Effects of electromagnetic treatment of irrigation water on growth and yield of Lagos Spinach (*Celosia argentae*)

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Abstract: The effects of magnetic treatment of irrigation water on growth and yield of potted celosia plants (*Celosia argentae*) grown inside a screen house were investigated. The study was carried out using completely randomiseddesign replicated five times. Water was allowed to pass through fivedifferent flux densities of 719, 443, 319, 124 and0 Gausses (non – magnetized water). Analysis of selected 25 samples of the magnetic flux density experiment (at 6 WAP) showed that meanstem girth irrigated with ordinary water recorded the highest value of 11.95 mm.Meanleaf area of plants irrigated with magnetic flux density of 719 G had a percentage increase of 24.97%; mean bulk weight of 172.72 g; biomass weight of 133.48 g; and root weight of 39.24 g, when compared with plants treated with ordinary water (0G), with a bulk weight of 158.08 g; biomass weight of 124.22 g; and root weight of 33.86 g. Analysis of Variance (ANOVA) at a confidence interval of 95% showed that effects of varying magnetic treatments of water on bulk yield, edible weight, root weight, total leaf area and average plant height were significant at $P \leq 0.05$. This implies that magnetic technology contributed to the result of the aforementioned growth indices. Effect of magnetic treatment of water on number of leaves was not significant at $P \leq 0.05$. Further analysis of results using Duncan New Multiple Range Test (DNMRT) showed that the effects of 719, 443, and 319 Gauss were statistically and significantly different from one another on bulk yield of sampled plants. Memory (residual) effect of irrigation water was also enhanced by magnetic treatment. Magnetic treatment of water also reduced sodium hazard and salinity effect on crop yield. The study shows that magnetic treatment of irrigation water increases crop growth and yield.

Keywords:celosiaargentae,growth, yield and magnetic treated water

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1 Introduction

One of the most widely consumed vegetables all over the world today is the leafy green Lagos Spinach (*Celosia argentae L.)*. *Celosia argentae*(a.k.a. quail grass, soko, celosia, feather cockscomb) is a vigorous, broadleaf annual belonging to the Amaranth family (*Amaranthaceae*). It is traditional fare in countries of Central and Western Africa, and is one of the leading leafy green vegetables in Nigeria, where it is known as ‘sokoyokoto’, meaning ‘make husbands fat and happy’ (Yarger, 2007). Celosia grows well in the lowland humid forest zone at day temperatures of 30°C-35°C and night temperatures of 23°C-28°C and at an altitude up to 1700 m. Growth is greatly retarded by temperatures below 20°C, consequently, it does not grow well in the Savannah region of West Africa during the harmattan period. Celosia performs well under partial shade,

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especially in dry conditions. Celosia grows rapidly from seed and, depending upon the variety and soil fertility, it can reach a height of 200 cm (6.5 ft). Forbes and Watson (1992) reported that over 80% of the fresh weight of many plants, and over 90% of some plants are water. To meet water requirement of vegetables during the dry season, irrigation is imperative because, as plants remove water, the soil water content decreases with a decrease in total soil water potential. At the same time, hydraulic conductivity of the soil decreases.The economic value of celosiais of great importance in Nigeria. Several research works had been carried out to study a wide range of agronomic practices with the aim of increasing the production of celosia while considering optimum soil conditioning, physiological effects of celosia roots and leaf extracts on germination of surrounding crop plant seeds, and fertilizer application (Ewemoje and Majekodunmi, 2008). Also, a great deal of study made on the effect of magnetized water on the growth, development and yield of crops had shown that magnetized water contributed positively to plant growth. Moussa (2011) suggested that magnetic water could stimulate defence system, photosynthetic activity, and translocation efficiency of photo-assimilates in common bean plants. Yusuf (2015) reported that tomatoes irrigated with magnetized water treated at varying flux densities ranging from 124G to 719G showed faster growth and had bigger stem diameters than those treated with non-magnetised water. They were observed to mature faster with first harvest occurring 74 days after planting as compared to 85 days shown by ordinary water. Grewal and Maheshwari(2011) showed that magnetic treatment of seeds and irrigation water had a potential to improve early seeding growth and nutrient content of seedlings. It was also detected that the magnetic field stimulated the shoot development and led to the increase of germination potential, fresh weight and shoot length of maize (Aladjadjiyan and Ylieva,2003).The objective of this study was to determine the effects of magnetically-treated irrigation water on growth and yield of celosia.

1.1 Mechanisms of the effect of magnetic treatment on plant

Magnetohydrodynamics are based on the concept of Quantum physics and Electrodynamics. The Quantum physics indicates that water is a matter with an organized structure, and not chaotic as one might think. Water and its components can adopt many different structures. Depending on the structure taken from the water, the behaviour of dissolved minerals and biological materials is different. Electrodynamics acts on the structure of water, giving it properties that create a better dissolution and distribution of minerals in the water, better water retention in the soil, and better absorption of minerals by plants, while conserving the bacterial soil life and promoting a balance between the different elements of the living soil

Several closely - related studies have reported beneficial effects of electromagnetic fields on crop production. Magnetic treatment of water can influence the root growth of various plant species as reported by Turkeret al.(2007). Also, some studies reported by Esitken and Turan (2004) and Selim and El-Nady (2011) recorded an increase in number of flowers, earliness and total fruit yield of strawberry and tomatoes with the application of magnetic fields. Most researchers have treated seeds with different magnetic fields thereby stimulating seed germination and seedling growth. Selim and El-Nady (2011) reported significant increases in plant height, root length, fresh and dry weights of different organs, specific leaf area, leaf area ratio, leaf weight ratio and leaf area index of tomato plants as a result of the application of magnetic technologies.

2 Materials and methods

2.1 Description of the research project

The study was conducted on the Research farm of the Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin, Kwara State, Nigeria. Ilorin is geographically located 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 located in the Southern Guinea Savannah Ecological zone of Nigeria, and experiences an 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).

2.2Soil physical and chemical properties

Soil physical propertiesdetermined include; initial soil moisture content, soil bulk density, soil specific gravity, field capacity, percentage gravel, percentage sand, percentage clay and percentage silt and soil texture.The mean values of moisture content at field capacity and bulk density were 27.73% and 1.24 gcm^{-3}.

2.3Electromagnet for irrigation water treatment

The electromagnetic device was made up of a rectangular treatment chamber with internal dimensions of 1.5×4.6 cm and 20 magnetic cores with flux densities of 700 to 4,310G (Maheshwari and Grewal, 2009). The electromagnet was constructed from readily available materials in Ilorin, Kwara State Nigeria. The materials were copper wire (gauge 15) and lamination sheet of the transformer from burnt Blue gate UPS (uninterrupted power supply).Digital clamp meter and Gaussmeter were used to measure the current and magnetic flux density across the solenoid at various voltage terminals of the transformer. The voltage across the connection wire was read when there was no load and when the load was connected. Values of magnetic flux density were measured when the treatment chambers contained water and when they were empty. Table 1 showed mean values of flux density, voltage and current readings during the calibration process.

Table 1 Mean values of magnetic flux density, current and voltage obtained duringelectromagnet calibration

Terminal (V)	Terminal without load (V)	Terminal with load (V)	Current (A)	Flux density between two cores without air gap (G)	Flux density in chamber without water (G)	Flux density in chamber with water (G)
4	5.9	1.4	12.3	696.7	122.3	124.0
5	7.0	2.7	21.6	1251.0	259.7	254.0
6	7.5	3.0	25.0	1690.0	316.3	319.3
7	7.9	3.4	29.4	1711.7	407.3	401.0
8	8.3	4.0	32.3	1952.0	448.3	443.3
9	9.8	4.6	37.4	2320.0	542.7	530.0
10	10.0	5.2	40.8	1937.7	568.0	583.0
11	11.2	5.2	41.2	1905.0	616.0	613.0
12	12.0	6.2	49.2	2471.2	717.0	719.2

Memory (residual) effect of water was tested by allowing water pass through magnetic field with flux density of 719 G and ordinary water (0 G) to estimate the lifespan of the effect of the magnetic treatment. The mean values of flux densities (measured inside the pipe) used in this study as the treatments (T_1 to T_5) for treating irrigation water were:T_1 (719 G), T_2 (443 G), T_3(319 G), T_4(124 G), T_5 (0 G). T_5 is the control experiment and one Tesla is equal to Ten thousand Gauss (1 T = 10^4 G). Flux densities within the range of 35 – 1360 G were reported to be appropriate for the work of Maheshwari and Grewal (2009).

2.4 Experimental design for the study

The magnetic flux density experiment was arranged in a Completely Randomized Design (CRD) replicated 10 times. CRD wassoselected because soil factors such as soil fertility, soil organic matter and other factors such as photosynthetic active radiation and light transmission through poly cover were assumed to be homogenous. The only source of variation in the study wasdue to the effect of varying flux densities used in treating irrigation water on celosia growth and yield. Growth and yield parameters of celosia were subjected to statistical analysis using the IBM Statistical Package for Social Science Software (SPSS) Version 22 and comparison of means was done as post-hoc test.

2.5 measurement of growth and yield parameters of celosia plants

Plant growth parameters such as plant heights and stem girth on weekly basis were measured and recorded against each treatment for a total number of 50 buckets. Weekly readings commenced after two weeks of planting (2 WAP) and stopped at the end of the fifth week (5 WAP). At harvest (6 WAP), 25 buckets of plants (two plants per bucket) were picked randomly such that there were five different treatments replicated five times in the sample.Twenty–five (25) buckets of celosia (2 plants per bucket) were selected from the experiments and analyzed at 6 WAP. Numbers of leaves, leaf area, plant height, partitioned root length, stem girth, fresh weight (bulk weight), biomass weight (edible weight) and root weightwere determined. Leaf area measurement of 25 samples (two plants per bucket) was measured using IMAGEJ software.Number of leaves were measured through physical inspection. Measuring ruler was used to measure plant height and root length.A digital verniercalliper was used to measure celosia's stem girth and a sensitive digital weighing scale was used to measure yield parameters.

3 Results and discussion

3.1 Results of soil properties

Table 2 showed the summary ofthe results of physical and chemical properties of soil used for the study. Table 2 shows that the soil texture is loamy sand and that the soil has moderately high sodium content. Irrigation water with low sodium content should be used to irrigate the soil to avoid sodium hazards.

Table 2 Average soil physical and chemical properties of the soil

Properties	Composition
Sand (%)	84.01
Silt (%)	8.76
Clay (%)	7.52
Gravel (%)	Nil
pH in water (1:1)	5.8
Organic carbon (%)	0.97
Organic matter (%)	1.30
Total Nitrogen	1.3
Available Phosphorus (mg kg^{-1})	1.30
Ca^{2+}(cmol kg^{-1})	1.35
Mg^{2+} (cmol kg^{-1})	0.74
Na^{+} (cmol kg^{-1})	11.82
K^{+}(cmol kg^{-1})	2.30

3.2 Effect of magnetic treatment on chemical properties of water

Table 3 showed the residual (memory) effect of magnetic treatment on chemical properties of water , which was tested by allowing water pass through amagnetic field with flux density of 719 G and analyzing thechemical properties after every four hours from 9 a.m. to 5 p.m. for a day in the laboratory. Corresponding changes in chemical properties of ordinary water (0 G) were also tested every four hours.Theprecipitation of magnesium, calcium, sodium, lead, chloride and sulphate ions decreased overtime for magnetic water and ordinary water (with the exception of carbonates). However, values of calcium were higher for magnetic water when compared with corresponding values of calcium of ordinary water treatment; therefore, magnetic water improved the precipitation of calcium in water. The effect of magnetic treatment on thesuitability of irrigation water was ascertained by the computed values of Sodium Adsorption Ratio (SAR) and electrical conductivity (EC_w). The values of SAR varied from 9.31-9.50 and this was within the range of 1-10 (S_1 = low value) according to USDA 1954 (United States Department of Agriculture) as cited by Schwab et al.(1993). Magnetic and ordinary water had SAR values within the USDA low value (S_1) class, but the values of SAR for ordinary water were higher than corresponding values of magnetized water. Electrical conductivity of water (EC_w) decreased steadily across both treatments and these values were within the Class 1 (C_1, low value with no effect on soil) of the USDA standard. This means that sodium adsorption potential and salinity hazard of magnetically – treated water was lower than that of ordinary, making it more suitable for irrigation. Therefore, irrigation water treated with electromagnet was classified as S_1C_1 (i.e. low sodium hazard and low salinity with no effect on soil). Therefore, magnetic treatment of water reduces sodium hazard and salinity effect on crop yield.

Table 3 Residual effect of magnetic treatment on chemical properties of water from 9 a.m to 5 p.m

S/No	Element	Unit	Magnetized			Ordinary		
			4hrs (9am)	4hrs (1pm)	4hrs (5pm)	4hrs (9am)	4hrs (1pm)	4hrs (5pm)
1	Mg^{2+}	mg/L	1.205	1.194	1.190	1.204	1.203	1.202
2	Ca^{2+}	mg/L	3.780	3.730	3.730	3.710	3.682	3.679
3	Pb^{2+}	mg/L	0.390	0.389	0.381	0.396	0.391	0.380
4	Na^{+}	mg/L	81.32	81.29	81.28	82.21	82.15	82.07
5	SO_4^{2-}	mg/L	50.78	49.75	49.63	49.21	49.13	48.70
6	CO_3^{2-}	mg/L	4.770	4.750	4.735	4.725	4.730	4.733
7	Cl^{-}	mg/L	80.4	80.2	78.70	79.80	79.60	78.90
8	EC_w	dS/m	0.188^{C1}	0.183^{C1}	0.182^{C1}	0.189^{C1}	0.192^{C1}	0.193^{C1}
9	SAR	-	9.31^{S1}	9.38^{S1}	9.38^{S1}	9.49^{S1}	9.50^{S1}	9.50^{S1}

Note: C1= class 1 = low value EC without effect on soil. S1= low value SAR without effect on soil.

3.3 Results of light transmission through poly cover

The average readings of luminance, photosynthetic active radiation, daylight index, average light transmission and transmission efficiency in the screenhouse were as presented in Table 4 using an Extech digital light meter (model no. LT300). Mean values for luminance outside the screenhouse (4750 fch^{-1}) was greater than mean value of luminance inside (3720 fch^{-1}). These two values were slightly lesser than the standard value of luminance requirement (5000 fch^{-1}) of vegetables as recommended by Giacomelliet al.(1990).

The variation could be as a result of spatial and environmental differences in daylight radiation of Giacomelli's location and the study area. Mean values of PAR and DLI for outside shed were 950.1 mmol m^{-2} s^{-1} and 82.09 mol m^{-2} d^{-1} respectively and were found to be greater than those obtained in the screenhouse i.e. PAR = 744.2 mmol m^{-2} s^{-1} and DLI = 64.30 mol m^{-2} d^{-1}. These values obtained in the screenhouse were found to be sufficient for the optimal growth of celosia as reported by Giacomeliet al. (1990).

Table 4 Average values of light transmission on 26 – 5 – 2018 and 29 – 5 -2018

Time	Outside shed			Inside shed				
	Luminance ($Kfch^{-1}$)	PAR (mmol m^{-2} s^{-1})	DLI (mol m^{-2} d^{-1})	Luminance ($Kfch^{-1}$)	PAR (mmol m^{-2} s^{-1})	DLI (mol m^{-2} d^{-1})	Average light transmittance, T_{la}	Efficiency of transmission, ELT (%)
2:00 pm	5.49	1098	94.85	3.91	780.8	67.46	71.74	84.4
2:15 pm	5.27	1053	90.98	4.31	861.3	74.42	80.77	95.02
2:30 pm	5.09	1017	87.87	4.09	816.8	70.57	79.57	93.61
2:45 pm	5.11	1021	88.22	4.07	813.8	70.31	78.73	92.62
3: 00pm	2.81	561.5	48.51	2.24	448.3	38.73	78.71	92.6
Mean	4.75	950.1	82.09	3.72	744.2	64.30	77.90	91.65

Note: 1 fc (1 $lumenft^{-2}$) = 10.76 lux, 1$kfch^{-1}$ = 1000 fch^{-1}

3.4 Results of growth and yield parameters of celosia

Results of 25 samples that were analyzed at 6 WAP for plant height, root length, stem girth, total number of leaves and leaf area were presented in Table 5. Treatment T1 (719G) had the highest mean height of 53.80 cm from a total of 5 buckets of plants sampled per treatment,while T4R1 (124 G) had the lowest height of 27.01 cm. Ordinary water treatment (T5) had a mean height of 49.40 cm. Results of average root length show that plants irrigated with magnetically – treated water of 719 G (T1) had the longest root length since magnetic treatment of water increases water solubility and breaks hydrogen bonding of clustered water molecule thereby enhancing root growth of plants.The largest mean stem girth was recorded by T5 (11.95 mm) (ordinary water), followed by T1 (11.90 mm) (719 G). The lowest value of mean girth was observed on T4 (10.95 mm) (124 G).Number of leaves were the highest on T1 (104 leaves) (719 G) but lowest on T5 (60 leaves) (ordinary water). Canopy formation was greatly enhanced by the highest magnetic flux density of the treatment i.e. 719 G.Mean values of leaf area showed that T1(1365.36 cm^2) (719 G) had the highest leaf area and the lowest was recorded on T5 (1097.62 cm^2)(ordinary). This shows that high magnetic flux density increases canopy area development, thereby creating a larger surface for photosynthesis and plant metabolism. Table 5 showed overall mean values of all analyzed growth parameters per treatment. Mean bulk weight (BW) and edible weight (EW) of celosia were highest under treatment with highest magnetic flux density T1 (719 G) (i.e. 172.72 g and 133.48 g, respectively) , when compared with the other four treatments of 443 G, 319 G, 124 G and ordinary water (i.e. 158.08 Gand 124.22 G,respectively) as explained in Figure 1. This may be explained with the submission of Dhawi (2014) that, magnetic treatment of water may act as a plant hormone like Auxin in plant system to improve vegetative growth or accelerate enzymes related to Auxin reactions.

Table 5 Mean values of growth parameters (average taken from fivebuckets)

Trmt	Plant Height (cm)	Avrg. Root Length (cm)	Avrg. Stem Girth (mm)	Total No. of Leaves	Leaf Area (cm^2)
T1 (719G)	53.80	23.14	11.90	104.00	1365.36
T2 (443G)	53.41	19.52	11.30	84.00	1243.65
T3 (319G)	50.66	18.00	11.04	73.00	1296.69

T4 (124G)	41.90	17.14	10.95	71.00	1291.34
T5 (ORD.)	49.40	18.58	11.95	60.00	1097.62

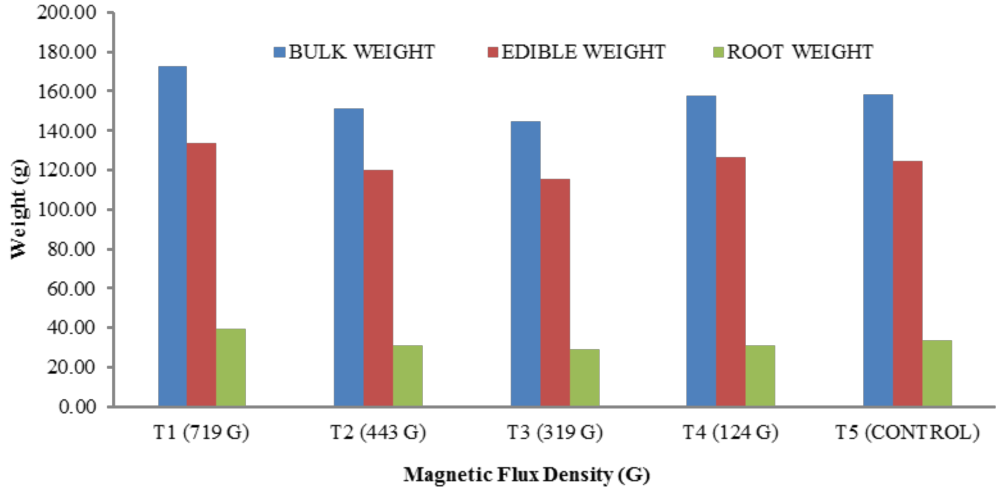

Figure 1Fresh yield of celosia plants at 6WAP

3.5 Statistical analysis of crop growth parameters

Results obtained on crop growth parameters were subjected to Analysis of Variance (ANOVA) at a confidence interval of 0.05 (i.e. $\alpha \leq 0.05$) and where significance existed, Duncan New Multiple Range Test (DNMRT) was employed to compare the means of the five treatments using the IBM Statistical Package for Social Science Students version 22 (SPSS). Table 6 showed the results of the ANOVA and it can be inferred from the table that effects of varying magnetic treatments of water on bulk yield, edible weight, root weight, total leaf area and average plant height were significant at $P \leq 0.05$. This implies that magnetic technology contributed to the result of the aforementioned growth indices as confirmed by De-Souza et al.(2005), that magnetic treatment of water aided the translocation of food and food materials in plants, thereby increasing its growth indices. Effect of magnetic treatment of water on number of leaves was not significant at $p \leq 0.05$.

Table 6 Results of analysis of variance for the test of significance (ANOVA)

		Sum of Squares	Df	Mean Square	F	Sig.
	Between Groups	2186.270	4	546.567	.375	.008*
Bulk Weight	Within Groups	29165.156	20	1458.258		
	Total	31351.426	24			
	Between Groups	919.412	4	229.853	.240	.009*
Edible Weight	Within Groups	19159.448	20	957.972		
	Total	20078.860	24			
	Between Groups	307.878	4	76.969	.901	.005*
Root Weight	Within Groups	1707.976	20	85.399		
	Total	2015.854	24			
	Between Groups	200294.994	4	50073.749	1.706	.002*
Total Leaf Area	Within Groups	587059.450	20	29352.973		
	Total	787354.444	24			
	Between Groups	5373.746	4	1343.436	3.310	.310^{ns}
Total No.of Leaves	Within Groups	8117.488	20	405.874		
	Total	13491.234	24			
Average Plant Height	Between Groups	85.586	4	21.396	.206	.009*
	Within Groups	2079.003	20	103.950		
	Total	2164.589	24			
Average Stem Girth	Between Groups	4.449	4	1.112	.561	.006*
	Within Groups	39.656	20	1.983		
	Total	44.105	24			

Note: * significant at $P \leq 0.05$,ns: not significant at $P \leq 0.05$

3.5.1 Effect of magnetic treatment of water on biomass yield

DNMRT is a post – hoc test that compares the means of treatments and analyzes how they are significantly different from one another. Further analysis of results of ANOVA by DNMRT showed that the effects of 719 G, 443 G, and 319 G were statistically and significantly different from one another on bulk weight yield of sampled plants. Results presented in Table 7 showed that at 6 WAP (harvest), mean bulk weight (BW) and edible weight (EW) of celosia were highest under treatment with highest magnetic flux density T1 (719 G), when compared with the other four treatments of 443 G, 319 G, 124 G and ordinary water. This may be attributed to higher water content in the edible parts of the vegetable crop induced by hydrogen bond breakage, increased solubility and reduced surface tension as a result of magnetic treatment and this submission agreed with the findings of Sorensen (2005). There was no significant difference between 124 G and 0 G (ordinary) on bulk weight. The effects of 719 G, 443 G and 319 G were statistically and significantly different from one another on edible weight,but there was no significant difference between 124 G and 0 G (ordinary) on edible weight. Significant difference was observed in 719 G, 443 G and 319 G on root weight. Interaction between 124 G and ordinary (0 G) showed that both treatments were not statistically and significantly different on root weight as illustrated in the DNMRT results presented in Table 7.

Table 7 DNMRT of effect of magnetic treatment of water on biomass yield

Treatment	Bulk Weight (BW)	Edible Weight (EW)	Root Weight (RW)
719 G	172.72[d]	133.48[d]	39.24[d]
443 G	151.96[b]	119.82[b]	31.24[b]
319 G	144.60[a]	115.14[a]	29.06[a]
124 G	157.42[c]	126.24[c]	31.18[b]
Ordinary	158.08[c]	124.22[c]	33.86[bc]

Note: Mean values with same superscript in same column are not significantly different at P≤0.05. DNMRT- Duncan New Multiple Range Test

3.5.2 Effect of magnetic treatment of water on total leaf Area (TLA)

Total Leaf Area (TLA) increased throughout the growing period. However, immediately after 5 WAP, yellowing of leaves and a little shrinkage of leaf edges were observed. Leaves also lost their deep green coloration as a result of post – maturity stress. It is therefore necessary to harvest celosia for leaves and biomass at 4 – 5 WAP. Results of DNMRT of TLA presented in Table 8 showed that TLA was highest under T1 (719 G) and lowest under T5 (ordinary water) when compared with the other three treatments. Therefore, total leaf area of celosia plants was greatly improved with highest flux density of 719 G. T1 (719 G), T2 (443 G) and T5 (ordinary) were statistically and significantly different from one another while T3 (319 G) and T4 (124 G) were not significantly different from each other across all total leaf area values.

Table 8 also showed that highest mean values of plant height of T1 (719 G) and T2 (443 G) were not statistically different from each other. There was no significant difference among T3 (319 G), T4 (124 G) and T5 (ordinary) all across plant height values.Results obtained from DNMRT presented in Table 8 showed that T5 (ordinary water) had the highest mean stem girth which was not statistically and significantly different from mean stem girth of T1 (719 G). Lowest mean stem girth recorded on T4 (124 G) was the only significantly different treatment across all mean stem girth values. There was no significant difference between the mean stem girth value of T2 (443 G) and that of T3 (319). From these results, it may be suggested that stem girth of celosia be improved either by irrigating with ordinary water or high magnetic flux density of 719 G or greater.

Table 8 DNMRT of effect of magnetic treatment of water on total leaf area, plant height and stem girth

Treatment	Total Leaf Area (TLA)	Plant Height (PH)	Stem Girth (SG)
719 G	1365.364[d]	53.796[c]	11.898[c]
443 G	1243.650[b]	53.406[c]	11.304[b]
319 G	1296.689[c]	50.662[ab]	11.040[b]
124 G	1291.339[c]	49.722[a]	10.950[a]
Ordinary	1097.619[a]	49.402[a]	11.950[c]

Note: Mean values with same superscript in same column are not significantly different at P≤0.05DNMRT- Duncan New Multiple Range Test

3.6 Discussion of results

The study shows that electromagnetic treatment of water resulted to decrease in magnesium, calcium, sodium, lead, chloride and sulphate ions. Whereas, values of calcium were higher for magnetic water than ordinary water treatment correspondingly; therefore, magnetic water improved the precipitation of calcium in water, this was in agreement with the work of Fathiet al.(2006). The precipitation of this ion could influence vegetal growth and yield. Magnetic treatment decreased the precipitation of carbonates in water over the test of time, but carbonates increased slightly in ordinary water. The value of sulphates was slightly higher in magnetic water than in ordinary water. Mostafazadehet al.(2011) reported that magnetic water increased the precipitation of sulphates in water when compared with ordinary water. The result also showed that water could be treated and used later for irrigation without losing much effect of the magnetic treatment. This is termed the "memory" or "residual" effect. This finding was also in accordance with the work of Amiri and Dadkhah (2006) that magnetic treatment of water changes some physical and chemical properties of water, mainly hydrogen bonding, surface tension and solubility of salts. The study shows that sodium adsorption potential and salinity hazard of magnetically – treated water was lower than that of ordinary, making it useful for treating saline irrigation water. Electromagnetic treatment of water increased crop growth parameters such as bulk weight, edible weight, root weight, total leaf area and average plant height. The study shows that the higher the magnetic flux the more the effect on the plant.The magnetic treatment of irrigation water increases crop growth and yield.

4 Conclusions

The study shows that magnetic treatment of water reduced effects of sodium hazard and salinity problems of irrigation water on crops. Also, magnetic treatment increased the concentration of $Ca^{2+}$and SO_4^{2-} by 0.10 $mgL^{-1}$and 2.08 mg L^{-1}, respectively, while Na^+ was reduced by 0.93 mg L^{-1} and it was established that, magnetically – treated water could be used for irrigation later without adverse effect on water properties.Magnetic treatment increased weekly vegetative growth indices such as plant height, stem girth and leaf geometry of celosia. Weekly height of magnetically-treated plants had a percentage increase of 15% when compared with plants treated with ordinary water. Number of leaves increased by 45.89% and stem girth increased by 13.69% when compared with ordinary water – treated plants.Magnetic flux density of 719 G out of four flux densities used, performed best with fresh bulk yield of 172.72 g/bucket. It may be concluded that the highest flux density of 719 G performed optimally across all growth parameters.

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