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Effects of Magnetically-Treated Water on Tomato Yield and Uptake of Heavy Metals Under Water Deficit Conditions

Kamorudeen Olaniyi Yusuf[1*], Modupe Ruth Baiyeri[2] and Shakiru Ariyo Sakariyah[1]

[1] Department of Agricultural and Biosystems Engineering, University of Ilorin, P.M.B 1515, Ilorin, Kwara State, Nigeria

[2] Department of Agricultural and Bio-environmental Engineering, Kwara State Polytechnic, Ilorin, Nigeria
Corresponding author: kamaru.yusuf@yahoo.com

***Abstract*:** *This study was conducted to determine the effect of magnetically-treated water (MTW) on tomato yield and uptake of heavy metals by tomato fruit under water deficit conditions for possibility of food poisoning. The experiment was conducted twice for 85 and 114 days. The irrigation water was treated with magnetic flux density 319 gauss produced from electromagnet. The tomato seed (variety UC82B) was planted in 12 pots (1 tomato/pot) and irrigated with either MTW or non magnetically-treated water (NMTW). The treatments were 100% (1.0 litre), 80%, and 60% of available water (AW) in a Completely Randomized Design (CRD) and each treatment was replicated 4 times. The yields and concentrations of Cadmium, Copper, Chromium, Iron, Lead, Manganese, Nickel and Zinc were determined from the tomato fruit. The mean yields of tomato with MTW for 100, 80 and 60% were 275.8, 281.0 and 216.8 g/pot and the corresponding yields for NMTW were 200.1, 210.9 and 163.2 g/pot, respectively. The concentrations of Copper, Lead, Manganese and Iron in tomato for MTW at 100, 80 and 60% were 0.03, 0.02, 0.12 and 1.80 mg/L and the corresponding heavy metals for NMTW were 0.04, 0.02, 0.08 and 1.60 mg/L, respectively. The Zinc for MTW was 0.01 mg/L but not detected for NMTW. Concentrations of Cadmium and Chromium were not detected for MTW and NMTW. Concentrations of all heavy metals in the tomato were below (FAO/WHO) permissible limits. MTW increased tomato yield and didn't increase uptake of heavy metals that could cause diseases to man. The technology is recommended for tomato production.*

Keywords: *heavy metals in tomato, irrigation, magnetically-treated water, uptake of heavy metals.*

1. Introduction

Magnetic treatment of irrigation water (magnetically-treated water) is a non-chemical method, environmentally-friendly and a new technology for agriculture that boosts crop yield [1], [2]. Magnetically-treated water is obtained when water flows through magnetic field at right angle to the field, the structure of the water is altered, reduction in bonding angle of water from 104 to 103^{o} and reduction in surface tension of the water. This modification in water properties increase minerals dissolvability of water for macro and micro elements in the soil and this provide adequate nutrients for plant growth [1], [3]. It also improves crop quality and increases minerals dissolvability of water for Calcium, Nitrogen, Potassium, iron and Lead which could enhance nutrients uptake by the crops [4], [5], [6], [7]. [8] indicated that magnetically-treated water significantly increased essential elements (N, P, K) uptake when compared with plants irrigated with tap water (non magnetically-treated water). [9] also pointed out that magnetically-treated water (magnetized water) improved the Calcium, Iron, Potassium and Zinc contents in seeds of onion, sunflower and tomato fruit which significantly increased the production quality of the plants compared to non magnetically-treated water.

Magnetically-treated water could also stimulate defense system, photosynthetic activity, and translocation efficiency of photoassimilates in common bean plants [10]. The uptake of the some elements such as Nitrogen, Calcium and Sulphur by tomato can improve the nutritional quality (like protein and vitamin C contents) of tomato. On the other hand, if magnetically-treated water increases uptake of heavy metals such Arsenic, Barium, Copper, Lead, Manganese and Zinc above the permissible limits of FAO/WHO and accumulation of the heavy metals could cause cancer and some other diseases to man after a prolong period of time. The objective of this study was to determine effect of irrigating tomato plant with magnetically-treated water on uptake of heavy metals by tomato fruit and yield of tomato.

Plants experience water deficit (irrigation deficit) when the irrigation requirement is not fully supplied and the crop is subjected to water shortage which could affect evapotranspiration, uptake of plant nutrients, photosynthesis and crop yield. [11] pointed out that magnetic treatment of irrigation water could alleviate adverse effect of water stress (water shortage) in crop because it reduces free radicals production and antioxidant enzymes activity. Magnetically-treated water increases evapotranspiration rate and water use efficiency [12]. This means that crop irrigated with magnetically-treated water could withstand water shortage, absorb little water available in the soil and the yield is not affected as crop irrigated with non magnetically-treated water.

The north and south poles of the electromagnetic cores on the treatment pipe were alternated for effective treatment of the irrigation water by the magnetic field as stated by [14] used a permanent magnet with magnetic field strength of 5500 G (0.55 T) to treat irrigation water and the effect was significant on growth and yield of okra that was irrigated with magnetically-treated water. [5] used magnetic flux density between 35 and 1360 G which was measured inside the pipe. [15] pointed out that the residence time for treatment of irrigation water in magnetic field should be 15 s while [16] stated that 60 to 600 s was appropriate for effective magnetic treatment of irrigation water. The objectives of this study were to determine the effect of magnetically-treated water under water deficit conditions on tomato yield and uptake of some selected heavy metals by tomato fruit.

2. Materials And Methods

2.1. Location of the Study

The study was conducted twice at the Research Farm of the Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin, Kwara State, Nigeria between 23rd December, 2016 and 15th July, 2017. Ilorin lies on the latitude 8°30´N and longitude 4°35´E at an elevation of about 340 m above mean sea level [17]. 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 ends in October while the dry season starts in November and ends in March [18].

2.2. Chemical Properties of Soil used

The chemical properties of soil used in the study were shown in Table 1. Sample A was the chemical properties of soil used in the first experiment which was conducted between 23rd December, 2016 and 18th March, 2017 (85 days) in which only the concentrations of some selected heavy metals in the tomato fruit were determined. Sample B was the chemical properties of soil used in the second experiment which was carried out between 23rd March and 15th July, 2017 (114 days) in which yield and concentrations of some selected heavy metals in the tomato were determined while the tomato plant was subjected to water deficit in which water was applied at different quantities.

TABLE I: Chemical Properties of Soil used

Element	**Sample A**	**Sample B**
pH	4.70	5.30
N (%)	0.80	1.00
P (mg/L)	0.39	0.22
K^{+} (mg/L)	0.11	0.13
Pb^{2+} (mg/L)	1.80	1.30
Zn^{2+} (mg/L)	0.90	0.80
Cr^{2+} (mg/L)	0.14	0.07
Cu^{2+} (mg/L)	0.54	0.55
Cd^{2+} (mg/L)	0.01	0.01
Fe^{2+} (mg/L)	8.50	8.70
Mn^{2+} (mg/L)	0.55	0.60

2.3. Chemical Properties of Water used

The water used in this study was obtained from University of Ilorin dam (at downstream, about 80 m away from the dam) and chemical properties of the water were presented in Table 2. The irrigation water was allowed to flow through a magnetic flux density of 319 gauss (G) (31.9 mT) for about 113 s in a pipe. The equivalent magnetic flux density between two magnetic cores without air gap was 1,684 G. The magnetic field strength was measured inside the rectangular treatment pipe in which 2 magnetic cores was 20 mm apart using a gaussmeter, Model GM-2 by Alpha Lab Inc. The concentrations of some selected heavy metals for magnetically-treated water and non-magnetically-treated water (water before magnetically-treated) were analyzed and presented in Table 2.

TABLE II: Concentration of Some Selected Heavy Metals in the Water Used for Irrigation

Element	WHO limits (2001)	MTW	NMTW
Pb^{2+} (mg/L)	5.00	ND	ND
Zn^{2+} (mg/L)	2.00	ND	ND
Cr^{2+} (mg/L)	1.00	ND	ND
Cu^{2+} (mg/L)	0.20	ND	ND
Cd^{2+} (mg/L)	0.01	ND	ND
Fe^{2+} (mg/L)	5.00	ND	0.10
Mn^{2+} (mg/L)	0.26	ND	ND

WHO = World Health Organisation, ND = Not detected, MTW = Magnetically-treated water, NMTW = Non magnetically-treated water.

2.4. Determination of Crop Evapotranspiration, Volume of Water Requirement and Irrigation Interval

Crop evapotranspiration is the amount of water that is needed to meet the required evapotranspiration, photosynthesis and metabolic processes. 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 and volume of water required daily by tomato plant and volume of water required in three (3) days irrigation interval by the tomato plant were determined using Equations (1), (2), (3), (4), (5), (6), (7) and (8), respectively.

$$ET_c = k_c \times ET_o \tag{1}$$

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

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

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

$$d_n = P_n \times AW \tag{5}$$

$$I_v = \frac{d_n}{ET_c} \tag{6}$$

$$V_d = C_c \times A_b \times ET_c \tag{7}$$

$$V_i = C_c \times A_b \times ET_c \times I_v \times N_p \tag{8}$$

where ET_c 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 of water required to bring moisture content to FC at the beginning of the experiment (mm), ρ_b is the soil bulk density (g/cm^3), ρ_w is the density of water (g/cm^3), FC is the field capacity of the soil (%), Ɵ is the initial moisture content of the soil prior to irrigation (%), D_b is the depth of the bucket or pot (mm), Aw is the available water (mm), WP is the wilting point (%), I_v is the irrigation interval (day), d_n is the net depth of irrigation (mm), P_n is the percentage of available water to be supplied during irrigation (in fraction, 50% = 0.5), C_c is the crop canopy but taken as 100 % (1), V_d is the volume of water required by tomato plant (litre/day), A_b is the area of the bucket (m^2), N_p is the number of plants that are to be irrigated and V_i is the volume of water required by plant per irrigation (litre).

F in Equation (4) is a factor ranging from 2.0 - 2.4 depending on the percentage of silt in the soil [19]. The value of F used was 2.2 and WP was calculated to be 12.26 % when FC was 26.98%. The values of crop coefficient (k_c) used was 1.15 because [20] indicated that k_c of tomato at flowering stage was 1.15. Reference evapotranspiration (ET_o) of Ilorin for the North Central zone from the graph by Chineke *et al.* [21] for peak value during the month of March of the year is 5.5 mm/day and it was used in this study and A_b of the bucket (pot) was equal to 0.05433 m^2.

2.5. Chemical Parameters Analyzed from Tomato

Two samples of tomato fruits for each level of water applications were randomly harvested in the first and second experiments from magnetically-treated and non-magnetically-treated water after 65 and 95 days, respectively. The two samples of tomato fruits were obtained from tomato plant irrigated with 100, 80 and 60% of available water for the determination of concentrations of heavy metals in the tomato fruit. The heavy metals determined were Cadmium, Copper, Chromium, Iron II, Lead, Manganese, Nickel and Zinc.

2.6. Determination of Lead Concentration and Other Heavy Metals

The tomato was ground (wet tomato paste) and sieved through 2 mm sieve. A 2 g of the sample was weighed and heated to dryness in a well-cleaned porcelain crucible between 450 and 500 $^{\circ}$C in a hot plate. The ash content was then dissolved in 5 ml HNO_3, HCL and H_2O in ratio of 1:2:3, respectively and this was heated on a hot plate until brown fume disappeared. A 5 ml of deionized water was added and heated until a colourless solution was obtained. The mineral solution was transferred into 100 ml volumetric flask and filtered through Whatman No 42 filter paper. This solution was then analyzed by Atomic Absorption Spectrophotometer (AAS) as given by [22]. The same procedure was used for digestion process and AAS was used to analyze other heavy metals as given by [22].

2.7. Statistical Analysis on Yield of Tomato by CRD and Pair t-test

2.7.1. Statistical Analysis by Completely Randomized Design (CRD)

Statistical analysis on the yield of tomato was computed to determine if the effects of magnetically-treated water and non-magnetically-treated water were statistically significant on the tomato yields or not using Completely Randomized Design (CRD). Sum of square treatment (SST_R), Sum of square total (SST_O), Correction factor (C.F) and Sum of square error (SS_E) were computed using Equations (9), (10), (11) and (12), respectively. The Analysis of Variance (ANOVA) was based on values generated from Equations (9), (10) and (12).

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

$$SST_O = \sum X_i^{\ 2} - C.F \tag{10}$$

$$C.F = \frac{G^2}{N} \tag{11}$$

$$SS_E = SST_O - SST_R \tag{12}$$

where T_i is the total yield of each treatment, t is the number of treatments used, X is the individual yield based on the treatment used, G is the total yield from all the treatments used and N is the number of observation which is equal to the product of number of treatments (t) and number replications (r)

2.7.2. Statistical Analysis by Pair t-test

A pair t-test statistical analysis was also computed between T_1 versus T_4 and T_2 versus T_4. The difference between the two mean of the results was determined and used to compute the standard deviation, standard error and t-test value using Equations (13), (14a) or (14b), (15) and (16), respectively as given by [23]. The calculated values of the t-test and that of table values were shown in Table 4.

$$\bar{d} = \frac{\sum d}{n} \tag{13}$$

$$\delta = \sqrt{\frac{\sum \left(d - \bar{d}\right)^2}{n-1}} \tag{14a}$$

$$\delta = \sqrt{\frac{\sum d^2 - n\left(\bar{d}\right)^2}{n-1}} \tag{14b}$$

$$\delta_{Er} = \frac{\delta}{\sqrt{n}} \tag{15}$$

$$t_{cal} = \frac{\bar{d}}{\delta_{Er}} \tag{16}$$

where $\bar{d}$ is the mean of the difference from the data x_1 and x_2, Σd is the summation of d, n is the number of the treatments (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} at $\alpha = 5$ % significant level but 2.5 % ($\alpha = 0.05/2 = 0.025$) for paired t-test. For example, the tomato yield between MTW and NMTW extracted from Table 4 for pair t-test was computed as follows.

TABLE III: Data of Tomato Yield for Computation of Pair t-test

MTW	NMTW	d = (MTW - NMTW)	d^2
1103.1	800.4	302.7	91,627.29
1124.1	843.6	280.5	78,680.25
867.3	652.6	214.7	46,096.09
n = 3		**$\sum d = 797.9$**	**$\sum d^2 = 216,403.63$**

$$\bar{d} = \frac{797.9}{3} = 265.97 \tag{13}$$

$$\delta = \sqrt{\frac{216,403.63 - 3(265.97)^2}{3-1}} = 45.74 \tag{14b}$$

$$\delta_{Er} = \frac{45.74}{\sqrt{3}} = 26.41 \tag{15}$$

$$t_{cal} = \frac{265.97}{26.41} = 10.071 \tag{16}$$

3. Results And Discussion

3.1. Effect of Magnetically-Treated Water on Yield of Tomato Under Deficit Conditions

The total and mean yields of tomato for magnetically-treated water (MTW) and non-magnetically-treated water (NMTW) under different water levels of application (under different water deficit conditions) of 100, 80 and 60% of available water supplied were presented in Table 4. Tomato plant irrigated with 80% of water requirement gave the highest mean yield of 281.0 g/pot for MTW and 210.9 g/pot for NMTW, followed by tomato plant irrigated with 100% with 275.8 g/pot for MTW and 200.1 g/pot for NMTW and the lowest tomato mean yield of 216.8 g/pot for MTW and 163.2 g/pot was obtained when 60% of water requirement was supplied to the plant. This means that water depletion by 40% of available water in tomato farm would lead to reduction in tomato yield. Tomato plant irrigated with MTW under the same water deficit produced higher tomato yield than the tomato plant irrigated with NMTW. The tomato yields from MTW when compared with yields from NMTW at 100, 80 and 60% water applications, the yields were increased by 27.4%, 25.0% and 24.8%, respectively. This means that MTW reduced the negative effect of water stress (water deficit) on the yield which agreed with the work by [10] that magnetically-treated water could also stimulate defense system, increased photosynthetic activity and enhanced translocation efficiency of photoassimilates in common bean plants. [11] also concluded that magnetic treatment of irrigation water could alleviate adverse effect of water stress (water deficit) in crop because it reduces free radicals production and antioxidant enzymes activity. [24] also found out that irrigating tomato plant by applying 100, 80, 60, 50 and 40% of water requirement using MTW, the yields were increased by 38.0, 42.1, 93.0, 123.6 and 88.7 %, respectively when compared to the corresponding yields from NMTW using the same levels of water application of 100, 80, 60, 50 and 40% water requirement.

The effect of water deficit on yields with Completely Randomized Design (CRD) for MTW and NMTW separately were not statistically significant on tomato because the calculated value of F for MTW was 0.62 and for NMTW was 0.79 while the Table value of F was 4.26 ($0.62 < 4.26$ and also $0.79 < 4.26$) as shown in

ANOVA Tables 5 and 6 for the CRD. In addition to that, a pair t-test statistical analysis was conducted to compare tomato yields from MTW and NMTW. The pair t-test showed that MTW had a significant effect on the yield of tomato when compared to the yield from NMTW with calculated value of t-test was 10.071 while Table value at α = 5% (α = 0.05) but for pair t-test α = 2.5% (α = 0.025) and at 2 degree of freedom was 6.205. This means that the effect of MTW was statistically significant on the yield of tomato in this study because calculated value of pair t-test was 10.071 which was greater than the Table value of t-test 6.205.

3.2. Effect of Magnetically-Treated Water on Uptake of Heavy Metals by Tomato Fruit

Uptake of heavy metals by the tomato was assessed based on the concentration of heavy metals in the tomato fruit. In the first experiment conducted, the mean concentrations of Cadmium, copper, Chromium, Iron II, Lead, Manganese and Zinc for MTW and NMTW in which 100% (T_1) and 80% (T_2) of water requirements were supplied, the results of some selected heavy metals were presented in Table 7. The concentrations of heavy metals in the second experiment for MTW and NMTW in which 100% (T_1), 80% (T_2) and 60% (T_3) of water requirement were supplied, the results of the heavy metals were presented in Table 8.

In the first experiment with the results shown in Table 7, Cadmium and Chromium were not detected (negligible) but values of Copper, Iron, Lead, Manganese and Zinc with MTW for T_1 and T_2, the range were 0.02-0.03, 1.2-1.8, 0.03-0.07, 0.10-0.12 and 0.00-0.01 mg/L, respectively. The corresponding values for NMTW were 0.02-0.02, 1.30-1.60, 0.04-0.04, 0.08-0.11 mg/L but Zn was not detected.

In the second experiment in Table 8, the concentrations of Lead for T_1, T_2 and T_3 for MTW were 0.015, 0.010, and 0.010 mg/L and the corresponding values for NMTW were 0.015, 0.010, and 0.010 mg/L, respectively. The mean concentrations of Zinc in the tomato fruit for T_1, T_2 and T_3 irrigated with MTW were 0.110, 0.015 and 0.010 while the corresponding values for NMTW were 0.125, 0.110 and 0.135 mg/L, respectively. This means that NMTW increased uptake of Zinc in the tomato than the tomato plant irrigated with MTW as shown in Table 8. Concentrations of Iron II for both MTW and NMTW were the same with 0.010 mg/L except for 60% water deficit that had 0.045 mg/L. Therefore, MTW slightly increased uptake of Lead, Copper and Iron II by 42.9, 42.9 77.8%, respectively especially when water was supplied at 80% and 60% of water requirements. This was in agreement with the work conducted by some researchers that magnetically-treated water resulted in the increased in Nitrogen, Phosphorous and Potassium uptake and their translocation in plant [8]. [25] also concluded that magnetically-treated irrigation water increased available soil Phosphorous in celery and snow pea. Concentrations of Cadmium, Manganese and Nickel in tomato were not detected. From the two experiments conducted, concentrations of all the heavy metals assessed in this study were below [26] and [27] permissible limits. Magnetically treated water (magnetized water) increased tomato yield and did not add heavy metals to tomato fruit that could make the tomato fruit toxic for consumption cause certain diseases as stated by [28].

TABLE IV: Total and Mean Yields of Tomato from Magnetically-Treated and Non-Magnetically-Treated Water

Row	Total and mean yield of tomato (g/pot)					
	Magnetically-treated water			Non magnetically-treated water		
	T_1	T_2	T_3	T_1	T_2	T_3
1	168.9	390.7	265.8	165.4	233.1	133.4
2	390.7	236.8	261.7	305.2	186.8	182.1
3	231.8	261.7	247.2	146.6	204.7	241.6
4	311.6	234.9	97.7	183.2	219.0	95.5
Total yield	**1103.1**	**1124.1**	**867.3**	**800.4**	**843.6**	**652.6**
Mean yield	**275.8**	**281.0**	**216.8**	**200.1**	**210.9**	**163.2**

T_1 = 100% of water requirement was supplied, T_2 = 80% of water requirement was supplied T_3 = 60% of water requirement was supplied

TABLE V: Analysis of Variance (ANOVA) of the Tomato Yield for MTW with CRD

Source of error	(D.F)	Sum of square (SS)	Mean square (MS)	Calculated F	Tabular F at $P \leq 5\%$
Treatment	2	10,165.74	5,082.87	0.62^{NS}	4.26
Error	9	73,685.17	8,187.24		
Total	11	63,518.43	5774.9		

NS = Not significant, MTW = Magnetically-treated water, CRD as previously defined

TABLE VI: Analysis of Variance (ANOVA) of the Tomato Yield for NMTW with CRD

Source of error	Degree of freedom (D.F)	Sum of square (SS)	Mean square (MS)	Calculated F	Tabular F at $P \leq 5\%$
Treatment	2	5,016.01	2,508.01	0.79^{NS}	4.26
Error	9	28,550.75	3,172.33		
Total	11	33,566.76	3051.52		

NS = Not significant, NMTW = Non magnetically-treated water

TABLE VII: Concentrations of Heavy Metals in Tomato in the First Experiment

Heavy metal	Concentration of heavy metals in the tomato (mg/L)						Health implication on man according to SON Act 2007
	Magnetized water		Non-magnetized water		WHO 2003 limits	FAO 1985 limits	
	T_1	T_2	T_1	T_2			
Cadmium	ND	ND	ND	ND	0.01	0.01	Toxic to kidney
Copper	0.02	0.03	0.02	0.02	0.20	0.20	Gastrointestinal disorder
Chromium	ND	ND	ND	ND	1.00	1.00	Cancer
Iron II	1.80	1.20	1.60	1.30	5.00	5.00	None
Lead	0.03	0.07	0.04	0.04	5.00	5.00	Cancer, mental retardation in children, toxic to central and peripheral nervous systems
Manganese	0.12	0.10	0.08	0.11	0.26	-	Neurological disorder
Nickel	ND	ND	ND	ND	1.00	0.20	Possible carcinogenic
Zinc	0.01	ND	ND	ND	2.00	2.00	None

T_1 = 100% of water requirement was supplied, T_2 = 80% of water requirement was supplied
ND = Not detected, SON = Standards Organisation of Nigeria for Drinking Water Quality
FAO = Food and Agriculture Organisation of the United Nations,
WHO = World Health Organisation

TABLE VIII: Concentrations of Heavy Metals in the Tomato in the Second Experiment

Heavy metal	Concentration of heavy metals in the tomato fruit (mg/L)						WHO limits 2003 (mg/L)
	Magnetically-treated water			Non magnetically-treated water			
	T_1	T_2	T_3	T_1	T_2	T_3	
Cadmium	ND	ND	ND	ND	ND	ND	
	ND	ND	ND	ND	ND	ND	0.02
Copper	ND	ND	0.030	ND	ND	0.030	
	ND	0.050	ND	ND	ND	ND	
Mean	ND	**0.050**	**0.030**	ND	ND	**0.030**	1.00
Iron II	0.010	0.010	0.040	0.010	0.010	0.010	
	0.010	0.010	0.050	0.010	0.010	0.010	
Mean	**0.010**	**0.010**	**0.045**	**0.010**	**0.010**	**0.010**	5.00
Lead	0.010	0.010	0.040	0.010	0.010	0.010	
	0.010	0.010	0.050	0.010	0.010	0.010	
Mean	**0.010**	**0.010**	**0.045**	**0.010**	**0.010**	**0.010**	0.26
Manganese	ND	ND	ND	ND	ND	ND	
	ND	ND	ND	ND	ND	ND	0.01
Nickel	ND	ND	ND	ND	ND	ND	
	ND	ND	ND	ND	ND	ND	1.00
Zinc	0.110	0.020	0.010	0.140	0.110	0.160	
	0.110	0.010	0.010	0.110	0.110	0.110	
Mean	**0.110**	**0.015**	**0.010**	**0.125**	**0.110**	**0.135**	2.00

T_1 = 100% of water requirement was supplied, T_2 = 80% of water requirement was supplied
T_3 = 60% of water requirement was supplied, ND and WHO are as previously defined in Table 7

Magnetically-treated water reduced effect of water deficit on tomato yield and tomato yields at 100, 80 and 60% water applications were increased by 27.4%, 25.0% and 24.8%, respectively. Tomato plant irrigated with magnetically-treated water at 80 and 60% of water requirement had higher concentrations of heavy metals than when 100% of water requirement was supplied. Magnetically-treated water did not add or significantly increased uptake of heavy metals to tomato fruit which could be harmful to man. All the concentrations of heavy metals in the tomato were below FAO/WHO permissible limits.

4. Recommendation

Magnetically-treated water (Magnetic treatment of irrigation water) is a non-chemical method and environmentally-friendly that boosts crop yield should be adopted and use for crop production. More research should be conducted on the uptake of heavy metals by crops irrigated with magnetically-treated water in areas having high concentration of heavy metals.

5. References

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