Effect of Magnetized Irrigation Water on Germination and Yield of IAR-48 Cowpea Cultivar

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Abstract: Cowpea (*Vigna unguiculata*) is a leguminous crop that is grown in some parts of Nigeria that is needed by man and livestock for plant protein.The cultivation of cowpea in the country is normally having problems with diseases and low yield.This study was conducted to study whether the magnetized irrigation water could promote germination and yield of cowpea. Two magnetic flux densities of 1127.4 G (T1) and 1071.5 G (T2) were applied to treat irrigation water while there was a control treatment (Tc) without magnetization. The magnetic fields were generated from permanent magnets produced by neodymium and round-bar magnets within the treatment chambers.The cowpea seeds (IAR-48 cultivar) were planted in buckets under a transparent garden shed. A randomized complete block design experiment was used in this study and each of the three treatments was replicated five times.The results indicated that cowpea plants irrigated with magnetized water had better germination indices, plant height, stem diameters and yields than those of control. The germination of cowpea plants with T1, T2 and Tc 6 days-after- planting (DAP) were 16, 13 and 9 seedlings, respectively, while plant heights at 65 DAP were 66.3 cm, 64.0 cm and 56.4 cm, and the stem diameters were 0.803 cm, 0.801 cm and 0.630 cm, respectively.Mean cowpea yields harvested for T1, T2 and Tc were 13.40±0.7483 g, 9.540±0.5192 g and 4.766±2.3659 g, respectively.The cowpea yield for plants treated with magnetized water increased by 50% - 64% compared to the yields obtained from control.

Keywords: magnetization; neodymium magnets; round-bar magnets; transparent garden; water

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1 Introduction

Cowpea (*Vigna unguiculata L. Walp*.) is a leguminous plant that sustains drought and high temperatures (Ngalamu *et al*., 2014). It serves as food for man and livestock throughout the world. There is problem of low cowpea yield that did not commensurate with the cost of production due to poor soil condition and pest infestation in the zone. Cowpea (variety-IAR- 48) was developed by Prof. O.I. Leleji at the Institute of Agricultural Research (I-A-R), Samaru, Zaria, Nigeria due to its outstanding qualities such as consistent and stable, high yielding potential and good palability reported by Nigerian Seed Portal Initiative (NSPI, 2022). Therefore, there is need to sustain better cowpea production that necessitated this study.

The crop coefficient (Kc) of cowpea is estimated through the ratio of the cowpea evapotranspiration, ETc

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(mm day^{-1}) and the reference evapotranspiration, ETo (mm day^{-1}). Crop coefficients are similar for crops within the same group where crop height, leaf area, ground coverage and water management are equal. The Kc value of 1.15 can be taken for green beans, peppers and cucumbers and 1.20 for tomatoes, dry beans and peas (Snyder and O'Connell, 2007; Snyder *et al*., 1996).The single (time-averaged) crop coefficients, Kc values for beans, dry and pulses in sub-humid regions using FAO Penman-Monteith ET_o are 0.40, 1.15 and 0.35 for Kc at initial, mid and at the end of the growing period. Crop coefficients integrate the effects of transpiration and evaporation over time for a standard crop irrigated under normal conditions (Ko *et al*., 2009; Wright, 1982).

Crop production could be improved by stimulation of irrigation water through sunlight, ultraviolet light, electrical and magnetic fields. Researches had shown that magnetic induction of water could be attained at different magnetic field strengths, frequency and time of exposure (Elfadil and Abdallah, 2013; Ziaf *et al*., 2015).

Magnetization of water to produce magnetized water could be achieved by using electromagnetic induction or a permanent magnet. The permanent magnets can be arranged as inverted (N-S, S-N, N-S, S-N) and non-inverted (N-S, N-S, N-S, N-S) orientations within the treatment device (Gabrielli *et al*., 2001). However, production of magnetized irrigation water by electromagnetic principle is not practicable and not economical for local farmers. Elfadil and Abdallah (2013) reported that because water is paramagnetic, it loses its magnetic charge as it travels through pipes, and it has been proven that treating irrigation water with magnetic fields restores the charge.

The time of producing magnetized water is a function of design and construction technology (size of pipe diameter and shape configurations). Hozayn and Abdul-Qados (2010) produced magnetized water at 4-6 m^3h^{-1}, Abedinpour and Rohani (2017) at 0.36 $m^3 h^{-1}$ flow rate and Yusuf and Ogunlela (2015) used circulation method four times for duration of 113 s so as to achieve better and effective water treatment by magnetic fields.

Magnetized water dissolved more nutrients thereby making more nutrients available for plants and little fertilizer is required for normal plant growth that is resistant to pests and diseases (Zhang *et al*., 2009). Elimination of chemicals reduced production costs and sustained environmental health (Shoeb *et al*., 2001). Magnetic field changes the structures of irrigation water by reducing surface tension and acidity, increasing minerals' dissolvability and sustaining adequate nutrients for plant development (Babu, 2010; Huang and Bie, 2010). Water that passes through magnetic water softener experiences a Lorentz force that affects some physical characteristics of water such as density, salt solution capacity and mineral precipitate through the frequency of collisions between ions of opposite directions (Higashitani and Oshitani, 1998; Abedipour and Rohani, 2017).

Application of magnetized water possesses many advantages such as an increase in leaching of excess soluble salts, prevention of uptake of harmful elements by plant roots, activation of enzymes and hormones in the germination process, support plant growth by increasing mobile forms of fertilizers and crop yields (Hozayn and AbdulQados,2010). Magnetized water is environmentally friendly and has no adverse effect on the crop. Abedinpour and Rohani (2017) emphasized that magnetized water reduced soil alkalinity and improved the leaching of excess salts. Hozayn and Abdul-Qados (2010) stated from their study that magnetic fields influenced germination of seeds, plant growth and development, ripening of fruits and crop yield.

The objective of this study was to determine the effect of magnetized irrigation water on germination and yields of the IAR-48 cowpea cultivar.

2 Materials and methods

2.1 Experiment setup

The study was conducted in the Food and Agricultural Engineering Department, Kwara State University Malete, Moro Local Government Area of Kwara State, Nigeria. Malete town lies on the latitude 8^{o}42`0``N and longitude

4°28`0``E with an elevation within 364 m above mean sea level (Figure 1). The rainfall was 65.4 mm during the period of the study while the minimum and maximum temperatures of the study area were 26°C and 39°C while soil temperature was 34°C. The soil used for the study was excavated very close to the transparent garden located on latitude: 8° 43 ́14 .6 ́N, longitude: 4° 28 ́53.4 ́E and altitude: 296.4 m. It was filled into buckets of 11 L capacity to a depth of 220 mm.

Cowpea (*Vigna unguiculata L. Walp*.) cultivar IAR-48 was planted under a transparent garden with dimensions 9.0 m long, 7.0 m wide and 4.0 m high.The cultural practices majorly required in cowpea cultivation were seed rate, planting date, planting depth and spacing, irrigation and weed control.Three cowpea seeds were planted per bucket at a depth of 3 cm in February 20, 2020. Weeding was carried at every two weeks using manual method to curb weeds competitions for nutrients and water.

A rectangular water treatment device-generated magnetic field from twelve pairs of neodymium magnets (Neodymium Ferrite Boron, NdFeB) of N50 grade, 50 mm × 25 mm × 10 mm fixed to a metal frame with 45 mm distance between pairs and 20 mm gap at the edges (Figure 2). The round-bar water treatment chamber consisted of six pairs of magnets of thickness 20 mm; diameter 120 mm and weight 550 g fixed on a metal plate. Magnets were placed 30 mm at the interval and 15 mm gaps at both ends (Figure 3). The magnetic flux densities at the outlets for both treatment devices were measured using a permanent magnet digital Gauss meter model TD 8620 manufactured by Dexing Magnet Company, Xiamen, China and were denoted as T1 (1127.4 G) and T2 (1071.5 G) respectively. Mean water flow rates for two runs of water from 30 L bucket to the outlet as shown in Fig. 4 for the two devices were 2.68 and 2.86 Lmin^{-1}.

Scanning electron microscope (SEM) analysis of irrigation water was carried out through JSM 7600F machine (JEOL Ltd., Tokyo, Japan) where water samples were coated with platinum coating of electrically conducting material, deposited on the sample either by low-vacuum sputter coating or by high-vacuum evaporation. The specimens (water) were placed in a relative high-pressure chamber where the working distance is short and the electron optical column is differentially pumped to keep the vacuum adequately low at the electron gun within the SEM instruments. The high-pressure region around the sample neutralizes charge and provides an amplification of the secondary electron signal. Irrigation water samples were analysed at the laboratory to examine each treatment water essential chemical elements. The magnetized water was produced in the laboratory and taken to the garden shed to irrigate the cowpea immediately after magnetization against irrigation after 24 h adopted by Deshpande (2014). Magnetized water lost its magnetic properties (magnetic memory) after 2-3 days if not used. Cowpea plants in the buckets were irrigated directly with measured volume of magnetized and non-magnetized water.

2.2 Determination of crop water requirement and irrigation interval by cowpea plant

The volume of water was computed for the water required by two seeds of cowpea plants for a 3-day irrigation interval using Equations 1, 2, 3 and 4 as cited by Yusuf and Ogunlela (2015).

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

$$V_{dp} = K_c \times ET_o \times C_c \times A_p \tag{2}$$

$$I_v = \frac{d_n}{ET_c} \tag{3}$$

$$V_{days} = V_{dp} \times N_p \times I_v \tag{4}$$

Where,

ET_c represents crop evapotranspiration (mmday^{-1}), K_c is the crop coefficient (dimensionless), ET_o is the reference crop evapotranspiration (mmday^{-1}), V_{dp} is the volume of water needed daily per plant (mm^{3}day^{-1}), C_c is the crop canopy (%), A_p is the area of the pot (mm^2), I_v is the irrigation interval (day), d_n is the net depth of irrigation (mm), Np is the number of cowpea plant per stand in a pot and V_{days} is the quantity of water applied at the designed irrigation interval (L).

The peak value of reference evapotranspiration (ET_o) for Ilorin in second and third quarters of the year was 4.70

mm day^{-1} (Yusuf and Ogunlela, 2015) and mean (Kc) for cowpea at mid stage (1.15) was used in this study.

The values of parameters such as net depth of irrigation water (d_n = 16.79 mm), field capacity (FC=11.40%), area of the pot (A_p = 0.0564 mm^2), crop canopy (C_c = 0.8) and the number of cowpea plant per stand (Np = 2) were used to determine the crop evapotranspiration of cowpea ET_c , I_v and volume of water required estimated as follows;

$$ET_c = 1.15 \times 4.70 = 5.41 \text{mm day}^{-1}$$

$$I_v = \frac{16.79}{5.41} = 3.10 \approx 3 \text{days}$$

$$V_{dp} = 5.41 \times 0.8 \times 0.0564 = 0.244 \text{ mm}^3 \text{day}^{-1}$$

$$V_{3days} = 0.244 \times 2 \times 3 = 1.465 \approx 1.50 \text{ L}$$

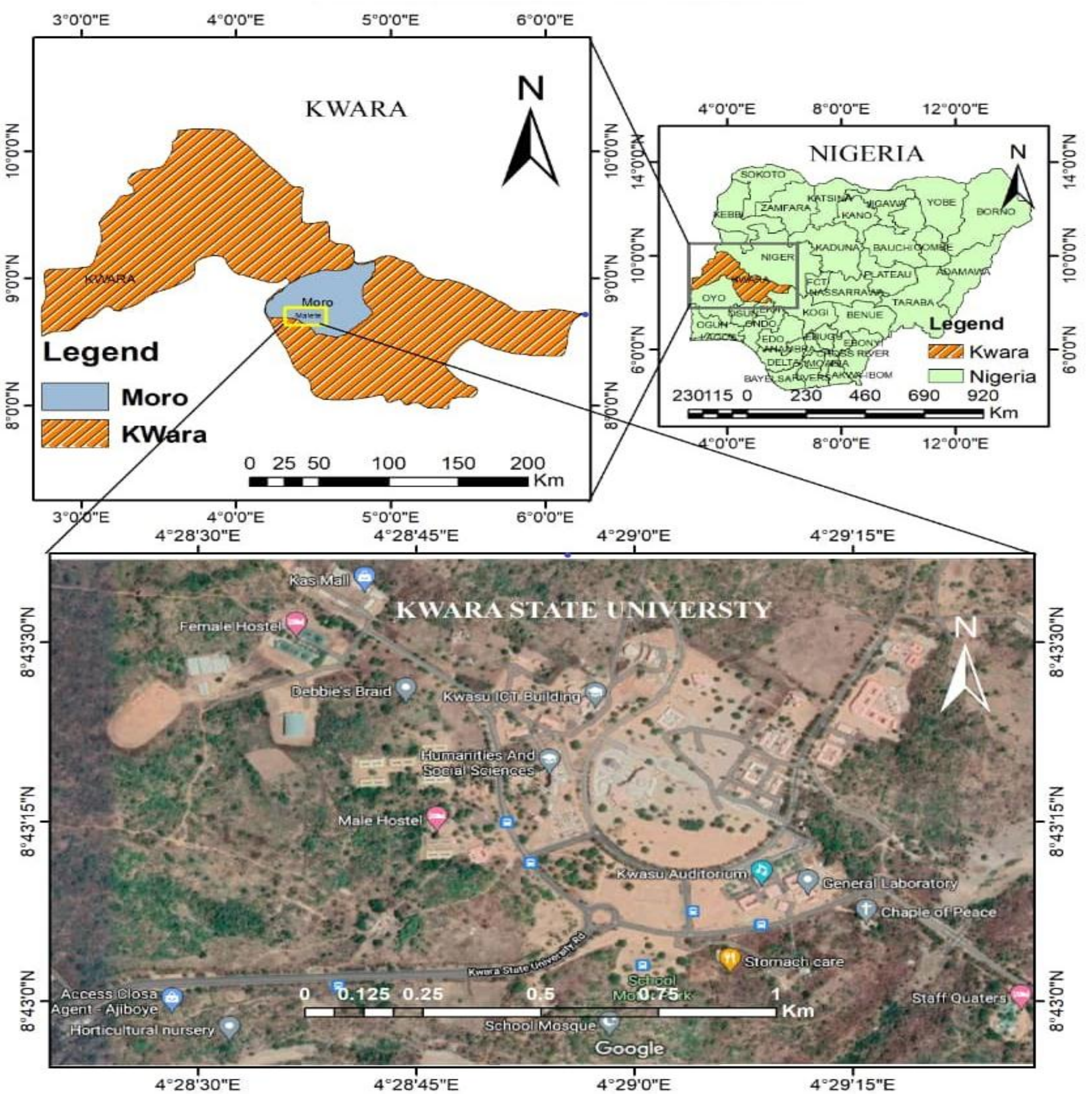


Figure 1 Map of study area located within the Kwara State University

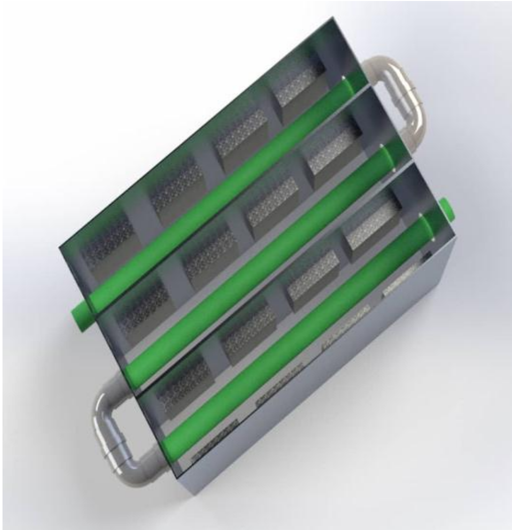


Figure 2 Neodymium magnetic chamber

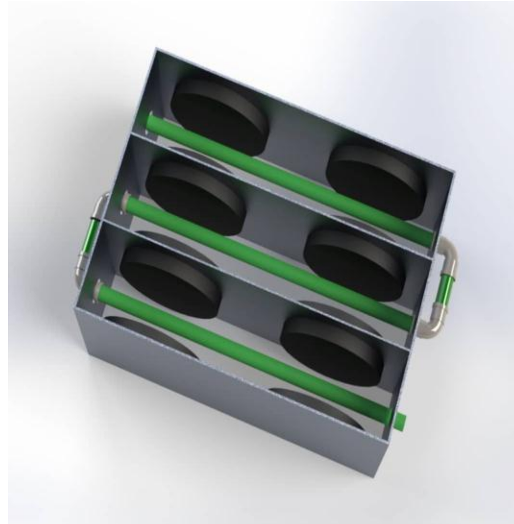


Figure 3 Round-bar magnetic chamber

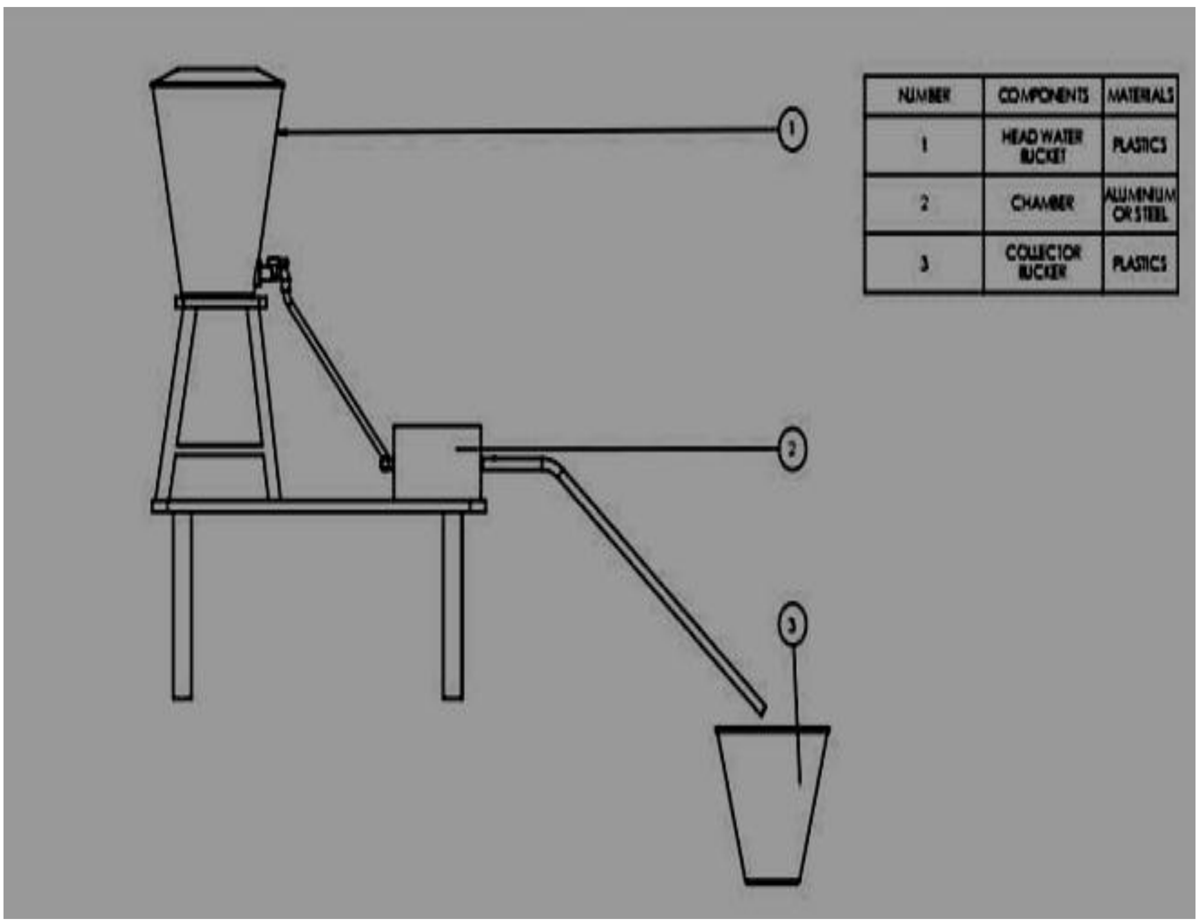


Figure 4 Magnetic water treatment set up

2.3 Soil properties of the soil

The preliminary laboratory soil analysis of the three soil samples at 35 cm below surface performed at the soil and water laboratory, Landmark University, Omu-aran, Nigeria. The soil sample was replicated three times using atomic absorption spectrophotometers and other general laboratory equipment. Analysis results showed that the soil was sandy-loam contained 81% sand, 13.5% silt and 5.5% clay. Results from the laboratory analysis indicated that the soil was acidic with a pH of 5.87 while the organic matter and organic carbon contents were about 63% and 36%, respectively, as shown in Table 1.

Table 1 Chemical properties of the experimental soil

Parameters	Values ± Std Dev.	Units
pH	5.87 ± 5.4	-
N	24 ± 4.6	mgL^{-1}
P	5.40 ± 2.2	mgL^{-1}
K	26.1 ± 6.5	mgL^{-1}
Ni	8.50 ± 1.3	mgL^{-1}
Ca	28 ± 3.8	mgL^{-1}
Na	4.49 ± 1.7	mgL^{-1}
Mg	150 ± 8.1	mgL^{-1}
Pb	0.03 ± 1.2	mgL^{-1}
Organic Matter(OM)	0.63 ± 1.4	%
Organic Carbon(OC)	0.36 ± 1.6	%
Cation-exchange capacity (CEC)	3.60 ± 2.5	$molkg^{-1}$

2.4 Data treatment and statistical analysis

The Randomized Complete Block Design (RCBD) experimental design was used with five replications for each treatment. The treatments were labelled as neodymium magnetic treated water -T1, round-bar magnetic treated water -T2, and ordinary water served as treatment control, Tc. Four cowpea seeds were planted per bucket but thinned to two seedlings 10 days-after- planting (DAP). Germination records and yields for each treatment were recorded throughout the growth period. Statistical analysis was carried out on the germination and yield using Duncan multiple range test at 5% significant level to estimate the significant differences between the treatments and the control using OriginPro 8.5 and GraphPad Prism 9.

Table 2 Chemical compositions of irrigation water in the different treatments

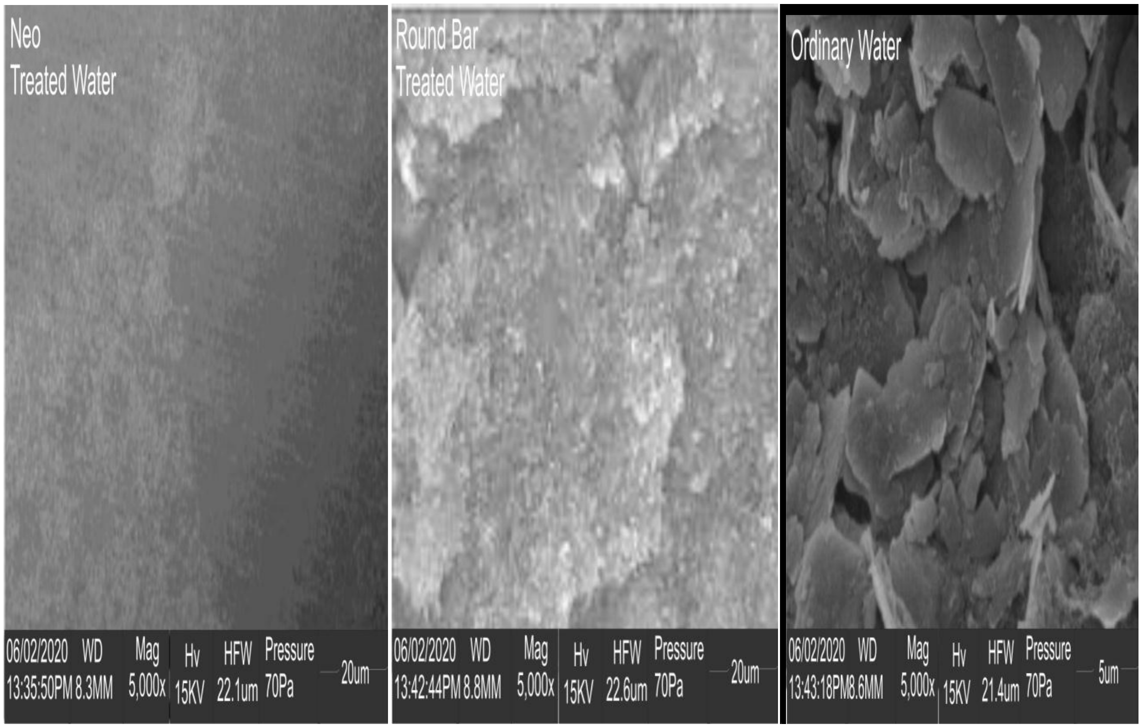
Parameters	Neodymium Magnets Treated Water(T1)	Round-bar Magnets Treated Water(T2)	Ordinary Water (Tc)	Units
Ca	42	47	10	mgL^{-1}
Mg	50	55	26	mgL^{-1}
K	21	24	11	mgL^{-1}
Na	1.28	1.28	0.96	mgL^{-1}
Pb	0.01	0.01	0.01	mgL^{-1}
Cr	0.14	0.12	0.07	mgL^{-1}
P	0.84	0.95	1.35	mgL^{-1}
CO_3^{2-}	32	36	10	mgL^{-1}
SO_4^{2-}	17	14	8	mgL^{-1}
NO_3^-	6.8	5.0	3.9	mgL^{-1}
Cl	36	38	26	mgL^{-1}
pH	6.38	6.42	5.10	-
EC	170.8	172.0	165.4	μScm^{-1}
Viscosity	3300	3393	2650	mPa.s
Total Hardness	16	25	60	mgL^{-1}

3 Results and discussions

3.1 Effect of magnetic field on chemical properties of the water and the internal structure of the water

The chemical elements present in treated and non-treated water are shown in Table 2. Magnetic field increased the pH, cations and anions, viscosity, electrical conductivity and total hardness compared to non-magnetic water. The results were in agreement with the results obtained by Hozayn et al. (2016), who found there was an increase in viscosity and decrease in surface tension over the treatment time due to the existence of minimum molecular energy with greater activation energy. Magnetic fields increased the inclination to coagulate large particles that lodged with the flow of water. The SEM micrographs are shown in Figure 5 (a, b, c) where the neodymium treated water was softer than water treated with the round-bar magnets and ordinary water due to its high coercive intrinsic forces (Deshpande, 2014). The micrographs of T1 and T2 at (5000 magnification; 20 µm) show that treatment T1 softened the water better than treatment T2 while the micrograph of control Tc shows that water particles remained unchanged and visible at smaller scale. Therefore, SEM proved that the magnets had an effect on the water clusters and internal structure of the water.

T1 **T2** **Tc**



(a) (b) (c)

Figure 5 Water images analysis displayed by SEM with magnification of 5000x

3.2 Germination and vegetative growth of cowpea plants

The results of this study indicated that magnetized irrigation water using magnetic flux densities 1127.4 and 1071.5 G influenced germination, vegetative growth and stem diameter of cowpea compared to ordinary water (control) as shown in Tables 3, 4 and 5. Germination of cowpea seedlings was highest for irrigation water treated with neodymium magnetic fields more than results obtained for round-bar magnetic fields treated water but lowest in treatment using non-magnetic treated water. Abedinpour and Rohani (2017) stated that magnetized water improved the activation of enzymes and hormones in the germination process. The statistical relationship between the treatments using Duncan multiple range test for cowpea germination at the third, fourth, fifth and sixth DAP is shown in Table 3. There was no significant difference (p>0.05) between the three treatments at 3 and 4 DAPs. Meanwhile, treatments T1 and T2 were significantly different (p<0.05) compared to control treatment (Tc) at 5 and 6 DAPs. Treatment T2 produced the best overall germination count numerically compared to T1 and Tc, respectively. However, no significant differences (p>0.05) were observed between T1 and T2.

Table 4 shows that treatment T2 had the best cowpea height at 20 and 35 DAPs but treatment T1 possessed the highest cowpea height at 65 DAP while the lowest plant heights were recorded for control treatment Tc throughout the growth period. Statistically, there were significant differences (p<0.05) in the cowpea height between all the treatments at 20, 35 and 65 DAPs, respectively.

Meanwhile, the cowpea stem diameter measured 25 mm above soil surface at 65 DAP showed that magnetized water treated cowpea plants had better stem thickness compared to cowpea treated with non-magnetized treated water. Table 5 showed that there was no significant difference (p>0.05) between treatments T1 and T2 for cowpea stem diameter measured at 65 DAP. Although, there was a significant difference (p<0.05) in the stem thickness between magnetic treatments (T1 and T2) and the control (Tc) as shown in Table 4.

These results indicated that magnetic treated water supported plants development compared to treatment control in line with the results obtained by Abedinpour and Rohani (2017) whereby the application of magnetized water promoted maize seedling height and heavier than non-magnetized treatments. El-Sayed and El-Sayed (2015) reported that broad bean plants irrigated with magnetized water improved plant height, fresh and dry weight of leaves, leaf area, stem and root compared to the control treatment. There was an increase in the germination of *Pinus tropicalis* seeds with magnetically treated water compared to the control reported by Grewal and Maheshwari (2011) similar to the results obtained for cowpea cultivar studied.

Table 3 Cowpea germination (mean ± standard error) irrigated and non-irrigated with magnetized water under transparent garden

Treatments	Germination at 3 DAP	Germination at 4 DAP	Germination at 5 DAP	Germination at 6 DAP
T1	2.0±0.32[a]	2.4±0.24[a]	3.2±0.20[a]	3.2±0.20[a]
T2	1.8±0.58[a]	2.6±0.75[a]	3.4±0.60[a]	3.4±0.60[a]
Tc	1.2±0.58[a]	1.8±0.37[a]	1.8±0.37[b]	1.8±0.37[b]

Note: **The values represent Mean ±Standard Error (SE), n= 5. Different superscript mean significant differences (p<0.05) between treatments in germination for a given DAP.

Table 4 Cowpea height (mean ± standard error) measured at certain days after planting

Days- after- planting (DAP)	Plant height (cm)		
	T1	T2	Tc
20	15.70±0.14[b]	19.00±0.37[a]	13.80±0.34[c]
35	41.30±0.37[b]	43.30±0.47[a]	38.00±0.65[c]
65	66.30±0.60[a]	64.00±0.56[b]	56.40±1.18[c]

Note: **The values represent Mean ±Standard Error (SE), n= 5. Different superscript mean differences in height between treatments for a given DAP.

Table 5 Diameter of the cowpea stems (mean ± standard error) at 65 days- after- planting (DAP)

DAP	Stem diameter (cm)		
	T1	T2	Tc
65	0.803±0.0027[a]	0.801±0.0044[a]	0.630±0.0253[b]

Note: **The values represent Mean ±Standard Error (SE), n= 5. Different superscripts mean significant differences (p<0.05) in cowpea stems between treatments.

3.3 Cowpea yield for magnetized and non-magnetized treatments

Table 6 shows cowpea mean yields produced by magnetized irrigation water (treatments T1 and T2) were 64% and 50% better than the control treatment,Tc. Neodymium magnetic flux treated water had the best cowpea yield (13.40 g) compared to the yields obtained from round-bar magnetic flux treated water (9.54 g) and the least (4.76 g) for control treatment.

Statistical analysis using Duncan multiple range test shows that there was no significant (p>0.05) differences on cowpea yields obtained for magnetic treatments T1 and T2. Meanwhile, there was a significant difference between the magnetic treatments (T1 and T2) and control treatment, Tc where p<0.05 as indicated in Table 6. This result was in agreement with the studies of El-Sayed and El-Sayed (2015) that broad bean plants irrigated with magnetic water improved the yield production significantly compared to normal tap water.

Table 6 Mean Cowpea Yields for Two Magnetic Irrigation Water and Control Treatments

Average Cowpea Yield (g/bucket)			
	Treatments		
Cowpea Cultivar	T1	T2	Tc
IAR-48			
Mean± SE	13.40±0.75[a]	9.540±0.52[a]	4.766±2.37[b]
Difference Compared to control treatment (%)	64.0	50.0	-

Note: **The values represent Mean ±Standard Error (SE), n= 5. Different superscripts mean significant differences (p<0.05) between treatments for cowpea yields.

4 Conclusions

Cowpea plants irrigated with magnetized water produced better germination rate, growth characteristics and good yields compared to non-magnetized water treated cowpea plants because there were significant differences statistically. These results were attributed to magnetization (magnetic water softener) where the water molecules were easily absorbed by the cowpea plants that made nutrients more readily available to plants. Conclusively, cowpea plants treated with irrigation water of higher magnetic flux densities (1127.4G) through neodymium magnets (T1) had the best growth characteristics and mean yield of 13.40 g/bucket than irrigation water with lower magnetic flux densities (1071.5G) using round-bar magnets (T2) and control treatment (Tc).

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