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Enhancing the Productivity and Quality of Tomato using Magnetized Water and Humic Acid as Bio-stimulant Agents

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ABSTRACT

Background: Humic acid is a natural bio-stimulant, which has a major influence on growth and crop quality. Also, Magnetic water treatment enhances both crop productivity and quality, which leads to the efficient use of cultivated land by using water resources available for crop production. This study aims to determine the effects of magnetized water irrigation and application of humic acid with different concentrations as a bio-stimulation on tomato plants, *Solanum lycopersicon* cv. Hybrid "86".

Methods: The experiment was conducted during the two growing seasons of 2018 and 2019 at the Agricultural Experimental Station Farm at Abies region, Faculty of Agriculture, Alexandria University, Egypt. The experiment design was split-plot with three replications. Two irrigation water treatments (magnetized and non-magnetic water) were arranged in the main plots and four concentrations of humic acid (0, 1, 2 and 3 g L^{-1}) were distributed over sub-plots.

Result: The results showed that irrigation with magnetized water had a positive effect on the vegetative growth traits, yield and its components and the quality of tomato fruits parameters. There was also a clear desirable effect of humic acid addition with different concentrations, as the results indicated that the use of the highest concentration of humic acid (3 g L^{-1}) reflected the highest values for all the studied traits. The results of the interaction between irrigation with magnetized water and application of humic acid showed that the best results and the highest values for all studied characters were recorded when using magnetic water (MW) combined with 3 g L^{-1} of humic acid (HA), without significant differences from the interaction treatment MW combined with 2 g L^{-1} HA for most traits. However, the two treatments combinations MW with 2 g L^{-1} HA and Non-MW with 3 g L^{-1} HA didn't significant differ from each other for all studied characters at the two growing seasons. These results indicated that using the magnetic water with humic acid led to the possibility of reducing the amount of humic acid by one-third and enhances both crop productivity and quality of tomato plants. Generally, we can recommend using magnetized water irrigation with humic acid addition at concentration of 3.g L^{-1} or 2.g L^{-1} to enhance the productivity and quality of the tomato plant.

Key words: Bio-Stimulants, Fruit quality, Humic acid, Magnetic water, *Solanum lycopersicon* L., Tomato.

INTRODUCTION

Tomato (*Solanum lycopersicon* L.) is one of the major crops grown all over the world. According to FAO (2018), tomato occupies the first rank among the cultivated area of all vegetable crops in Egypt. Tomato has a main role in human nutrition because of its rich source of lycopene, minerals and vitamins such as vitamins C and E, flavonoids, chlorophyll, β-carotene, which are anti-oxidants and promote good health (Sainju *et al*., 2003).

Modern agricultural efforts are now looking for an effective, environmentally friendly production technology to improve crop yields without harming the environment, as magnetic water treatment is one of these areas and applications of the magnetic field have been known for centuries (Colic and Morse, 1999). The first commercial magnetic water treatment device was patented in Belgium (Vemeiren, 1958). When studying the effect of water passing through a magnetic field, its properties change, including optics, electromagnetism, thermodynamics and mechanics, for example, changes in dielectric constant, viscosity, surface tension strength, freezing, boiling point and electrical conductivity compared to pure water. Thus, magnetized water has wide applications in industry, agriculture and medicine (Maheshwari and Grewal, 2009; Teixeira Da Silva and Dobránszki 2014; Yusuf and Ogunlela 2015 and Ebrahim and Azab, 2017). The practical application by using the magnetic field in agriculture starting from seed treatment, germination studies, seedling development and productivity of various species, such as agriculture, horticulture, herbs, medicinal plants, forages and industrial crops. However, the results sometimes tend to be positive, other times they are negative. However, some studies have used magnetized water and found that it can improve water productivity and crop yields by increases the solubility of water-soluble minerals such as calcium, nitrogen, potassium, iron and lead which can enhance absorption of nutrients for crops

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(Maheshwari and Grewal, 2009; Surendran *et al*., 2016; El-Sagan and Abd El-Baset, 2015; Al-Tarjuman *et al*., 2020 and Ali *et al*., 2014). Increasing the production of tomato with high quality was achieved through using the irrigation with magnetized water as recorded by Yusuf and Ogunlela, (2015, 2017a and 2017b) and Helaly (2018).

Plant bio-stimulants, defined as any substance applied to plants in order to improve nutrition efficiency, tolerance to abiotic stress and enhance crop quality (du Jardin 2015). Bio-stimulants are used in vegetable production to regulate the physiological actions in plants and consequently increases the productivity. Humic and fulvic acids can affect plant physiology, stimulates the plant growth and thus, considered as plant bio-stimulants (Van Oosten *et al*. 2017; Shah *et al*., 2018; Jindo *et al*. 2020). Humic acid (HA) is a heterogeneous mixture of several humic compounds that increase root cell growth and cell membrane permeability, respiration, photosynthesis and absorption of oxygen and phosphorous (Cacco and Dell Agnolla, 1984) which is a mixture of aliphatic and weak organic acids, which do not dissolve in water under acidic conditions, but are soluble in water under alkaline conditions (Cacco and Dell Agnolla 1984 and Husein and Abou El-Hassan, 2015). Humic acid is produced commercially as an organic fertilizer and it is well known that humic compounds improve soil structure, increase the number of microbes in the soil, increase the ability to exchange cations in the soil and indirectly provide some specific substances to the plant through the provision of macro and micro minerals. This leads to increased soil fertility (Canellas *et al*., 2015). Generally, humic substances provide novel approaches for modifying physiological activities inside plants to improve growth, quality and tolerance to abiotic stresses (Canellasa *et al*., 2015; Van Oosten *et al*. 2017; Jindo *et al*., 2020).

The impact of humic acid application on tomato plants was investigated by many researchers, such as Virgine Tenshia and Singaram 2005; Kazemi, 2013; Husein andAbou El-Hassan, 2015; Abou El-Hassan and Husien 2016; Kumar *et al*., 2017 and Abdellatif *et al*., 2017. Their results indicated that the addition of humic acid was very beneficial for tomato growth and productivity, as well as increased vegetative growth, yield and fruit quality. Therefore, the current study was conducted to investigate the response of tomato plants to magnetized water irrigation and addition of humic acid with different concentrations, as bio-stimulation agents on growth, yield and fruit quality. As well as studying how magnetized water availability influences the physiological responses, fruit quality attributes of tomato plants exposed to humic acid.

MATERIALS AND METHODS

Experimental site and plant materials

This study was conducted at the Agricultural Research and Experimental Station Farm at Abies region, Faculty of Agriculture, Alexandria University, Alexandria Governorate, Egypt during the two successive summer seasons of both 2018 and 2019. The scope of this investigation was to study the effect of irrigation with magnetic and non-magnetic water (MW and Non-MW) under different concentrations of humic acid (HA), as bio-stimulating agents, on tomato plant growth to reach the highest value of the crop in quantity and quality and their interactions with vegetative growth characters, total yield and its components and some chemical constituents of ripe tomato fruits. Before the start of each experiment, soil samples from the surface layers of the experimental area were taken and prepared for analysis in the Plant Nutrition Laboratory, Soil, Water and Environmental Research, Faculty of Agriculture, Alexandria University, according to the procedures described by Page *et al*. (1982). The results of the analysis clarified that soil texture was clay loam (clay 50%, sand 29% and silt 21%), pH was 8.16 and the electrical conductivity (EC) was 2.56 dS m^{-1}. While HCO^{-3}, CL^{-} and Na^{+} were 4.62, 10.5 and 15.66 meq. L^{-1}, respectively. Seeds of commercial tomato (*Solanum lycopersicon* L.) cv. Hybrid 86 were sown in seedling trays on March 2nd and 4th in 2018 and 2019, respectively. Seedling trays were grown in a fiberglass greenhouse. After 35 days of seed sowing, tomato seedlings having five true leaves and uniform size were transplanted into an open field in drip irrigation rows of 3.5 m length and 70 cm width with a plant spacing of 40 cm.

Magnetic water and humic acid treatments

In this study, two types of irrigation water; magnetized and non-magnetized (MW and Non-MW); four humic acid (HA) concentrations; 0, 1, 2 and 3 g L^{-1}; and their interactions were applied. The magnetized water was obtained by passing water through a magnetizing device, as described by Helaly (2018) and shown in Fig 1 and 2. According to Wang *et al.* (2018) and Helaly (2018), passing the water through the magnetic field lead to some physical changes to the composition and shape of water molecules as shown in Fig 3. Chemical analysis for some chemical properties of the two types of irrigation water was carried out at the

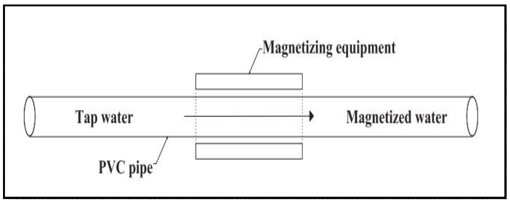

Fig 1: The schematic diagram of magnetization.

Fig 2: Delta magnetic water device with a capacity of 14,500 GAUSS.

Plant Nutrition Laboratory, Soil, Water and Environmental Research, Faculty of Agriculture, Alexandria University. The results of the analysis showed that both the two types of irrigation water had approximately the same value for all chemical properties (pH * 7.49, EC= 1.45 dsm^{-1}, cl = 7.51 meq. L^{-1}, SO_4= 2.5 meq. L^{-1} and Na= 9.39 meq. L^{-1}), except for dissolved oxygen (D.O) which was 22.32 mg. L^{-1} for magnetic water, however, it was 5.25 mg. L^{-1} for non-magnetic water.

A commercial product of humic acid containing 68% humic acid, 15% fulvic acids, 10% potassium, 5% nitrogen, 1% iron, 0.5% manganese and 0.5% zinc was used at four concentrations (0, 1, 2 and 3 g L^{-1}). This product named CANADA HUMEX and was dissolved in water and added by injection into the soil next to the plants at different concentrations (0, 1, 2 and 3 g L^{-1}), on four intervals 3 and 5 and 7 and 9 weeks after planting seedlings.

The experimental layout and statistical analysis

In a randomized complete block design (R.C.B.D.) with three replications, the experimental treatments were organized in a split plot system. All possible combinations between magnetic and non-magnetic water (MW and Non-MW) with four humic acid (HA) concentrations (0, 1, 2 and 3 g L^{-1}) were represented by each replicate consisting 8 treatments. The experiment was prepared and installed by establishing a drip irrigation network with an integrated magnetizing water supply. The field layout of the experiment included the main lines in the application of the water treatment in the form (magnetic and non-magnetic) as the main factor from which the branch lines were branched, representing the sub-plots, for the application of humic acid treatments. (Fig 4) describes one replicate of the experimental layout in detail. All experiment units were received the recommended dose of NPK fertilizers (110 kg N $feddan^{-1}$ as ammonium sulfate 20.5% N, 50% kg P $feddan^{-1}$ as phosphoric acid 58% P_2O_5 and 100 kg K% $feddan^{-1}$ as potassium sulfate 48% K_2O).

The fertilizer solutions were injected directly into the irrigation water using a venture injector at two doses weekly. Other recommended agricultural practices have been followed as widely used in the commercial production of tomato. All the data provided was statistically analyzed using the Co-Stat Software Computer Program (2004). Using the Duncan multiple range test at 0.05 probability, as defined by Steel and Torrie, 1980, the comparisons between the means of the different treatments were achieved.

Data recorded

Four plants were randomly selected for two seasons from each treatment after 60 days of transplantation for the measurements of the vegetative growth characters of the tomato plants. The plant height (cm), number of branches per plant, number of leaves per plant and fresh foliage weight (kg) were recorded.

A random sample of four standardized plants was selected from each experimental unit in the middle of the harvest season to determine the fruit yield and its component parameters. Number of clusters and the number of fruits per plant have been recorded. Total fruits from each plant were harvested and used to assess both the early yield (first three harvests) and total yield (all harvests) per plant (kg).

Ten representative marketable fruits from each treatment were harvested and carefully washed with purified water in the middle of the harvesting season, then weighted and analyzed for comparison the chemical composition of rip fruit. The content of lycopene (mg 100 g^{-1} fresh weight) was measured as per Witham *et al*. (1971). The total soluble solid, dry matter content and vitamin C were measured following the normal association methods of official analytical chemists (AOAC, 1995).

RESULTS AND DISCUSSION

Vegetative growth characters

The impact of irrigation with magnetized and non-magnetized water, on the vegetative growth characters of tomato in 2018 and 2019 seasons are presented in Fig 5. The obtained results indicate that irrigation with magnetic water significantly increased all vegetative growth characters; plant height, number of branches, number of leaves and foliage fresh weight; in both seasons compared with the irrigation with non-magnetic water (control treatment). The increased percentage in the different vegetative growth characteristics were recorded at rates ranging from 6.9% for plant height at first season to 20.6% for number of branches at second season. These results are in agreement with those obtained by Yusuf and Ogunlela (2015 and 2017a) and Dawa *et al*. (2017) on tomato plants. In addition, similar results recorded by Dawa *et al*. (2013), Sadeghipour and Aghaei, (2013) and Shahin and Mashhour (2016) on pea, cowpea and cucumber, respectively. In this

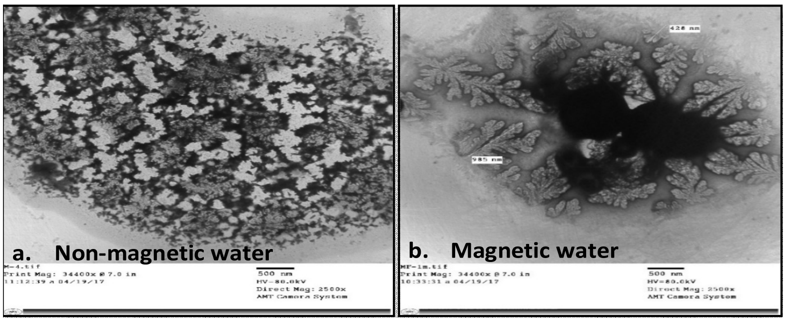

Fig 3: Transmission electron microscope of water (TDS= 1000 ppm) before and after magnetic treatment (Helaly, 2018).

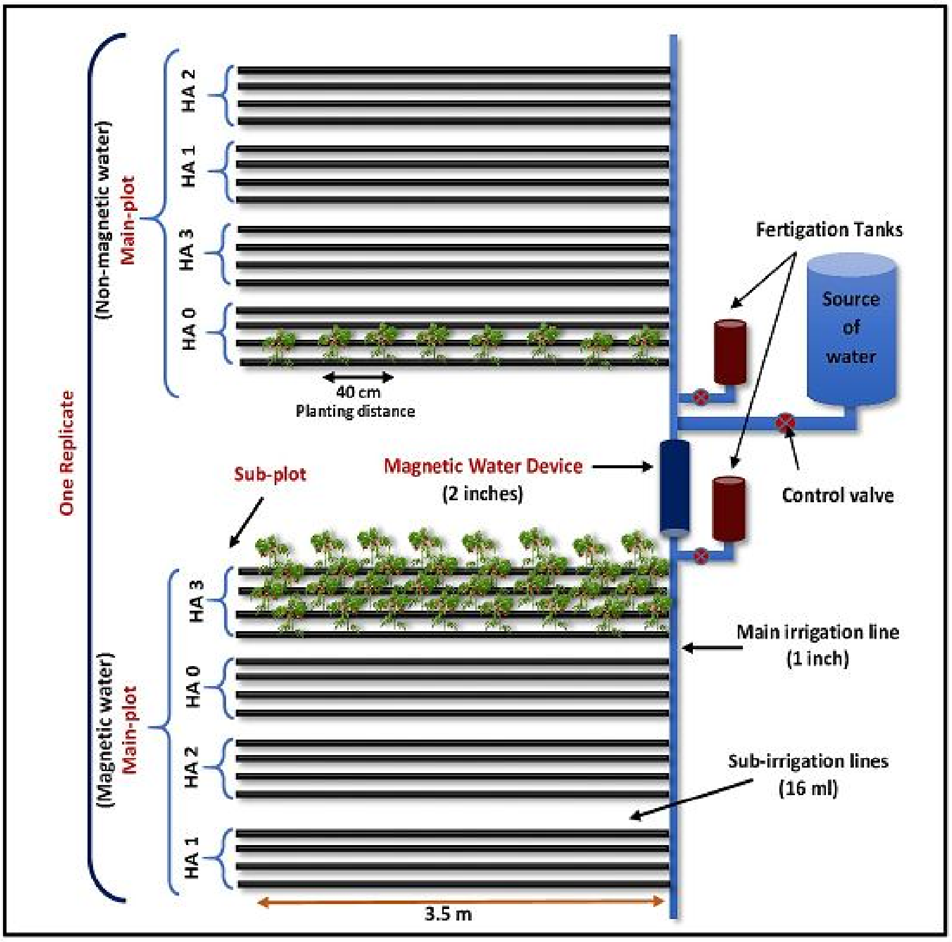

Fig 4: Lay out of the experimental field.

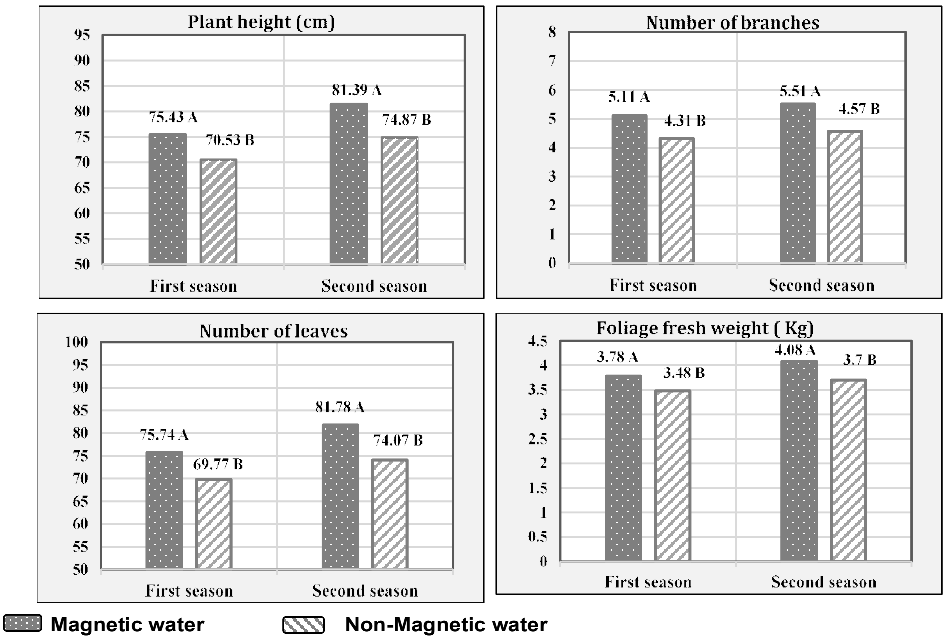

Fig 5: Effects of magnetized and non-magnetized water on vegetative growth characters of tomato plants cv. Hybrid 86 during two growing seasons of 2018 and 2019.

respect, the stimulatory impact of magnetic water may be explained by the effects of magnetic water on plant metabolism, such as photosynthesis, hormonal and enzyme activities and movements to endogenous solute, especially of carbohydrates, plant growth regulators and enzymes. Additionally, Eşitken and Turan (2004) reported that magnetic water has an effect on plant nutrient element uptake from growth media for strawberry plants.

Effect of using different concentrations of humic acid (HA) on the vegetative growth characteristics of tomato plants are presented in Fig 6. The results showed, in both seasons, a significant gradual increase in the values of all vegetative growth parameters with each increase in humic acid concentrations compared to the control treatment (0 g L^{-1}). These findings are in agreement with those obtained by Aman and Rab (2013) and Husein and Abou El-Hassan (2015), in tomato plants. This increase in plant growth may be due to the positive effect of humic acid as a plant growth stimulator in increasing cell membrane permeability, respiration, photosynthesis, oxygen and phosphorus uptake and root cell growth. Also, the effectiveness of vitamins transporters in the cell was positively affected by humic acid application (Canellasa *et al.*, 2015)

The interaction effects of irrigation water types; magnetized and non-magnetized water (MW and Non-MW) and different concentrations of humic acid (HA) significantly affected the vegetative growth characters in both growing seasons as showed in Table 1. The highest values for the four studied characters were recorded when using magnetic water combined with the highest concentrate (3 g L^{-1}) of humic acid (HA). However, the two treatments combinations MW with 2 g L^{-1} HA and Non-MW with 3 g L^{-1} HA did not significantly differ from the highest values for all vegetative characters at the two growing seasons, except for number of branches. These results indicated that using the magnetic water with humic acid led to the possibility of reducing the amount of humic acid by one-third without affecting the aforementioned growth characteristics, except for a number of branches. However, the lowest values were gained when using the treatment combination (Non-MW with 0 g L^{-1} HA). The obtained results are in harmony with Dawa *et al.* (2013), which confirmed that the interaction of irrigation with magnetized water with adding of humic acid on the pea plant led to the highest values of vegetative growth and yield. In this regard, the enhancement of growth due to magnetic treatments at the different concentrations of humic acid may be attributed to the physiochemical changes of natural water by weakling the hydrogen bonds between water molecules, which reduces surface tension, increases minerals dissolvability and provides adequate nutrients for plant growth, development of roots and shoots (Selim *et al.*, 2009).

Ripe fruit yield and its components

The results of the effects of water irrigation types, humic acid concentrations and their interactions on the fruit yield and its components of tomato are shown in (Fig 7 and 8) and (Table 2), respectively. Concerning the influences of

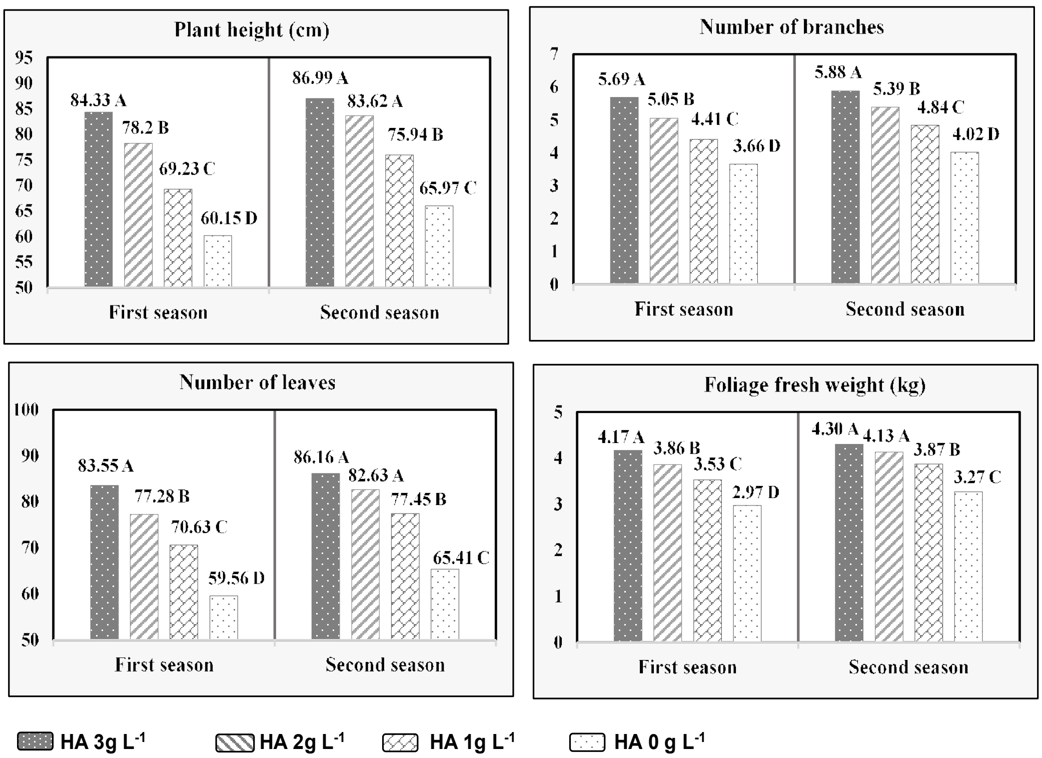

Fig 6: Effects of humic acid concentrations (HA) on some vegetative growth characters of tomato plants cv. Hybrid 86 during two growing seasons of 2018 and 2019.

Table 1: Interaction effects of irrigation water types and different concentrations of humic acid on some vegetative growth characters of tomato plants cv. Hybrid 86 during two growing seasons of 2018 and 2019.

Irrigation water	Humic acid rates (g L^{-1})	Plant height (cm)		Number of branches		Number of leaves		Foliage fresh weight (kg)	
		2018	2019	2018	2019	2018	2019	2018	2019
Magnetic	3	85.07a	89.55a	6.16a	6.49a	82.81a	87.17a	4.14a	4.36a
	2	80.52ab	84.76ab	5.44b	5.73b	80.01ab	84.22a	4.00ab	4.21a
	1	73.20c	81.33b	4.8cd	5.34bc	72.58d	80.65ab	3.63cd	4.03a-c
	0	62.95d	69.94c	4.01e	4.46d	67.59d	75.10b	3.38d	3.75bc
Non-magnetic	3	83.60a	84.44ab	5.24bc	5.29bc	84.30a	85.15a	4.22a	4.26a
	2	75.89bc	82.48b	4.66d	5.07c	74.55bc	81.04ab	3.73c	4.05ab
	1	65.27d	70.57c	4.03e	4.35d	68.70cd	74.27b	3.43d	3.71c
	0	57.35e	62.00d	3.31f	3.58e	51.55e	55.73c	2.58e	2.79d

*Values in each column for each treatment followed by different letters are significantly different using Duncan's multiple range test, at 0.05 level.

Table 2: Interaction effects of irrigation water types and different concentrations of humic acid on yield and its components characters of tomato plants cv. Hybrid 86 during two growing seasons of 2018 and 2019.

Irrigation water	Humic acid rates (g L^{-1})	Number of cluster per plant		Number of fruits per plant		Early yield per plant (kg)		Total yield plant (kg)	
		2018	2019	2018	2019	2018	2019	2018	2019
Magnetic	3	12.16a	12.80a	72.96a	76.80a	1.19a	1.25a	5.97a	6.28a
	2	11.28bc	11.88ab	67.70b	71.26ab	0.98ab	1.03ab	5.50b	5.79b
	1	10.46cd	11.62bc	62.78cd	69.76bc	0.91b	1.01b	4.92c	5.47bc
	0	9.04e	10.04d	54.26e	60.29bc	0.89b	0.99b	3.94e	4.38d
Non-magnetic	3	11.45b	11.57bc	68.73b	69.42bc	0.97b	0.98b	5.41b	5.46bc
	2	10.42d	11.32bc	62.51cd	67.95cd	0.88b	0.96b	4.74c	5.15c
	1	9.97d	10.77cd	59.81d	64.67d	0.87b	0.94b	4.20d	4.54d
	0	7.98f	8.63e	47.89f	51.77e	0.56c	0.61c	2.59f	2.80e

*Values in each column for each treatment followed by different letters are significantly different using Duncan's multiple range test, at 0.05 level.

MW, the results reflected that irrigation with MW significantly increased the mean values of the characters; number of clusters per plant, number of fruits per plant, early yield and total fruit yield compared with irrigation using Non-MW in both growing seasons. The percentage of increase in early yield at irrigation with MW was 21 and 23% for the first and second season respectively, over irrigation with Non-MW. However, the percentage of increase in total yield at irrigation with MW was 20 and 22% for the first and second season respectively, over Non-MW. These results generally, are in agreement with those obtained by Dawa *et al*. (2017) on tomato plants. They reported that the irrigation with magnetic water had significant impacts on tomato yield and its components characters. The stimulating effect of irrigation with magnetized water may be due to improving and increasing free-living micro-organisms population and activity in soil, which in turn enhance root development, increase water and mineral uptake and produce plant hormones that might be responsible for better growth of tomato plants. Also, magnetic treatments enhance the activation of phytohormone and bio-enzyme systems, which then affects various metabolic pathway activities as well as increasing the frequency of water absorption. Kuzin *et al*., (1986) suggested that magnetic fields modulate the rate of recombination of free radicals during normal plant metabolism, however the basic mechanisms responsible for the magnetic stimulation of plant growth remain a mystery and the effects of magnetic exposure on plant growth still require more explanation. Other authors suggest that magnetic fields might affect the activity of ion channels or ion transport within cells (Garcia-Sancho and Javier, 1994).

Varying concentrations of humic acid (HA), significantly affected the fruit yield and its components in tomato plants. Whereas, the mean values for the number of clusters per plant, number of fruits per plant and total fruit yield traits significantly increased with each increase in humic acid (HA) concentrations in the two seasons studied, as shown in the Fig 8. However, for early yield trait the treatments 1, 2 and 3 g L^{-1} of HA did not significantly different from each other, in the second season. These results reflect a general agreement with those obtained by Kumar *et al*. (2017) and Jayasinghe and Weerawansha (2018) on tomato plants. While these results did not agree with De Lima *et al.* (2011), who did not find a significant effect of adding of tomato plants with humic acid on the characteristics of the crop and its quality, except for the T.S.S. parameter. Through the previous results, the positive effect of adding humic acid may be due to the role of humic acid in improving some of the soil characteristics such as improve water holding capacity, pH buffering and thermal insulation (McDonnell *et al.*, 2001). Humic acid assimilates contains minor and major elements which activates or inhibits enzyme and causes changes in membrane permeability resulting in protein synthesis and

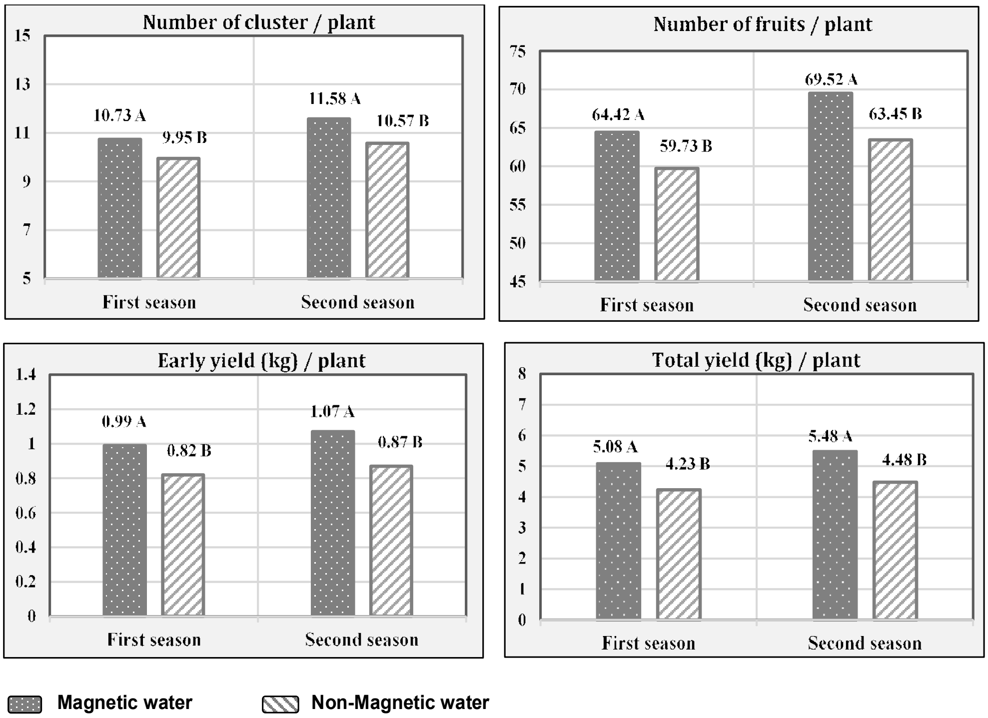

Fig 7: Effects of magnetized and non-magnetized water on yield and its components characters of tomato plants cv. Hybrid 86 during two growing seasons of 2018 and 2019.

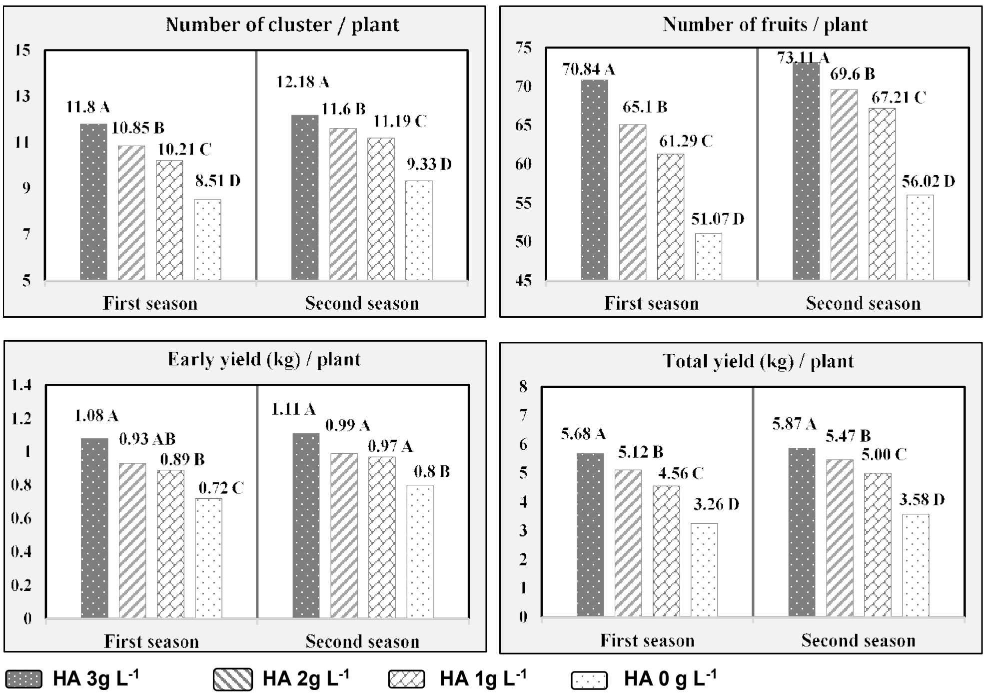

Fig 8: Effects of humic acid concentrations (HA) on yield and its components characters of tomato plants cv. Hybrid 86 during two growing seasons of 2018 and 2019.

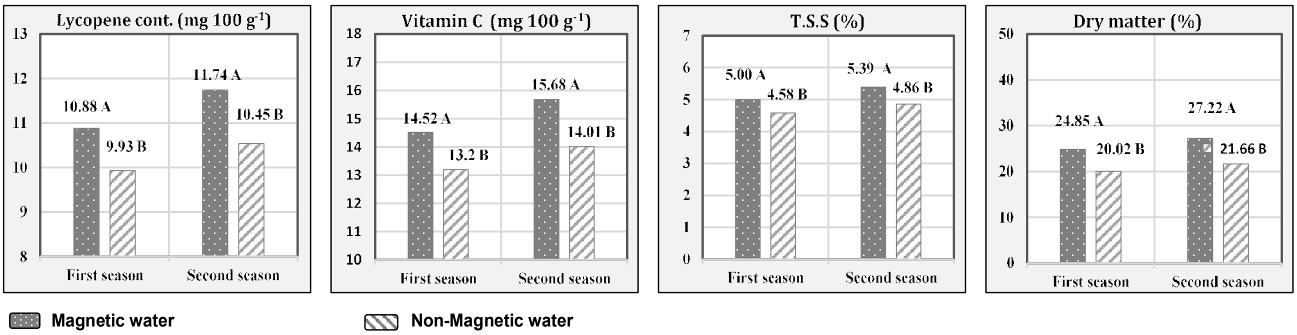

Fig 9: Effects of magnetized and non-magnetized water on some chamical composition fruits characters of tomato plants cv. Hybrid 86 during two growing seasons of 2018 and 2019.

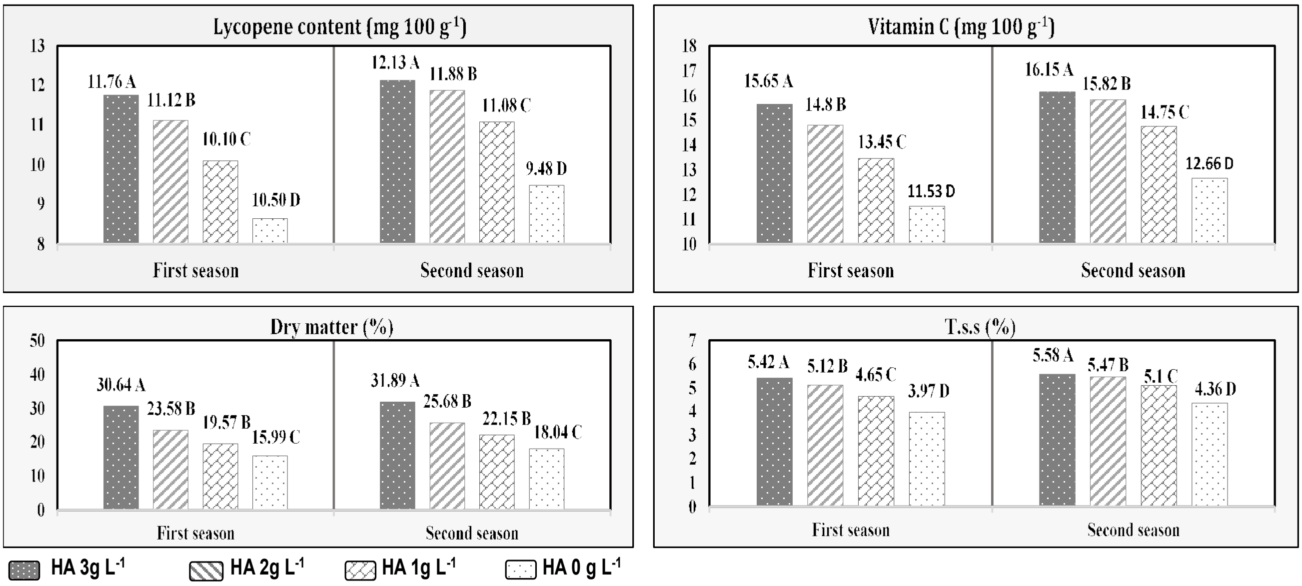

Fig 10: Effects of humic acid concentrations (HA) on some chamical composition fruits characters of tomato plants cv. Hybrid 86 during two growing seasons of 2018 and 2019.

activating biomass production, which in turn stimulates plant growth (El-Ghamry *et al*., 2009).

Regarding the effects of the interaction between two types of irrigation water (MW and Non-MW) and the four different concentrations of humic acid (HA), the obtained results listed in Table 2 showed that, tomato plants irrigated with MW combined with 3 g L^{-1} HA, gave the highest value for all fruit yield and its component traits, without significant differences from the interaction treatment between plants irrigated with MW and 2 g L^{-1} HA for number of clusters and fruits per plant at the second season and for early fruit yield at the two growing seasons. Also, the results indicated that the treatment combination MW and 2 g L^{-1} HA did not significantly differed from the treatment Non-MW and 3 g L^{-1} HA for all yield traits. These results reflect the possibility of reducing the humic acid (HA) concentrate when irrigating with magnetized water to about 33% without affecting the tomato yield and its components. These results reflected similar trends to those reported by Dawa *et al.* (2013), who studied physiological response and productivity of pea plants to irrigation with magnetized water under different concentrations of humic acid (HA). These results could probably be generally explained on the basis that the passing the water through a magnetic field increases the number of water molecules in the volume unit and increases the ability of water molecules to absorb nutrients. Magnetic water treatment has found to have a pronounced effect on plants productivity (Teixeira and Dobranszki 2014).

Chemical composition of rip fruit

Significant variations in chemical compositions properties of tomato fruit were obviously due to types of irrigation water. Irrigation with MW gave significantly higher values for lycopene content, vitamin C, total soluble solid and dry matter content as compared with Non-MW in 2018 and 2019 seasons (Fig 9). On the other hand, various concentrations of humic acid (HA) treatments reflected the significant positive effect on chemical composition traits. The highest concentrate of humic acid 3 g L^{-1}) produced significantly higher value for all above-mentioned characters. A gradual significant increase in the values was also observed with each increase in the humic acid (HA) concentrate, as shown

Table 3: Interaction effects of irrigation water types and different concentrations of humic acid on some chemical composition parameters of tomato plants cv. Hybrid 86 during two growing seasons of 2018 and 2019.

Irrigation water	Humic acid rates (g L^{-1})	Lycopene content (mg 100 g^{-1})		Vitamin C (mg 100 g^{-1})		T.S.S (%)		Dry matter (%)	
		2018	2019	2018	2019	2018	2019	2018	2019
Magnetic	3	11.79a	12.41a	15.73a	16.56a	5.42a	5.70a	33.98a	36.14a
	2	11.55b	12.16b	15.42b	16.23b	5.31b	5.59b	26.00b	27.74b
	1	10.73c	11.92c	14.31c	15.91c	4.93c	5.48c	21.52bc	24.69bc
	0	9.46d	10.51e	12.62d	14.03e	4.35d	4.83e	17.79cd	20.32cd
Non-magnetic	3	11.74a	11.86c	15.58ab	15.74c	5.42ab	5.48c	27.30b	27.64b
	2	10.69c	11.62d	14.19c	15.43d	4.94c	5.37d	21.17bc	23.62bc
	1	9.48d	10.25f	12.59d	13.60f	4.38d	4.73e	17.62cd	19.62cd
	0	7.83e	8.46g	10.45e	11.29g	3.60e	3.89f	14.20d	15.76d

*Values in each column for each treatment followed by different letters are significantly different using Duncan's multiple range test, at 0.05 level.

in Fig 10. The enhanced effects of addition of HA on tomato plants were also obtained by Kazemi (2013). These results reflected similar trends to those reported by Husein and Abou El-Hassan, (2015) and Kumar *et al*. (2017), on tomato. Generally, these authors found that tomato plants responded to different magnetic water and adding of humic acid, were recognized as a vital step in stepping up the fruit yield quality.

The differences between the mean values of the lycopene content, vitamin C, total soluble solid and dry matter percentage, appeared to be significantly influenced by the interaction effects between the types of water (MW and Non-MW) with the different concentrations of humic acid (HA), in the two seasons (Table 3). The results, generally, illustrated that the addition of humic acid as 3 g L^{-1} HA, combined with MW, resulted in the highest mean values in all the above-mentioned treats. Also, the results indicated that the treatment combination MW and 2 g L^{-1} HA did not significantly differed from the treatment, Non-MW and 3 g L^{-1} HA for all traits. These results reflected the general trends of the finding of Kazemi, (2013) and Kumar *et al.,* (2017) on a tomato plant. The results are in harmony with Al-Tarjuman *et al.* (2020) on the productivity of tomato plant. Moreover, the effects of magnetic field on plant metabolism, such as photosynthesis, hormonal and enzyme activities and movements to endogenous solute, especially of carbohydrates and hormones transported from regions of synthesis to the fruits and growth zone (Ali *et al.,* 2014).

CONCLUSION

This study clearly indicated that the use of magnetic irrigation as a new environmentally friendly technology, in combination with humic acid addition on tomato plants, leads to many benefits such as promoting vegetative growth, increasing yields and improving crop quality. Whereas, the significant positive effect of the interaction between the types of magnetized irrigation water and the different concentrations of humic acid appeared clearly on all the studied characteristics. The best results of vegetative growth attributes, fruit yield and its components and chemical constituents of fruits were recorded when plants irrigated with magnetized water and sprayed with HA at 3 gL^{-1} or 2 gL^{-1} in both seasons. Thus, these treatments could be recommended to improve tomato plants' performance under similar conditions of this study. Humic acid application as bio-stimulation agents and magnetic water technology as one of the effective non-chemical agents in improving the productivity and quality of tomato plants can be a promising technique for vegetable crops improvement.

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