Effects of magnetized water on the vegetative growth and yield of tomato

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Abstract: This study was conducted to determine the effect of magnetized water on the vegetative growth and yield of tomato. The values of magnetic flux densities used for treating the irrigation water varied from 124 to 719 G (T_2 to T_{10}) were produced from electromagnet and T_1 was the control experiment which was not treated with magnetic field. The water after passing through (treated with) magnetic field (T_2 to T_{10}) was called magnetized water while the control experiment (T_1) was called non-magnetized water. The experimental layout for the study was a 10 by 10 Latin Square Design. The tomato (variety UC82B) was planted in 100 buckets in a transparent garden shed for 130 d and irrigated with magnetized and non-magnetized water, respectively. The heights of tomato plant for magnetized water (T_2 to T_{10}) after 68 d were 546, 565, 575, 572, 596, 561, 572, 558 and 572 mm and the total yield after 130 d were 1900.7, 1673.6, 2043.4, 1848.6, 1897.2, 1336.5, 1697.3, 1758.1 and 2004.4 g, respectively. The height of tomato plant and the yield for non-magnetized water (T_1) were 511 mm and 1205.5 g, respectively. The results indicated that tomato irrigated with magnetized water grew faster than the non-magnetized water. The increment in yield with the magnetized water varied from 39% to 70% compared to that of non-magnetized water.

Keywords: magnetized water, tomato yield, vegetative growth, irrigation, electromagnet, magnetic field

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1 Introduction

Magnetic treatment of irrigation water is a new technology for agriculture and not common in Nigeria. It is environmentally friendly, boost crop yield, improve crop quality and enhance effective utilization of the arable land using the available water sources for crop production. Some researchers indicated that magnetic treatment of irrigation water offers many benefits in agriculture such as increased yield, saving water, early maturity of crop, reduced plant diseases, improved crop quality, increased fertilizer efficiency and reduced cost of farm operation (Lin and Yotvat, 1990; Podlesny et al., 2004; Maheshwari and Grewal, 2009; Babu, 2010; Moussa, 2011; Chern, 2012 and Dhawi, 2014). Magnetic field actually changes the structure of water thereby reducing the surface tension of water, increasing the minerals dissolvability of water and providing adequate nutrients for plant growth (Babu, 2010).

There are controversial issues on the use of magnetic field for the treatment of irrigation water. Some researchers agreed that magnetic treatment of irrigation water can increase the crop yield (Podlesny et al., 2004; Moussa, 2011 and Chern, 2012). Gruber and Carda (1981) concluded that there were no change in the physical and chemical properties or the calcium ion concentration of water treated with the magnetic devices. Alleman (1985) pointed out that there was no significant variation in the chemical quality for temperature, specific conductivity, surface tension, boiling point of depression, pH, alkalinity, total hardness and calcium existed between the magnetic water and non-magnetic water. Penuelas et al. (2004) stressed that magnetic field of 21-176 G can inhibit root growth. Anand et al. (2012) indicated that magnetic treatment of irrigation water can alleviate adverse effect of water stress in crop because it reduces free radicals production and antioxidant enzymes

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activity. Moussa (2011) concluded that magnetized water treated with 300 G can improve quantity and quality of common bean crop. Moussa (2011) also pointed out that magnetically treated water (magnetized water) could stimulate defense system, photosynthetic activity, and translocation efficiency of photoassimilates in common bean plants. Noran et al. (1996) pointed out that the results of their work confirmed the assumption that as a result of the influence of the magnetic field on solutes, the interaction between soil particles and salts dissolved in ordinary water does not resemble that interaction between the soil particles and the salts dissolved in magnetically treated water. Muraji et al. (1992) discovered that there was an enhancement in root growth of maize (*Zea mays*) by exposing the maize seedling to 50 G magnetic fields at alternating frequencies of 40-160 Hz. Kochmarsky (1996) indicated that the effective magnetic flux density for water treatment ranges from 1000 to 6000 G. He also pointed out that 4000 to 5000 G can attain the efficiency of 60% to 80% when applied on heater and low-pressure boilers. Chern (2012) used permanent magnet with magnetic field strength of 5500 G for treating water which was used to irrigate lady's finger moench plant and the effect on plant growth and yield was significant. The specific objective of this study was to determine the effect of magnetized water on vegetative growth and yield of tomato using nine different values of magnetic flux densities.

2 Material and methods

2.1 Site of the study

The study was carried out in the Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin, Kwara State, Nigeria. Ilorin lies on the latitude 8°30'N and longitude 4°35'E at an elevation of about 340 m above mean sea level (Ejieji and Adeniran, 2009). Ilorin is in the Southern Guinea Savannah Ecological zone of Nigeria with annual rainfall of about 1300 mm. The wet season begins towards the end of March and ends in October while the dry season starts in November and ends in March (Ogunlela, 2001). Amusan (2010) indicated that minimum and maximum temperatures of Ilorin between December, 2009 and June, 2010 were 16°C and 41°C. The minimum and maximum temperatures of Ilorin during the experiment between May and September, 2014 were 16.5°C and 41°C.

2.2 Magnetized water

Magnetic field used for the treatment of irrigation water in this study was produced from the electromagnet. The electromagnetic device was developed using the readily available materials in Ilorin, Nigeria. It has a variable voltage unit with nine terminals for selecting 4, 5, 6, 7, 8, 9, 10, 11 and 12 V. Magnetic flux densities used were 124, 253, 319, 400, 443, 530, 592, 612 and 719 G (measured inside the treatment pipe), respectively for the nine voltage terminals. These flux densities were used for the treatment of the irrigation water and labelled as T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9 and T_{10} while T_1 for untreated water with 0.0 gauss as the control experiment. The north and south poles of the electromagnetic cores on the treatment chamber seat in this study were arranged in alternated form for effective treatment of irrigation water by the magnetic field (McMahon, 2006). The irrigation water was allowed to pass through the treatment chamber (pipe) of the electromagnetic unit four (4) times by circulation method for duration of 113 s for effective treatment by magnetic field according to Chern (2012). The electromagnetic treatment unit and collection of magnetically treated water from the electromagnet were shown in Figures 1 and 2.

Figure 1 Electromagnetic treatment system with a fan

Figure 2 Collection of magnetically treated water from the electromagnet

2.3 Determination of water requirement by tomato and irrigation interval

Water requirement of a plant is the amount of water required to meet the required evapotranspiration, photosynthesis and metabolic process. Crop evapotranspiration, depth of water required to bring the soil to field capacity at the beginning of the experiment, available water, wilting point, net depth of irrigation, irrigation interval, volume of water required daily by tomato plant and volume required in three (3) d irrigation interval for two stands of tomato plant were determined using Equations (1), (2), (3), (4), (5), (6) and (7), respectively. All the Equations are available in (Michael, 2008) but Equation (4) was given by (Sani, 2003).

$$ETc = K_c \times ET_o \tag{1}$$

$$D_F = \frac{\rho_b}{\rho_w}\left(\frac{FC - \Theta_1}{100}\right)D_b \tag{2}$$

$$AW = \frac{\rho_b}{\rho_w}\left(\frac{FC - WP}{100}\right)D_b \tag{3}$$

$$WP = \frac{FC}{F} \tag{4}$$

$$I_v = \frac{d_n}{ETc} \tag{5}$$

$$V_{dp} = K_c \times ET_o \times C_c \times A_p \tag{6}$$

$$V_{days} = V_{dp} \times N_p \times I_v \tag{7}$$

where, ETc is the crop evapotranspiration (mm day^{-1}); Kc is the crop coefficient; ETo is the reference evapotranspiration (mm day^{-1}); D_F is the depth required to bring moisture content to field capacity at the beginning of the experiment (mm); ρ_b is soil bulk density (g cm^{-3}); ρ_w is the density of water (g cm^{-3}); FC is the field capacity of the soil (%); Θ is the moisture content of the soil prior to irrigation (%); D_b is depth of the bucket (mm); Aw is the available water (mm), WP is the wilting point (%); F is a factor ranging from 2.0-2.4 depending on the percentage of silt in the soil. The value of F used was 2.2 and wilting point was calculated to be 12.26% when field capacity (FC) was 26.98%; I_v is the irrigation interval (day); d_n is the net depth of irrigation (mm); V_{dp} is the volume of water required daily per plant (litre day^{-1}); C_c is the crop canopy (%); A_p is the area of the bucket (mm^2) and N_p is the number of tomato stand in a bucket or point. The maximum values of reference evapotranspiration for Ilorin between May and September of the year was 4.7 mm day^{-1} (Chineke et al., 2011) and mean crop coefficient (k_c) for tomato at flowering stage is 1.15 (Ufoegbune et al., 2012) but 1.05 was used in this study. The crop evapotranspiration of tomato (ETc), AW, d_n, I_v and volume of water required were determined as follows:

$$ETc = 1.05 \times 4.7 = 4.94 \text{ mm day}^{-1}$$

$$AW = \frac{1.433}{1.000}\left(\frac{26.98 - 12.26}{100}\right) \times 235 = 49.57 \text{ G}$$

$$d_n = \frac{30}{100} \times 49.57 = 14.871 = 14.87 \text{ mm}$$

$$I_v = \frac{14.87}{4.94} = 3.010 \text{ mm day}^{-1}$$

$$V_{dp} = 1.05 \times 4.7 \times 0.8 \times 0.054332 = 0.215 \text{ litre day}^{-1}$$

$$V_{3days} = 0.215 \times 2 \times 3 = 1.30 \text{ litres}$$

A 1.30 L of water was calculated as the water requirement for two stands of tomato plant per bucket for 3 d irrigation interval.

2.4 Soil properties

The soil used in this study was loamy sand obtained at the descried site of the study, from the top soil layer at the back (North) of the Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin. Three soil samples were taken from the soil for textural and chemical analyses. The tests were performed at the laboratory of the Department of Agronomy, University of Ilorin. Chemical tests included pH, nitrogen (N), phosphorous (P), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), sodium (Na^+), organic matter, organic carbon and soil cation-exchange capacity (C.E.C). The results are shown in Tables 1 and 2. The soil was properly mixed together in order to have the uniform soil property. The soil was used to fill the test buckets to a depth (level) of 235 mm and the diameter of the bucket at that level was 263 mm (A_p = 0.05433 m^2). The soil volume per bucket (pot) was approximately 13.0 L.

2.5 Plant material

The tomato (*Lycopersicon esculentum Mill.*) variety UC82B seed was purchased from the Kwara State Ministry of Agriculture, Ilorin and eight seeds were planted directly into each test bucket. The tomato plant was thinned 23 d after planting into two stands per bucket and kept in a transparent garden shed on the experimental field as shown in Plate 3, for 130 d. The tomato variety can be harvested from 80 to 120 d after planting. The buckets were arranged in 10 by 10 Latin Square Design (LSD) experimental layout in a transparent garden shed of the experimental field as shown in Figure 3.

Table 1 Textural analysis of the soil used

Sample	Silt, %	Clay, %	Sand, %	Soil type
A	10.00	5.76	84.24	Loamy sand
B	10.00	5.76	84.24	Loamy sand
C	6.00	5.76	88.24	Loamy sand
Mean	8.67	5.76	85.57	Loamy sand

Table 2 Chemical properties of the soil used

Element	Sample A	Sample B	Sample C	Mean
pH	6.0	5.8	5.6	5.8
N, %	0.58	0.63	0.71	0.64
P, mg kg^{-1}	2.51	2.46	3.25	2.74
Ca^{2+}, cmol kg^{-1}	1.28	1.14	1.68	1.37
Mg^{2+}, cmol kg^{-1}	0.92	0.58	1.01	0.84
K^+, cmol kg^{-1}	2.20	2.11	2.42	2.24
Na^+, cmol kg^{-1}	1.03	1.24	1.18	1.15
Organic matter, %	1.56	1.15	1.22	1.31
Organic carbon, %	0.90	0.67	1.01	0.86
C.E.C, meq 100g^{-1} of soil	5.63	5.12	6.46	5.74

Figure 3 Experimental field of the transparent garden shed for the tomato plant

2.6 Experimental design

The experimental layout for the study was a 10 by 10 (LSD), fulfilling a total of 100 buckets with 10 buckets for each treatment. Nine treatments were carried out with magnetized water, treated with different magnetic flux densities ranging from 124 to 719 G (T_1=0, T_2=124, T_3=253, T_4=319, T_5=400, T_6=443, T_7=530, T_8=592, T_9=612 and T_{10}=719 G) and a control experiment with non – magnetized water (T_1). Pots were irrigated with 1.30 L of magnetized and non–magnetized water every 3 d.

2.7 Parameters assessed

2.7.1 Chemical properties of water measured

The water used flowed through magnetic flux density and chemical properties of water before magnetization and after magnetization were determined for four different magnetic flux densities as shown in Table 3.

Table 3 Mean values of chemical properties of water treated with four selected magnetic flux densities

Element	Unit	Water treated with various magnetic flux densities				
		719 (G)	443 (G)	319 (G)	124 (G)	NMW
Ca^{2+}	mg L^{-1}	3.150	3.140	3.195	3.300	3.130
Mg^{2+}	mg L^{-1}	1.125	1.135	1.355	1.300	1.285
K^+	mg L^{-1}	0.905	0.905	0.890	0.850	0.885
Na^+	mg L^{-1}	80.44	80.73	80.93	80.10	81.91
Pb^{2+}	mg L^{-1}	0.295	0.310	0.285	0.310	0.300
Cd^{2+}	mg L^{-1}	0.090	0.090	0.850	0.085	0.075
P	mg L^{-1}	0.675	0.665	0.650	0.625	0.670
CO_3^{2-}	mg L^{-1}	3.760	3.580	3.960	3.300	3.690
SO_4^{2-}	mg L^{-1}	52.38	51.20	49.14	47.53	47.80
N (NO_3^-)	mg L^{-1}	40.89	43.91	42.99	44.50	42.73
Cl^-	mg L^{-1}	75.40	71.07	77.38	75.60	74.67
pH		7.46	7.41	7.46	7.43	7.36
EC	µS cm^{-1}	185.5	182.5	186.5	177.0	186.0

Note: NMW = Non-magnetized water (Water before magnetization).

2.7.2 The plant parameters measured

Heights of tomato plant were measured at 31, 41, 51 and 68 d after planting with a tape rule. The stem diameters were measured twice during the vegetative growth 68 and 76 d after planting at 30 mm above the soil level in the bucket using venire caliper. The yields of the fresh tomato were also measured (estimated) for each test bucket.

2.8 Statistic tests

The statistical tests carried out on the yield of tomato were the Latin Square Design (LSD) and Paired t-test. LSD was carried out to determine if the effect of treating irrigation water by magnetic flux densities of 0, 124, 253, 319, 400, 443, 530, 592, 612 and 719 G was statistically significant on the yield of tomato or not.

The effects due to row, column and treatment in the Latin Square Design are calculated by Sum of square row (SSR), Sum of square column (SSC), Sum of square treatment (SST_R) and Sum of square total (SST_O) using Equations (8), (9), (10) and (11), respectively while correction factor (C.F) and sum of square error (SSE) could be respectively determined using Equations (12) and (13), respectively as stated by Gomez and Gomez (1984). Calculations were done after the Equations and the ANOVA is shown in Table 4.

$$SSR = \frac{\sum R^2}{t} - C.F \tag{8}$$

$$SSC = \frac{\sum C^2}{t} - C.F \tag{9}$$

$$SST_R = \frac{\sum T^2}{t} - C.F \tag{10}$$

$$SST_O = \sum X^2 - C.F \tag{11}$$

$$C.F = \frac{G^2}{t^2} \tag{12}$$

$$SSE = SST_O - (SSR + SSC + SST_R) \tag{13}$$

where, *t* is the number of treatments, G is the grand total.

$$SSR = \left(\frac{1922.2^2 + 1514.6^2 + 2030.8^2 + \ldots.. + 1912.3^2}{1O} \right) - \frac{17253.3^2}{100} = 49491.31$$

$$SSC = \left(\frac{1620.4^2 + 1321.3^2 + 1638.0^2 + \ldots.. + 2502.5^2}{1O} \right) - \frac{17253.3^2}{100} = 110742.86$$

$$SST_R = \left(\frac{1205.0^2 + 1866.2^2 + 1673.6^2 + \ldots.. + 1956.1^2}{1O} \right) - \frac{17253.3^2}{100} = 66040.29$$

$$SST_O = (224.6^2 + 134.4^2 + 129.9^2 + \ldots. + 423.8^2) - \frac{17253.3^2}{100} = 747098.31$$

$$SSE = 747098.31 - (49491.31 + 110742.86 + 66040.29) = 520823.85$$

Table 4 ANOVA for the yield of tomato using LSD

Source of error	Degree of freedom (D.F)	Sum of square (SS)	Mean square (MS)	Calculated F	Tabular *F* at *P*≤5%
Row	9	49,491.31	5,499.0	0.7602^{NS}	2.01
Column	9	110,742.86	12,304.76	1.7010^{NS}	2.01
Treatment	9	66,040.29	7,337.81	1.0144^{NS}	2.01
Error	72	520,823.85	7,233.66		
Total	99	747,098.31			

Note: NS= not significant.

Paired t-test was also carried out to determine if the magnetized water was statistically significant on the yield of tomato compared to the yield from non-magnetized water. The difference between the two mean of the results was determined and then used to compute standard deviation, standard error and t–test value using Equations (14), (15a) or (15b), (16) and (17) as given by Montgomery et al. (1998). Data of the yield of tomato for computation of paired t-test is shown in Table 5.

$$\bar{d} = \frac{\sum d}{n} \tag{14}$$

$$\delta = \sqrt{\frac{\sum (d - \bar{d})^2}{n-1}} \tag{15a}$$

$$\delta = \sqrt{\frac{\sum d^2 - n(\bar{d})^2}{n-1}} \tag{15b}$$

$$\delta_{Er} = \frac{\delta}{\sqrt{n}} \tag{16}$$

$$t_{cal} = \frac{\bar{d}}{\delta_{Er}} \tag{17}$$

where, $\bar{d}$ is the mean of the difference from the data x_1 and x_2; Σ*d* is the summation of *d*; *n* is the number of the observations; δ is the standard deviation; δ_{Er} is the standard error and t_{cal} is the calculated value of t which was compared with the Table value of t_{Tab}.

Table 5 Yield of tomato for computation of paired t-test

MTW (x_1)	NMTW (x_2)	$d = x_1 – x_2$	d^2
1900.7	1205.0	695.7	483,998.49
1673.6	1205.5	468.6	219,585.96
2043.4	1205.5	838.4	702,914.58
1848.6	1205.5	643.6	414,220.96
1897.2	1205.5	692.2	479,140.84
1336.8	1205.5	131.8	17,371.24
1697.3	1205.5	492.3	242,359.29
1735.1	1205.5	553.1	305,919.61
2004.4	1205.5	799.4	635,040.36
n = 9	Σd = 5315.1		Σd^2 = 3,504,551.33

Note: MTW=Magnetized water, NMTW=Non-magnetized water.

$\bar{d} = \frac{5315.1}{9} = 590.57$, Then, the standard deviation (δ) from Equation (15b) is

$$\delta = \sqrt{\frac{3504551.33 - 9(590.57)^2}{9-1}} = 213.774$$

$$\delta_{Er} = \frac{213.774}{\sqrt{9}} = 71.258$$

$$t_{cal} = \frac{590.57}{71.25} = 8.288$$

3 Results and discussion

3.1 Vegetative growth and stem diameter

The results of this study revealed that using magnetic flux density of 124-719 G for treating irrigation water had effect on vegetative growth and the stem thickness (diameter) of tomato. Tomato plant which was irrigated with magnetized water grew faster and had bigger stem diameter than those irrigated with non-magnetized water as shown in Tables 6 and 7. Tomato plant irrigated with magnetized water also matured faster with the first harvest occurred 80 d after planting but harvesting started 91 d after planting with non – magnetized water. Reduction in time or early maturity of the tomato and high yield with the tomato irrigated with magnetized water were in agreement with the research conducted by Selim (2008), Maheshwari and Grewal (2009).

Table 6 Average height of tomato plant per treatment, over time

Treatment date	Days after planting	Tomato plant height, mm									
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
3/6/2014	31	163	175	187	177	204	178	204	180	185	180
13/6/2014	41	324	331	350	333	381	337	340	342	340	344
23/6/2014	51	444	471	511	466	528	473	450	483	504	512
10/7/2014	68	511	546	565	575	572	596	561	572	558	572

Treatment code: T_1, Non–magnetized water; T_2 to T_{10} = magnetized water treated with different magnetic flux densities 124-719 G, T_1=0, T_2=124, T_3=253, T_4=319, T_5=400, T_6=443, T_7=530, T_8=592, T_9=612 and T_{10}=719 G.

Table 7 Stem diameter of tomato plant at 30 mm above the soil level in the bucket

Treatment date	Days after planting	Diameter of the stem of tomato plant, mm									
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
10/7/2014	68	7.02	9.00	8.82	8.93	9.18	8.22	8.67	8.62	8.30	8.77
18/7/2014	76	9.11	9.68	9.69	9.70	10.42	9.73	10.85	9.49	9.82	9.32

Note: Treatment code as defined in Table 6.

3.2 Fruiting stage and tomato yield

The fruiting of tomato irrigated magnetized water was better in term of number of fruits and with bigger fruit size than the tomato irrigated with non-magnetized water. A tomato plant was randomly selected with fruit irrigated with magnetized water was shown in Figure 4 while the tomato plant with biggest fruit for non-magnetized water was selected as shown in Figure 5. The yields of tomato irrigated with treated water using different magnetic flux densities were higher than that of untreated water as shown in Table 8 and bar chart in Figure 6. The yield with the magnetized water varied from 1673.6 to 2043.4 g while that of non-magnetized water was 1205.0 g as shown in Table 8. The percentage increment in yield of tomato with the magnetized water varied from 39% to 70% compared to the yield of tomato from the non–magnetized water. Magnetized water increased yield as stated by (Selim, 2008; Maheshwari and Grewal, 2009; Hozayn and Abdul – Qados, 2010; Moussa, 2011 and El-Sayed and Sayed, 2014). Treatment seven (T_7) at column 1 failed to bear fruit and because of that T_7 was not used as a reference value for calculating the percentage increment in yield of the tomato. The samples of tomato fruits obtained from magnetized water and non-magnetized water were shown in Figure 7. The effect of using different magnetic flux densities 124 to 719 G as the treatments for treating irrigation water was not statistically significant on the yield of tomato with calculated value of F was 1.01 while the Table value of F was 3.48 at 5% significant level. The paired t-test indicated that magnetized water had significant effect on the yield of tomato. The calculated value of t (t_{cal}) was 8.288 while the Table value of t (t_{Tab}) was 2.306 when degree of freedom was 8 at α = 0.05 (α = 5/2 = 0.025) (t_{cal} = 8.288 > t_{Tab} = 2.306) which meant that the yield of tomato produced using magnetized water to irrigate the tomato plant was statistically significant when compared to the yield of tomato produced using non-magnetized water.

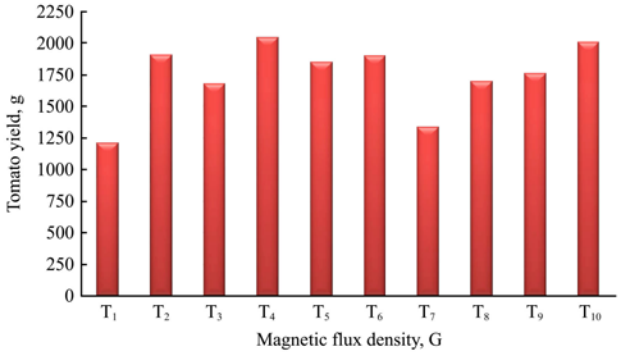
Table 8 Yield of the fresh tomato

Column	Tomato yield, g									
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
1	224.6	162.7	151.2	284.7	75.6	177.2	0.0*	397.3	128.1	62.0
2	73.1	231.5	134.4	241.6	144.7	212.6	119.6	36.2	46.0	92.1
3	82.8	282.7	215.1	322.5	139.9	185.2	48.0	76.7	187.7	129.9
4	181.2	160.3	116.6	146.2	282.3	90.9	105.3	90.5	139.8	78.0
5	184.2	178.7	267.4	110.0	280.4	183.7	70.2	117.0	208.7	165.5
6	42.5	160.5	275.0	241.9	259.1	187.5	290.1	147.1	214.7	251.0
7	8.2	91.5	135.7	173.3	203.9	202.8	239.0	175.8	282.7	321.0
8	119.1	61.2	35.6	118.6	74.5	188.7	144.7	195.7	180.2	362.4
9	138.2	318.0	179.2	104.0	141.1	131.4	141.6	158.2	217.6	118.7
10	151.1	253.6	163.4	300.6	241.1	337.2	178.0	302.8	152.6	423.8
Total	1205.0	1900.7	1673.6	2043.4	1848.6	1897.2	1336.5	1697.3	1758.1	2004.4
Mean	120.50	190.07	167.36	204.34	184.86	162.55	133.65	169.73	175.81	200.44

Note: Treatment code as defined in Table 6.

Figure 4 Tomato fruit irrigated with magnetized water at row 10 column 10 (treated with 719 G) after 80 d

Figure 5 Tomato fruit irrigated with non-magnetized water at row10, column 8 after 80 d with the biggest fruit



Note: Treatment code as defined in Table 6. T_7*= one bucket of the tomato plant with the treatment 7 failed to bear fruit.

Figure 6 Average tomato yield per treatment using different magnetic flux densities

Figure 7 Sample of tomato fruits from magnetic treated water (the 2 samples by the right) and non-magnetic treated water with the biggest sizes after 95 d (1 sample by the left)

4 Conclusions

Magnetic treatment of irrigation water has positive effect of the vegetative growth on tomato by increasing the rate of growth, reduction in the time of maturity and increased the yield of tomato. The heights of tomato plant for magnetized water (T_2 to T_{10}) after 68 days were 546, 565, 575, 572, 596, 561, 572, 558 and 572 mm and the total yield after 130 days were 1900.7, 1673.6, 2043.4, 1848.6, 1897.2, 1336.5, 1697.3, 1758.1 and 2004.4 g, respectively. The height of tomato plant and yield for non-magnetized water were 511 mm and 1205.5 g, respectively. Magnetic flux densities used for the treatment of irrigation water varied from 124 to 719 G inside the treatment pipe and were adequate for the treatment of irrigation water. The magnetized water increased the yield of tomato by 39% to 70%.

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