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Impact of Magnetic Treatment of Irrigation Water on the Growth and Yield of Tomato

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Abstract

This study was carried out to determine whether magnetic treatment of the irrigation water may actually enhance vegetative growth and yield of tomato. Three magnetic flux densities of 124, 319 and 719 G (treatments T_1, T_2 and T_3) were used to treat the water and a control experiment (Tc) which was irrigated with non-magnetically treated water was also set up. The magnetic field was produced by an electromagnet that had a variable voltage unit varying the voltage from 4 to 12 V. The tomato were planted in buckets, kept in a transparent garden shed for 130 days and irrigated with magnetically treated water and non-magnetically treated water. A completely randomized design experimental layout was used in this study and each of the three treatments was replicated seven times. The results indicated that tomato crop irrigated with magnetically treated water grew faster than that of the non-magnetically treated water and the stem diameters were bigger than those of control. The heights of tomato plants (T_1, T_2 T_3 and Tc) after 47 days were 560.0, 556.4, 588.6 and 469.3 mm respectively. The total yield after 130 days of survey for T_1, T_2 T_3 and Tc were 892.1, 1075.8, 1045.7 and 637.7 g respectively. The percentage increment in yield from the plants treated with magnetically treated water varied from 39.9 to 68.7% compared to the yield from untreated water.

Keywords: crop booster, irrigation, magnetically treated water, voltage

Introduction

The use of magnetic field for the treatment of water is still a controversy issue especially in the Western world and Asian countries. Some researchers agreed that magnetic treatment of irrigation water can increase the crop yield (Podlesny *et al*., 2004; Moussa, 2011; Chern, 2012). There are several studies indicating that magnetic treatment of irrigation water offered many benefits in agriculture such as increased yield, water economy, early maturity of crops, reduced plant diseases, improved crop quality, increased fertilizers' efficiency and reduced cost of farm operations (Kronenberg, 1985; Maheshwari and Grewal, 2009; Babu, 2010; Hozayn and Qados, 2010; Suchitra and Babu, 2011).

Magnetic field may actually change the structure of water, thereby reducing surface tension, increase minerals' dissolvability and provide adequate nutrients for plant growth (Babu, 2010). When water passes through a magnetic field, its structure and some physical characteristic such as density, salt solution capacity and deposition ratio of solid particles are to be changed (Higashitani *et al*., 1993).

Anand *et al.* (2012) indicated that magnetic treatment of irrigation water alleviated adverse effect of water stress as it reduced free radicals production and antioxidant enzymes activity. Moussa (2011) concluded that magnetically treated water with 3,000 G improved quantity and quality of common bean crop. He pointed that magnetic water could stimulate the defence system of plants, photosynthetic activity and translocation efficiency of photoassimilates. Noran *et al*. (1996) also 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 did not resemble the interaction between the soil particles and the salts dissolved in magnetically treated water. Muraji *et al.* (1998) 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. However, there was a reduction in primary root growth of maize plants grown in a magnetic field alternating at 240-320 Hz. The highest growth rate of maize roots was achieved in a magnetic field of 50 G at 10 Hz. Kochmarsky (1996) also applied a magnetic flux density for water treatment ranging from 1,000 to 6,000 G. Chern (2012) used permanent magnet with magnetic field strength of 5,500 G for treating water which was used to irrigate okra plants and the effect on plant growth and yield was significant.

This study was carried out to determine whether magnetic treatment of the irrigation water may actually enhance vegetative growth and yield of tomato.

Materials and Methods

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[1]N and longitude 4°35[1]E at an elevation of about 340 m above mean sea level (Ejieji and Adeniran, 2010). Ilorin is in the Southern Guinea Savannah Ecological zone of Nigeria with annual rainfall of about 1,300 mm. The wet season begins towards the end of March and

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ends in October, while the dry season starts in November and ends in March (Ogunlela, 2009). The temperatures from the wet and dry bulb thermometer in the transparent garden shed where the tomato (variety UC82B) were grown between 23rd September 2014 and 30th January 2015 varied from 16.5 to 30 °C (wet bulb) and 23.3 to 38 °C (dry bulb) with relative humidity of 50 to 90%.

A rectangular treatment chamber with an internal dimension of 1.5 by 4.6 cm and 100 cm long was used. The magnetic flux density measured between two magnetic cores without air gap varied from 700 to 4,310 G. The effective mean magnetic flux densities inside the rectangular treatment chamber when water was flowing through it were determined using gaussmeter and were 124, 319 and 719 G respectively. These three flux densities were used to treat the irrigation water and labeled as the treatments T_1, T_2 and T_3, compared with a control experiment (Tc) which was not treated. The North and South poles of the electromagnetic cores on the treatment chamber seat in this study were alternated for effective treatment of irrigation water by the magnetic field (Gabrielli *et al.*, 2000). The irrigation water was allowed to pass through the treatment chamber unit four (4) times for duration of 113 seconds with a circulation flowing method as shown in Fig. 1 and Fig. 2.

Determination of the water requirement by tomato plants and the irrigation interval

Water requirement of tomato plant is the amount of water

Fig. 1. Electromagnetic treatment system with a fan
1- water tank, 2- tap, 3- hose, 4- stood, 5- variable voltage device, 6- pipe, 7- electromagnet, 8- cooling fan

Fig. 2. Magnetically treated water from the electromagnet
9- positive terminal from variable voltage device, 10- variable voltage device, 11- distribution copper wire, 12- electromagnet with 180 turns of coil, 13- rectangular treatment chamber, 14- connecting wire to socket, 15- treated water from electromagnet, 16- bucket containing magnetically treated 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 plants and volume of required in three (3) days irrigation interval for two stands of tomato plants were determined using equations (1), (2), (3), (4), (5), (6) and (7) respectively. The quantity of 1.30 liter of water was determined as the water required by two stands of tomato plants for 3 days irrigation interval.

$$ETc = K_c \times ET_o \qquad (1)$$

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

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

$$WP = \frac{FC}{F} \qquad (4)$$

$$I_v = \frac{d_n}{ETc} \qquad (5)$$

$$V_{dp} = K_c \times ET_o \times C_c \times A_p \qquad (6)$$

$$V_{days} = V_{dp} \times N_p \times I_v \qquad (7)$$

Where: ETc is the crop evapotranspiration (mm/day), K_c is the crop coefficient, ET_o is the reference evapotranspiration (mm/day), 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 (liter/day), 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.

$$ETc = 1.05 \times 4.7 = 4.94\,mm\ /\ day$$

$$D_F = \frac{1.433}{1.000}\left(\frac{26.98 - 5.23}{100}\right) \times 235 = 73.24$$

$$V_F = 0.07324\ X\ 0.054332 = 0.003979\ m^3 = 3.979\ litres$$

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

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

$$I_v = \frac{14.87}{4.94} = 3.010\,mm\ /\ day$$

$$V_{dp} = 1.05 \times 4.7 \times 0.8 \times 0.054332 = 0.215\,litre\ /\ day$$

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

Soil properties

The soil used in this study was loam sand with percentage contents of silt, calay and sand of 8.67, 5.76 and 85.57% respectively. The soil was mixed together properly after the soil analyses in order to have the same soil property. The chemical properties of the soil used were shown in Table 1. The soil was filled into the bucket (21 buckets with 7 buckets for each treatment and 7 buckets for untreated water) to a depth (level) of 235 mm and the diameter of the bucket at that level was 235 mm (A_p= 0.05433 m^2). A completely randomized design (CRD) experimental layout was used for allocating the treatments in the transparent garden shed.

Table 1. Physico-chemical properties of experimental soil

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)	2.51	2.46	3.25	2.74
Ca^{2+} (cmol/kg)	1.28	1.14	1.68	1.37
Mg^{2+} (cmol/kg)	0.92	0.58	1.01	0.84
K^{+} (cmol/kg)	2.20	2.11	2.42	2.24
Na^{+} (cmol/kg)	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 of soil)	5.63	5.12	6.46	5.74

Results and Discussion

Vegetative growth and stem diameter of tomato plants

The results of this study revealed that using magnetic flux densities of 124, 319 and 719 G for treating the irrigation water influenced the vegetative growth and stem diameter (thickness) of the tomato plants. Tomato plants which were irrigated with magnetically treated water grew faster and had bigger stem diameter than that of non-magnetized water as shown in Tables 2 and 3. Tomato plants irrigated with magnetized water also matured faster, with the first harvest occurred 74 days after planting, while harvesting started 85 days after planting with non-magnetically treated water plants. Reduction of time needed for plants to reach maturity (early maturity) when irrigated with magnetized water was in agreement with the research conducted by Mashehwari and Grewal (2009). The growth rate (height) of tomato plants irrigated with magnetically treated water was statistically significant compared with tomato plants irrigated with non-magnetized water; calculated value of F was 8.10, while the table value of F was 2.78 as shown by ANOVA test in Table 4.

Table 2. Mean height of the tomato plants recorded during the vegetative growth

Date	Tomato plant height (mm)			
	T_1	T_2	T_3	T_C
19/10/2014	154.3	178.6	199.3	137.1
25/10/2014	302.1	325.0	330.0	243.6
30/10/2014	446.4	453.6	457.9	345.7
03/11/2014	515.0	532.0	530.0	407.9
09/11/2014	560.0	556.4	588.6	469.3

T_1 = 124 G, T_2 = 319 G, T_3 = 719 G and T_C = 0.0 G

Table 3. Mean diameter of the tomato stems, measured 30 mm above the soil level

Date	Stem diameter (mm)			
	T_1	T_2	T_3	T_C
01/11/2014	6.21	6.43	6.19	5.09
09/11/2014	8.64	7.99	8.21	6.96

T_1 = 124 G, T_2 = 319 G, T_3 = 719 and T_C = 0.0 G

Table 4. ANOVA for the height of tomato plants in the consumptive use experiment

Source of error	Degree of freedom (DF)	Sum of square (SS)	Mean square (MS)	Calculated F	Tabular F at P ≤ 5 %
Treatment	3	558.50	186.17	8.07	2.78
Error	24	553.76	23.07		
Total	27	1,112.26			

Tomato yield

The tomato yield after using three different magnetic flux densities are shown in Table 5. The tomato yields from plants treated with the magnetically treated water at 124, 319 and 719 G were 892.1, 1075.8 and 1045.7 g respectively, while the tomato yield from the non-magnetized water was 637.7 g. It can be concluded that the magnetic flux density of 319 G produced the highest yield. The variation of the tomato yield based on the magnetic flux densities was not statistically significant because the calculated value of F (F_{cal} =1.31) was less than the Table value (F_{Tab} = 2.78) as shown in Table 6. This means that there was no much variation in the yields of tomato based on the three magnetic flux densities applied in the experiment to treat the irrigation water. On the other hand, the yields from magnetically treated water were all higher than the yield obtained from non-magnetically treated water. The percentage increment of the tomato yields were 39.9, 64.0 and 68.7% respectively when compared with the yield from the control experiment. The increment was in concordance with the findings of other researchers who concluded that magnetic treatment of irrigation water increased crop yield (Mahsehwari and Grewal, 2009; Hozayn and Qados, 2010; Moussa, 2010; Anand *et al.*, 2012; Chern, 2012). The results of this study revealed that magnetic treatment of the irrigation water had effect on the vegetative growth of tomato plants and enhanced tomato yield (being obtained high yield as shown in Table 5), which is in agreement with the work done by Babu (2010) and El-Sayed and Sayed (2014).

The tomato plants irrigated with magnetically treated water contained fresh leaves and tomato fruits after 120 days from the beginning of the survey, while the tomato plants irrigated with non-magnetically treated water had dry leaves and very few tomato fruits as shown in Fig. 3 and Fig. 4.

Table 5. Tomato yield from the different magnetized water treatments

Row	Tomato yield (g)			
	T_1	T_2	T_3	T_C
1	26.2	35.0	153.1	111.1
2	160.5	45.6	210.4	81.1
3	152.5	103.1	151.6	31.5
4	150.9	223.1	124.3	10.0
5	123.8	174.0	218.2	119.8
6	159.0	304.5	78.1	115.6
7	119.2	190.5	110.0	168.6
Total	892.1	1,075.8	1,045.7	637.7
Mean	127.44	153.69	149.39	91.10

T_1 = Magnetized water treated with 124 G, T_2 = 319 G, T_3 = 719 G and T_C = 0.0 G (Non-magnetized water). The tomatoes were planted on 23/09/2014 and harvesting was stopped on 30/01/2015 (tomato plants were monitored for 130 days).

Table 6. ANOVA for the yield of tomato in the consumptive use experiment

Source of error	Degree of freedom (DF)	Sum of square (SS)	Mean square (MS)	Calculated F	Tabular F at 5%
Treatment	3	17,191.05	5,730.35	1.31	2.78
Error	24	105,056.00	4,377.33		
Total	27	122,247.05			

Fig. 3. Tomato plant irrigated with magnetic treated water after 120 days with more fresh leaves and tomato fruits

Fig. 4. Tomato plant irrigated with non – magnetic treated water after 120 days with few fresh leaves and fruits but more dry leaves

Conclusions

Magnetic treatment of the irrigation water (magnetically treated water) influenced the vegetative growth of tomato by increasing the rate of growth, reducing the time until maturity and increased the yield of tomato by 39.9 to 68.7%. Magnetic flux densities of 124, 319 and 719 G inside the treatment chamber (pipe) or 700 to 4,300 G between two magnetic cores without air gap were adequate for the treatment of irrigation water and improved the tomato yield.

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