition recorded significant increment in leaf chemical composition characteristics especially with magnetized water combined with 1000 or 800 g N per tree, this came true in both seasons.

Lastly, these results cannot be evaluated individually without reference to NUE (Nitrogen use efficiency - kg fruit /1 kg Nitrogen) and NUR (Nitrogen unit return - EGP/1 kg nitrogen) to interpret these results economically as a monetary product of the nitrogen unit, so, if the results have generally shown superiority of magnetized water treatment in NUE and NUR but the treatments clarified that magnetized water with 1000 g N per tree was better than the control where the values were recorded for magnetized water with 800 g N per tree 55.14 for NUE and 220.56 for WUR while control recorded 41.56 for NUE and 166.24 for NUR with obvious and high significant differences, even if it was less in yield (8.73 ton per feddan) but it was better in nitrogen use efficiency and the economic return from using the nitrogen unit.

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