EFFECT OF MAGNETIZED IRRIGATION WATER AND SEEDS ON GERMINATION, WATER USE EFFICIENCY AND YIELD OF COWPEA CULTIVARS

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ABSTRACT

The effects of magnetized irrigation water and cowpea seeds on germination, water use efficiency (WUE), and yields were investigated under transparent garden. Irrigation water was treated with neodymium and round-bar magnets with magnetic fluxes of 112.74 mT and 107.15 mT. Water was applied at 1.50 litres per day for 3-day intervals at 2 plants per bucket. Cowpea cultivars (C_1= TVX-117, C_2= IAR-48, and C_3 = Ife brown) were stimulated within magnetic fields of fluxes 27.32 mT and 18.54 mT before planting. Four experiments and one control were replicated five times randomized using factorial design. The neodymium-treated water only (T_1), neodymium-treated water and seeds (T_2), round-bar treated water only (T_3), round-bar treated water and seeds (T_4), and non-treated water and seeds (T_c). The germination indices revealed that four magnetic treatments performed better than the control with significant differences at $p<0.05$ ($R^2 = 0.9598$). Cowpea yields showed that there was a significant difference at p=0.0006 ($p<0.05$, $R^2 = 0.9599$). There were no significant differences in WUE for all the treatments as $R^2 = 0.01830$ was closed to zero at $p<0.05$. This study concluded that magnetized water and/or seeds improved growth rate, WUE, and cowpea yield compared to the control.

Keywords: *Irrigation, Magnetized seeds, Magnetized water, Water use efficiency, Yield.*

INTRODUCTION

Production of the crop can be improved through stimulation of irrigation water by 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 within magnetic fields (Elfadil and Abdallah, 2013; Ziaf *et al*.,2015). The magnetic process was achieved through electromagnetic induction and stationary permanent magnets. Electromagnetic induction treatment generated much heat and it is not affordable by poor local farmers. Water lost its charges through transportation along the pipe and it was proved that treating irrigation water with magnetic fields restored the charges (Elfadil and Abdallah, 2013).

Magnetized water dissolved more nutrients thereby plant required less fertilizer and healthier to sustain 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; Abedinpour and Rohani, 2017).

The degree of magnetisation depends on the volume of the water within the magnetic chamber, the magnetic field strength and the duration of treatment (Mostafa, 2020). Magnetic fields break down large crystals into small crystals that are easily transporting through soils and the plants' root pores (Chibowski, 2018).

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 Abdul-Qados, 2010) . There were two methods of arranging permanent magnets within the treatment device known as inverted and non-inverted orientations (Gabrielli *et al*., 2001). Magnetically treated water is environmentally friendly and had no adverse effect on the crop produced through magnetized water. The magnetic fields influenced the germination of seeds, plant growth and development, ripening of fruits, crop yield (Penuelas *et al*., 2004); improve human and animal health (Hozayn *et al*., 2021). The magnetic field of 21 - 176 G can inhibit the root growth of crops based on the study of Ijaz *et al*., (2012). Application of magnetized water alleviates the problem of soil salinity through reduction in salt crystals size and become more absorbed by the plants (Hozayn *et al*., 2021; Ben *et al*., 2020).

The most common pre-sowing treatments employed for seeds stimulation were electric field, magnetic field, laser radiation, and microwave radiation (Ijaz *et al*., 2015). Pre-sowing of seeds before planting by magnetic stimulation improved the germination rate of seeds from 30% - 50% (Wojcik, 1995). This study was carried out to determine the effectiveness of magnetized irrigation water and/or seeds on germination, water use efficiency, and yields of cowpea cultivars.

MATERIALS AND METHODS

The study was conducted in the research farm of the Food and Agricultural Engineering Department, Kwara State University Malete, Moro Local Government Area, Kwara State, Nigeria. Malete. The town lies on the latitude 8°42`0``N and longitude 4°28`0``E with an elevation within 364 m above mean sea level and annual rainfall of about 1400 mm where wet and dry season temperatures of the study area were 25°C and 34°C respectively.

Cowpea (*Vigna unguiculata L. Walp*.) cultivars IAR-48, TVX-117, and Ife brown were planted under a transparent garden with dimensions 9.0 m long, 7.0 m wide and, 4.0 m high. A rectangular water treatment device; generated magnetic fields through twelve pairs of neodymium magnets (Neodymium Ferrite Boron, NdFeB) of N50 grade, 50 mm x 25 mm x 10 mm fixed to a metal frame with 45 mm distance between pairs and 20 mm gap at the edges. The round-bar water treatment device consists of six pairs of magnets of thickness 20 mm; diameter 120 mm and weight 550 g fixed on the metal plate. Magnets were placed 30 mm at the interval and 15 mm gaps at both ends.

The magnetic flux densities at the outlets for both devices were measured by digital magnetic gauss meter (Model TD 8620) as 1127.4 G and 1071.5 G for neodymium and round-bar magnetic water treatment chambers respectively. The mean water flow rates for two runs of water from 30 litres bucket to the outlet were 2.68 and 2.86 litres per minute respectively (Figure 1). Cowpea seeds were stimulated before planting through magnetic fluxes of 273.2 G and 185.5 G for neodymium and round-bar magnets respectively.

Figure 1. Magnetic water treatment set up

Soil properties of experimental soil

The preliminary soil analysis showed that the soil used was sandy-loam (81% sand, 13.5% silt, and 5.5% clay). The soil is acidic with a pH of 5.87 with organic matter and organic carbon contents of about 63% and 36% respectively as shown in Table 1. Magnetized water reduced soil alkalinity and improved the leaching of excess salts as it was emphasized by Abedinpour and Rohani, (2017).

Determination of crop water requirement and irrigation interval by cowpea plant

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

$$ET_c = K_c \times ET_o \quad (1)$$

$$V_{dp} = K_c \times ET_o \times C_c \times A_p \quad (2)$$

$$I_v = \frac{d_n}{ET_c} \quad (3)$$

$$V_{days} = V_{dp} \times N_p \times I_v \quad (4)$$

Table 1: Chemical properties of experimental soil

Parameters	Values	Units
pH	5.87	-
N	24	[mg/L]
P	5.40	[mg/L]
K	26.1	[mg/L]
Nickel	8.50	[mg/L]
Ca	28	[mg/L]
Na	4.487	[mg/L]
Mg	150	[mg/L]
Pb	0.031	[mg/L]
Organic Matter(OM)	0.628	[%]
Organic Carbon(OC)	0.360	[%]
CEC	3.60	[mol/kg]

* Cation Exchange Capacity (CEC)

Where, ET_c represents crop evapotranspiration [mm/day], K_c is the crop coefficient, ET_o is the reference crop evapotranspiration [mm/day], V_{dp} is the volume of water needed daily per plant [litre/day], 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] and N_p is the number of cowpea plant stand in a pot.

$$ET_c = 1.15 \times 4.70 = 5.41 \text{ mm/day}$$

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

$$V_{dp} = 5.41 \times 0.8 \times 0.0564 = 0.244 \text{ litre/day}$$

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

Experimental design and treatments

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 litres capacity to a depth of 220 mm. Five experiments replicated five times and randomized using factorial design were done for each cultivar. The experiments performed were neodymium treated water and seeds (T_1), neodymium treated water only (T_2), round-bar treated water and seeds (T_3), round-bar treated water only (T_4), and control treatment (T_c). Cowpea plants were irrigated with magnetized and ordinary water at an equal volume of 1.50 litres at a 3-day irrigation interval. Four cowpea seeds were planted per bucket for the three cowpea cultivars but thinned to two seedlings per bucket 10 days after planting (DAP). Cowpea germination records, water use efficiency (WUE) and yields were studied throughout the growing period.

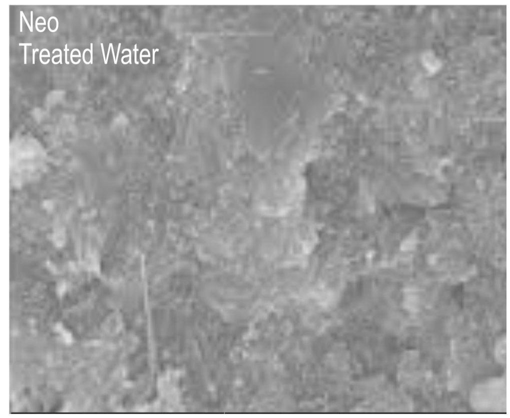
RESULTS AND DISCUSSIONS

Effect of magnetic treatments on properties of irrigation water

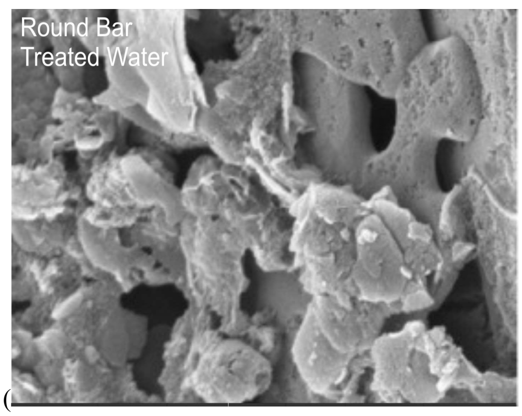
Irrigation water analysis showed the chemical elements present in treated and non-treated water as shown in Table 2. Magnetic fields had improved the pH, cations and anions, viscosity, electrical conductivity, and total hardness compared to non-magnetic water. The results were in agreement with the results obtained by Hozayn *et al.* (2016) where 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 scanning electron microscopy (SEM) micrographs (Figure 4) showed that neodymium treated water was softest while water treated with round-bar magnets was softer than ordinary water due to the high coercive intrinsic forces of the magnets as stated by Deshpande (2014).

Effect of magnetized water and seeds on germination and cowpea plants development

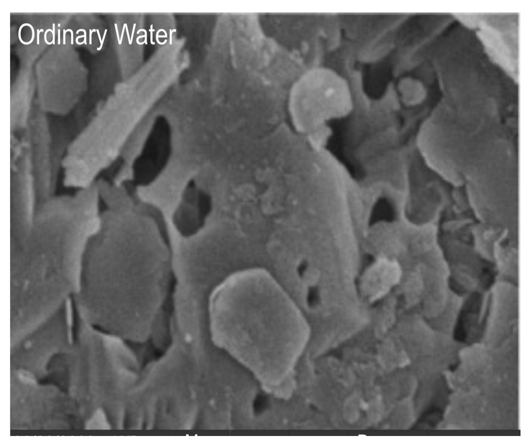
The results of this study indicated that magnetized irrigation water using magnetic flux densities 1127.4G and 1071.5G influenced germination of cowpea compared to ordinary water (control) as shown in Figure 5.



(a)



(b)



(c)

Figure 4. SEM micrographs of magnetized (a & b) and non-magnetized water (c) at 7000x.

Table 2. Chemical compositions of irrigation water

Parameters	NMTW	RMTW	OW	Units
Calcium	42	47	10	[mg/L]
Magnesium	50	55	26	[mg/L]
Potassium	21	24	11	[mg/L]
Na	1.28	1.28	0.96	[mg/L]
Pb	0.01	0.01	0.01	[mg/L]
Chromium	0.14	0.12	0.07	[mg/L]
P	0.84	0.95	1.35	[mg/L]
CO_3^{2-}	32	36	10	[mg/L]
SO_4^{2-}	17	14	8	[mg/L]
NO_3^-	6.8	5.0	3.9	[mg/L]
Chlorine	36	38	26	[mg/L]
pH	6.38	6.42	5.10	-
EC	170.8	172.0	165.4	[µs/cm]
Viscosity	3300	3393	2650	[Mpa.s]
Total Hardness	16	25	60	[mg/L]

*Neodymium Magnets Treated Water (NMTW), Round-bar Magnets Treated Water (RMTW), Ordinary Water (OW)

Germination favoured T_1 on the fourth day after planting (DAP), T_1 & T_2 at fifth DAP and T_2 & T_3 at sixth and seventh DAP respectively. 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 and/or seeds but lowest in treatment using non-magnetic treated water. The magnetized water improved the activation of enzymes and hormones in the germination process as stated by Abedinpour and Rohani (2017). Crop height at 20 DAP, T_3 had the best height; T_2 & T_3 performed better at 35 DAP while at 65 DAP, $T_2>T_1>T_3>T_4>T_c$ as shown in Figure 7. Magnetic treatment of both irrigation water and cowpea seeds before planting (T_2) best supported vegetative growth of cowpea while compared to other treatments. Treatments T_1 and T_3 were magnetic water only while T_2 and T_4 were treatments of magnetized water and seeds. The germination indices revealed that the four magnetic treated cases performed better than the control where T_1 had the best germination rate followed by

T_2, T_3, and T_4 with significant differences at $p < 0.05$ ($R^2 = 0.9598$). These results were very close to the results obtained by Grewal and Maheshwari (2011) where magnetically treated water only (MTW) was more productive than magnetically treated seeds (MTS) only for seedling emergence and performance. MTW resulted in a significant ($p < 0.05$) increase in germination index than the control treatment of cowpea cultivar according to Adebayo *et al*., (2021).

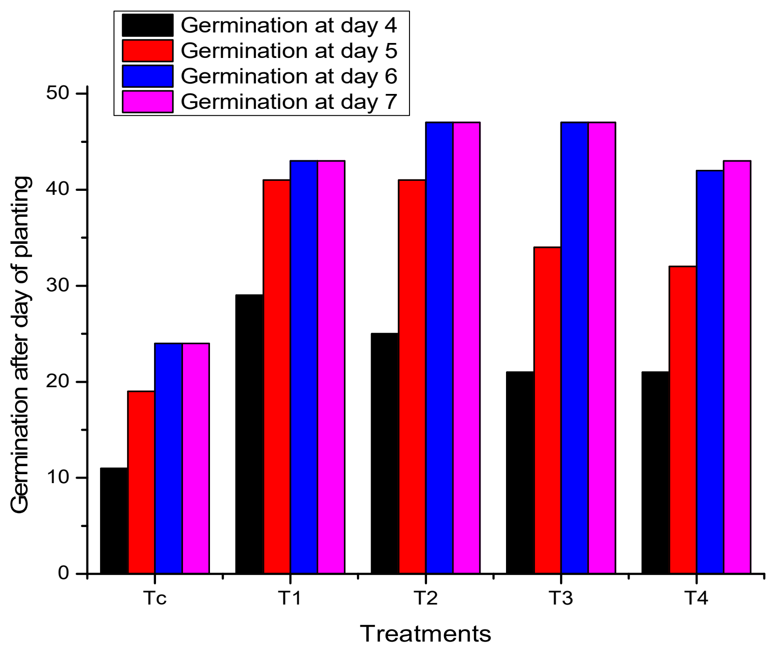


Figure 5. Mean germination of cowpea cultivars for magnetic and control treatments.

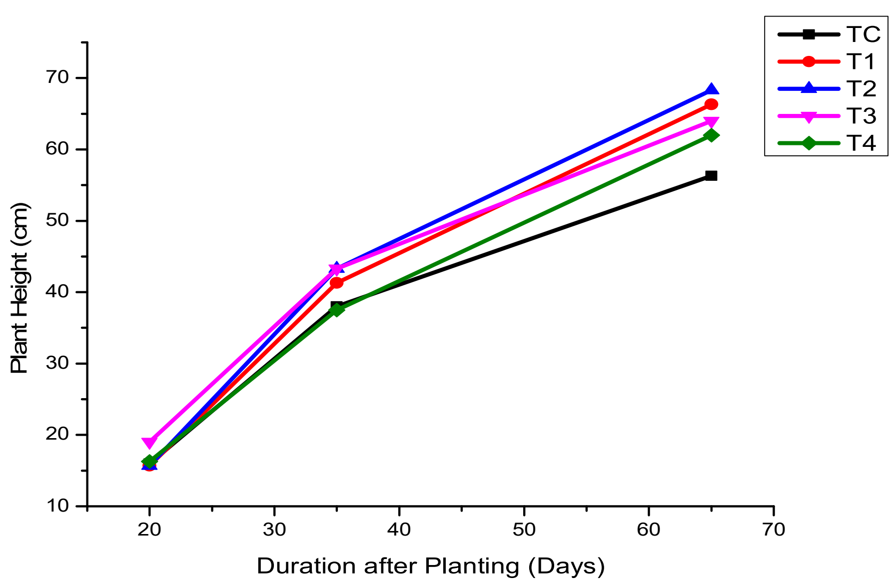


Figure 6. Cowpea plant height at different days after planting

Impact of magnetic treatments of water and seeds on water use efficiency of cowpea plants

The mean WUE of four magnetic treatments compared to control treatment were 16.4%, 24.7%, 11.6%, and 7.6% better than the control treatment for treatment T_1, T_2, T_3, and T_4 respectively (Table 3). Water use efficiency obtained in treatment T_2 was due to low water lost through transpiration and evapotranspiration. The ratio of cowpea yields per total water used throughout the growing period could be related to the leaf areas of each cultivar concerning the treatment. Treatment T_3 had better WUE more than T_4 in contrary to results obtained in T_1 and T_2 treated with neodymium magnets. It was observed that magnetized water and seeds using round-bar magnets had high WUE compared to magnetized water only.

Results obtained were in line with the study of Shrief and El-Mohsen (2015) which concluded that grain yield improved as water utilization increased per unit area and more water use efficiency. Regression analysis showed no significant differences (R^2 = 0.01830; $p < 0.05$) for all the treatments water use efficiencies and the control as the coefficient of determination value was closed to zero.

Table 3. Mean water uses efficiency of cowpea plant under magnetic treatments

Water Use Efficiency (WUE) [mg/L]					
Treatments					
Cultivars	**T1**	**T2**	**T3**	**T4**	**Tc**
C_1	0.75	0.86	0.69	0.73	0.59
C_2	0.76	0.82	0.72	0.65	0.66
C_3	0.69	0.76	0.66	0.60	0.59
Total	2.22	2.44	2.07	1.98	1.84
%WUE	73	81	69	66	61

Response of cowpea yields on magnetized and non-magnetized water and seeds

The mean cowpea yields obtained for all the treatments showed that treatment T_2 (magnetized water only using neodymium magnets) had the highest yield at 33% more than the control treatment (Table 4). Cowpea cultivar C_2 (IAR- 48) had the highest yield while the cultivar C_1 (TVX-117) and C_3 (Ife brown) respectively. Treatment T_1 (magnetized water only using neodymium magnets) had 27% better than control treatment where cultivar TVX-117 performed better than the other two cowpea cultivars. Statistical analysis using a one-sample t-test indicated that there was a significant ($p < 0.05$) difference at $p = 0.0006$ and coefficient of determination R^2 value of 0.9599 on cowpea yield under magnetic and non-magnetic treatments. This result was in agreement with the studies of Mostafa (2020); De-Souza *et al*., (2005) reported by El-Sayed and El-Sayed (2015) that broad bean plants irrigated with magnetic water improved the yield production significantly compared to normal tap water. It was also supported by Sary (2021) that magnetized water technology improved cowpea yields and save irrigation water.

CONCLUSIONS

The scanning electron microscope and laboratory analysis revealed that magnetic fields acted as a water softener which supported higher absorption and better nutrient uptake by cowpea roots. Magnetized cowpea seeds changed the rate of water absorption, plant tissues formation, and crop growth. Neodymium magnets performed better than round-bar magnets in treating irrigation water due to their high magnetic fields strength nonetheless performed far better than ordinary water. Magnetized water and/or seeds had better vegetative growth; water use efficiency and cowpea yield compared to non-magnetized water and seeds for the three cultivars studied.

Table 4. Mean cowpea yields under magnetic treatments

Average Cowpea Yield [mg/bucket]					
	Treatments				
Cowpea Cultivars	**T1**	**T2**	**T3**	**T4**	**Tc**
C_1	12.2	14.0	11.8	11.0	8.5
C_2	12.6	13.4	11.9	9.7	9.5
C_3	11.6	12.4	10.9	9.0	8.4
Total	**36.4**	**39.8**	**34.6**	**29.7**	**26.4**
Mean	**12.1**	**13.3**	**11.5**	**9.9**	**8.8**
% difference	**3.3 (27%)**	**4.5 (33%)**	**2.7 (24%)**	**1.1 (11%)**	**- (5%)**

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