EFFECTS OF MAGNETIZED WATER ON THE YIELD AND NUTRITIONAL QUALITY OF POPCORN *SEEDS*

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ABSTRACT

This investigation took place within a see-through garden shed sized at (8.0m × 4.0m × 3.0m), situated behind the Burhanudeen Primary and Secondary Schools in Ojagboro, Ilorin, Kwara State, Nigeria. In this experiment, water used for irrigation was subjected to treatment using round bar magnets. The water's average flow rate was 2.92 L/m. Over a 3-day period, water was applied at a rate of 2.0 liters, with 2 plants per bucket. Popcorn seeds of the flint maize variety (Zea mays L everta) were planted in 11-liter buckets filled with soil up to a depth of 180 mm. The study utilized a Complete Randomized Design, comprising three experimental groups and one control group, with each group replicated 10 times. The experimental groups were designated as follows: T1 (treated with eight round bar magnets), T2 (treated with six round bar magnets), T3 (treated with four round bar magnets), and T4 (control group using regular water). An analysis of the soil revealed that it consisted of sandy loam composition, with 63.33% sand, 20% silt, and 16.67% clay. Additionally, the soil contained 4.56% organic matter, 2.65% organic carbon, and had a pH of 7.97. The investigation into nutritional quality demonstrated that compared to the control group irrigated with untreated water, the groups receiving magnetized water displayed higher levels of crude protein (13.33%), ether extract (16.75%), and ash content (1.00%). Conversely, non-magnetized water led to elevated values of crude fiber (2.34%), moisture (12.5%), and nitrogen-free extract (59.30%).

Keywords: Magnetized water, round bar magnet, transparent garden, nutritional quality

1 INTRODUCTION

Popcorn (scientifically known as Zea mays L. everta) represents a unique variant of flint maize distinguished by its capacity to transform into edible flakes upon heating due to the substantial thickness of its endosperm. This specialized endosperm characteristic causes the kernel to burst when subjected to heat, a phenomenon arising from its ability to withstand the pressure generated by steam until it reaches a highly explosive state [1]. Globally, popcorn is among the most widely cultivated types of maize and holds a significant presence in countries such as Nigeria [2]. The sturdy hull of a popcorn kernel encompasses a robust, starchy shell-like endosperm with a moisture content ranging from 14% to 20%. This moisture transforms into steam when heated, resulting in a forceful expansion of the kernel to between 20 and 50 times its original size, followed by a cooling process. The prerequisites for the growth of popcorn are comparable to those of dent corn. The cultural practices for both corn varieties largely overlap, with only minor adjustments necessary for popcorn cultivation [3]. The concept of magnetized water pertains to water that flows through magnetic fields. The effectiveness of water treatment through magnetism hinges on three key factors: the volume of the liquid passing through the magnetic apparatus,

the potency of the magnet employed in this procedure, and the duration of treatment [4]. [5] documented that exposure to a magnetic field alters the structure of water molecules, causing them to cluster together more closely. This restructuring enhances the soil's capacity to absorb magnetized water compared to non-magnetized water. Additionally, magnetically treated water exhibits the ability to enhance a plant's immune system against certain diseases, elevate photosynthetic activity, and improve the efficiency of transporting photosynthetic products within common bean plants [5]. The application of magnetic treatment to irrigation water holds the potential to mitigate the adverse effects of water stress on crops. This is achieved by reducing the production of free radicals and altering the activity of antioxidant enzymes [6]. As When magnetic water infiltrates the soil, it imparts positive charges to both the chemical and physical attributes of the soil. This process yields several advantageous outcomes, such as lowering soil electrical conductivity (EC) and pH levels, enhancing soil permeability, expediting the movement of water to dissolve soil salts, and augmenting the absorption of nutrients for plant uptake [7, 8]. Magnetic water treatment stands as an environmentally friendly and chemical-free approach within agriculture, holding the potential to amplify crop yields, elevate crop quality, and enhance the efficiency of water usage [9, 10]. [11] also lends support to the benefits of magnetic water treatment in agriculture by noting that water treated magnetically spurs seed germination, shoot development, and overall crop growth. Passage of seeds through a magnetic field was found to enhance germination rates, the pace of seedling growth, the reproductive and growth aspects of meristem cells, and the synthesis of chlorophyll. [12] also documented that the impact of a magnetic field led to increased activities of antioxidant enzymes, elevated levels of photosynthetic activity, and enhanced production of photosynthetic pigments. As a result, these factors collectively boosted plant growth and productivity. Magnetized water has been demonstrated to enhance the nutritional qualities of tomatoes, including higher levels of vitamin A and vitamin C. However, it should be noted that this treatment also resulted in a slight increase in the uptake of lead (Pb^{2+}) in tomato fruits [13]. In the case of cowpea plants, when they were irrigated with magnetized water, significant improvements in germination rates, growth characteristics, and yield were observed [14]. The process of creating magnetized water can be accomplished through either electromagnetic induction or by utilizing permanent magnets. Permanent magnets can be arranged in either an inverted pattern (N-S, S-N, N-S, S-N) or a non-inverted configuration (N-S, N-S, N-S, N-S) within the treatment device [15]. The aim of this research is to investigate the effect of magnetized water and irrigation method on the yield, nutritional quality of popcorn seeds.

2 METHODOLOGY

2.1 STUDY AREA

The research was conducted within the timeframe of January 10, 2023, to March 10, 2023, at a location situated behind Burhanudeen Primary and Secondary School in Ilorin East Local Government Area of Kwara State. This area is situated adjacent to a stream named "Amule stream." The geographical coordinates of the study site are approximately 8° 30' 25.0" N latitude and 4° 33' 43.7" E longitude. Ilorin is positioned at approximately 8° 30' N latitude and 4° 35' E longitude, with an elevation of around 340 meters above mean sea level [16] explains that Kwara State is bordered to its north and east by the River Niger and shares boundaries with Niger State to the north, Kogi State to the east, and Oyo, Ekiti, and Osun States to the south. Moreover, it has an international border with the Republic of Benin to the west. The soils in the region of Ilorin are characterized as containing loamy and clay-rich compositions. The climate in Ilorin falls under the tropical category, with an annual precipitation of around 1500 mm. The average highest temperature reaches 38°C, and an average relative humidity of 77.50% is accompanied by approximately 7.1 hours of daily sunshine [17]. The wet season generally spans from the latter part of March to October, while the dry season lasts from November to March [16, 18]. Maps depicting the locations of Nigeria and Kwara State, with an indication of Ilorin East Local Government Area.

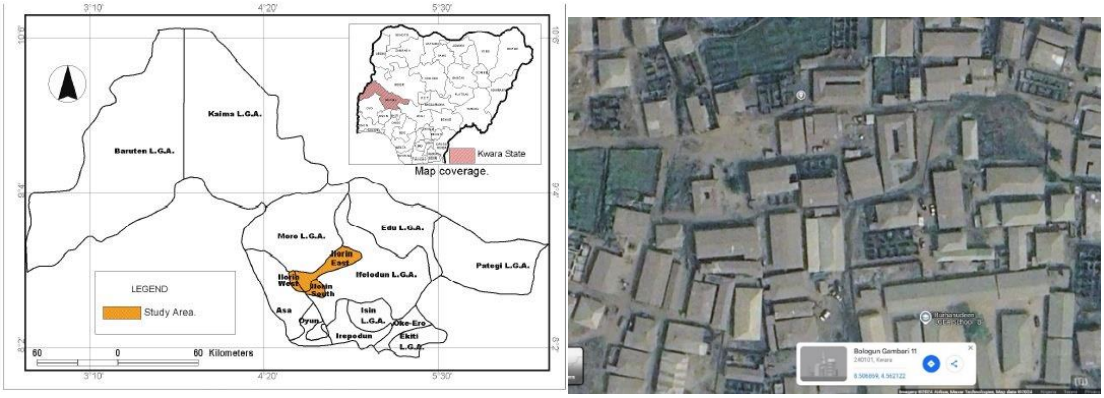

Figure 1. Map of Nigeria and Kwara State, showing the location of Ilorin and coordinates of study area

2.2 Determination of Magnetic Flux Densities Measurement Used in Treating the Water

The average magnetic flux densities employed in the study were determined using a gauss meter. Within the pipe, the measured value at the inlet was 73.25 millitesla (MT) or 732.5 gauss (G), while at the outlet outside the pipe, it was 100.61 MT (1006.1 G). The magnetic flux densities were also adjusted based on the number of magnets utilized in the experiment. In the first set, eight (8) round bar magnets were employed, resulting in an average magnetic flux density of 872.9 G. In the second set, six (6) round bar magnets were used, yielding an average magnetic flux density of 643.7 G. For the third set, involving four (4) round bar magnets, the average magnetic flux density measured 425.1 G. Lastly, the fourth set, which served as the control, employed regular water. [19] have noted that flux densities ranging from 35 to 1360 G are suitable for treating irrigation water.

Figure 2. Magnetic flux measuremment

2.3 Experimental Set Up

The transparent garden shed was positioned behind Burhanudeen Primary and Secondary Schools in Ilorin East Local Government Area of Kwara State, Nigeria. To construct the transparent shed, wood, transparent netting, and transparent nylon were employed. The wooden frames formed the structure of the shed, with transparent netting covering its four sides. The upper part of the shed and the remaining four

sides were covered with transparent nylon to shield the popcorn plants inside from rainfall. The dimensions of the transparent garden shed were 8.0 meters in length, 5.0 meters in width, and 3.0 meters in height. The entrance was located centrally at the front to facilitate entry and exit for daily activities. An experimental design layout employing a 4 by 10 Complete Randomized Design (CRD) was utilized to assign treatments to the popcorn plants grown in 40 buckets within the transparent garden shed. The first row was denoted as T1, containing ten buckets (T1-T10). The second row was labeled as T2, also comprising ten buckets (T2-T10). The third row was designated as T3, with another ten buckets (T3-T10). The fourth row, T4, encompassed ten buckets as well (T4-T10). T4 served as the control group where regular water was used, while T1, T2, and T3 were treated with magnetized water. The buckets used in the experiment had an 11-liter capacity, with a diameter of 200 mm and a depth of 268 mm. The buckets were 260 mm deep and had perforations at the bottom to facilitate drainage and prevent water accumulation. Loamy sandy soil was employed for the study, and its physical and chemical properties are detailed below. Each bucket was filled with this soil to a depth of 180 mm. On January 10, 2023, popcorn seeds (*Zea mays L everts*) were planted in the buckets at a depth of 25 mm each. After about ten days of germination, the seedlings were thinned down to two plants per stand. Water, totaling two liters, was applied at a three-day interval for irrigation. The research was conducted during the dry season to accurately evaluate the effectiveness of magnetized and non-magnetized water. In this region, the wet season spans from the end of March to October, while the dry season extends from November to March [20].

2.4 Determination of Water Requirement by The Popcorn Plant and Irrigation Interval

The water requirement of a tomato plant indicates the volume of water necessary to satisfy crucial processes like evapotranspiration, photosynthesis, and metabolic functions. Parameters such as crop evapotranspiration, initial soil saturation to field capacity at the beginning of the experiment, available water, wilting point, net irrigation depth, irrigation intervals, daily water requirement per popcorn plant, and the water volume needed for two popcorn plant stands over a three-day irrigation period were all calculated using Equations 1 to 8 respectively [21]. The wilting point value was determined using Equation (3) as defined by [21]. A total of 2.0 liters of water was established as the required amount for irrigating two stands of popcorn plants over a three-day span.

$$ETc = K_c \times ETo \quad (1)$$

$$D_f = \frac{\rho b}{\rho w}\left(\frac{Fc-\theta}{100}\right) D_b \ \ mm \quad (2)$$

$$W_p = \frac{Fc}{F}\ (\%). \quad (3)$$

$$AW = \frac{\rho b}{\rho w}\ \left(\frac{Fc-Wp}{100}\right)D_b\ mm \quad (4)$$

$$dn = 40\%\ AW \quad (5)$$

$$Iv = \frac{dn}{ETc} \quad (6)$$

$$Vdp = Kc \times ETo \times Ap \quad (7)$$

$$Vday = Vdp \times NP \times Iv \quad (8)$$

In the provided equations: ETc represents the crop evapotranspiration in millimeters per day. Kc denotes the crop coefficient, which started at 0.3 during the initial stage. ETo signifies the reference evapotranspiration, which reached a peak value of 4.0 millimeters per day. DF stands for the depth of water required to bring the soil's moisture content to field capacity at the commencement of the experiment, amounting to 12.9 millimeters. ρb represents the soil's bulk density, which was 0.26 grams per cubic centimeter. ρw denotes the density of water, equal to 1.0 gram per cubic centimeter. FC stands for the soil's field capacity, noted at 52%. Θ represents the soil's moisture content before irrigation, measured at 24.5%. Db corresponds to the depth of the bucket, measuring 180 millimeters. Aw signifies the available water

content, calculated as 12.75 millimeters. WP stands for the wilting point, determined at 24.76%. F is a factor that ranges from 2.0 to 2.4, contingent upon the percentage of silt within the soil. For this study, F was set at 2.1, leading to a calculated wilting point of 24.76% when the field capacity (FC) stood at 52%. Iv represents the irrigation interval, which was three days. dn corresponds to the net depth of irrigation, totaling 5.1 millimeters. Vp denotes the volume of water required by plants based on the days of the irrigation interval and the number of plants stands per bucket, calculated as 2 liters per day. Ap stands for the area of the bucket in square meters. Np represents the number of popcorn plant stands within a single bucket, amounting to 2 stands.

3 RESULTS AND DISCUSSION

3.1 Effect of Magnetized Water on Crop Yield

Conducted within a transparent garden shed, the study involved the growth of popcorn seeds in buckets, encompassing four treatment groups: T1 (magnetized with eight round bar magnets), T2 (magnetized with six round bar magnets), T3 (magnetized with four round bar magnets), and T4 (control group utilizing ordinary water). Upon examination of the treatments, the total yield for T1 reached 703.61 grams, T2 yielded 595.43 grams, T3 produced 571.34 grams, while T4 (serving as the control) had an outcome of 371.14 grams. In terms of mean yield, T1 displayed an average of 70.36 grams, T2 recorded 59.54 grams, T3 had 59.54 grams, and T4 exhibited 37.11 grams. Upon further analysis, it became evident that treatment one (T1) attained the highest yield of 703.6 grams, with a mean value of 70.39 grams, surpassing T2, T3, and the control. Treatment two (T2) yielded 595.43 grams, with a mean value of 59.54 grams, again surpassing T3 and the control. Treatment three (T3) generated a yield of 571.34 grams, with a mean value of 57.13 grams, which was superior to the control's yield of 371.14 grams and mean value of 37.11 grams. The application of magnetized water resulted in higher popcorn seed yields compared to non-magnetized water. This effect was attributed to the enhanced absorption of water for evapotranspiration, accompanied by heightened nutrient availability for plant growth in plants irrigated with magnetized water. This outcome corroborates the findings of [21], who concluded that magnetic irrigation treatment amplified water absorption rates for evapotranspiration in tomato plants by 1.25 to 1.35 mm per day, fostering increased vegetative growth. Similar results were observed by [22] in their study of broad bean plants irrigated with magnetic water, showing significant yield improvements compared to normal tap water. Additionally, [21] reported on the elevated yield of chickpea attributed to resonance-like phenomena that heightened the internal energy of the seeds.

Table 1. Chemical properties of the soil

Parameter	Values	Units
Phosphorus	2.06	mg/l
K	2.8	mg/l
Ca	30	mg/l
Mg	40	mg/l
Mn	0.018	mg/l
PH	7.97	
EC	28.5	Us/cm
TDS	19	mg/l
Fe	3.8	mg/l
CEC	72.8	meq/100g
Organic matter	4.56	%
Organic carbon	2.65	%
Nitrogen	0.64	%

Table 2. Soil and Plant Parameters

Parameters	Value
Popcorn (sea mays L everts) variety	Flint maize
Duration	Two months
Reference evapotranspiration, ETo mm/day	4.70mm/day
Crop coefficient, Kc.	0.3
Crop evapotranspiration, ETc mm/day.	1.14mm/day
Number of popcorns stand in a bucket after thinning.	2
Soil types used.	Loamy sandy
Soil moisture content (%)	24.50%
Soil bulk density (g/cm3).	0.26 g/cm3
Flow rate (L/s).	2.92 L/m
Soil field capacity (%).	52%
Soil wilting point (%).	24.76%
Available water for the plant (mm).	12.75 mm
Net depth of irrigation (mm)	5.1 mm
Irrigation interval. (days).	3 days
Depth of soil in the bucket	180 mm

Table 3. Popcorn yield for magnetized water and non-magnetized water

S/N	T1.	T2.	T3.	T4
1	63.10.	55.04.	61.27.	30. 21
2	68 14.	52.21.	54.30.	39 .41
3	70.03.	64.13.	56.44.	41.06
4	58.21.	50.28.	53.00.	37.19
5	72.75.	69.36.	49.51.	45.3
6	65.23.	66.07.	58.63	36.58
7	75.11.	59.44.	63.22.	34.71
8	87.10.	48.58.	70.17.	40.28
9	69.31.	71.61.	61.28.	33.6
10	74.62.	58.71.	43.52.	35.82
Total.	703.6.	595.43.	571.34.	374.14
Mean.	70.36	59.54.	57.13.	37.41

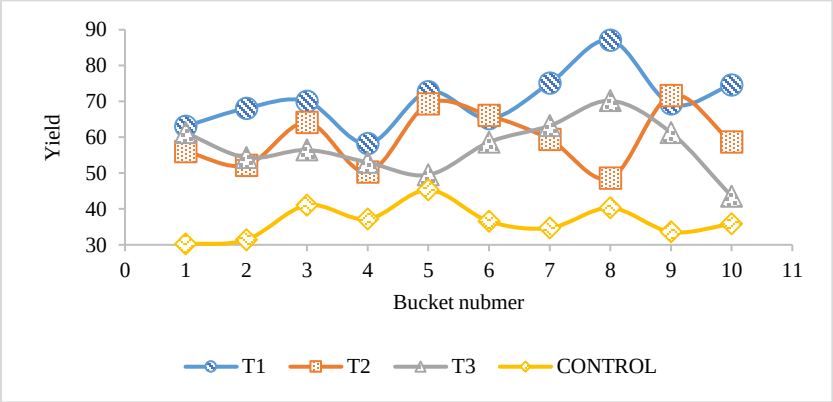

Figure 3. Chart of Popcorn yield for magnetized and non-magnetized water

3.2 Statistical Analysis of Yield for Popcorn Plant

The statistical evaluation conducted using a completely randomized design in Excel indicated that there was no notable significance among the factors under consideration when the F value from the table was 1.280414706 and the critical F value was 2.25013. However, a significant distinction among the

treatments was observed when the F value from the table was 41.61137602 and the critical F value was 2.96035. The results obtained from the ANOVA revealed significance across all treatments involving both magnetized and non-magnetized water.

Table 9. ANOVA Analysis

ANOVA							
Source of Variation	SS	df	MS	F	P-value	F crit	Significance test
Sample group Number	550.6022	9	61.17802	1.280415	0.29205	2.25013	factor not significant
Treatment	5964.627	3	1988.209	41.61188	2.90E-10	2.96035	factor is significant
Error	1290.056	27	47.77985				
Total	7805.285	39					

Table 10. Proximate Analysis Result (%)

S/N	Samples	CP (%)	EE. (%)	CF. (%)	ASH. (%)	MOISTURE (%)	NFE (%)
1	T1	13.33	16.28	1.25	1	10.75	57.18
2	T2	13.26	16.75	1.25	1	10.75	56.97
3	T3	12.32	15.67	1.5	0.5	11.25	58.94
4	T4	12.12	13.23	2.34	0.5	12.5	59.3

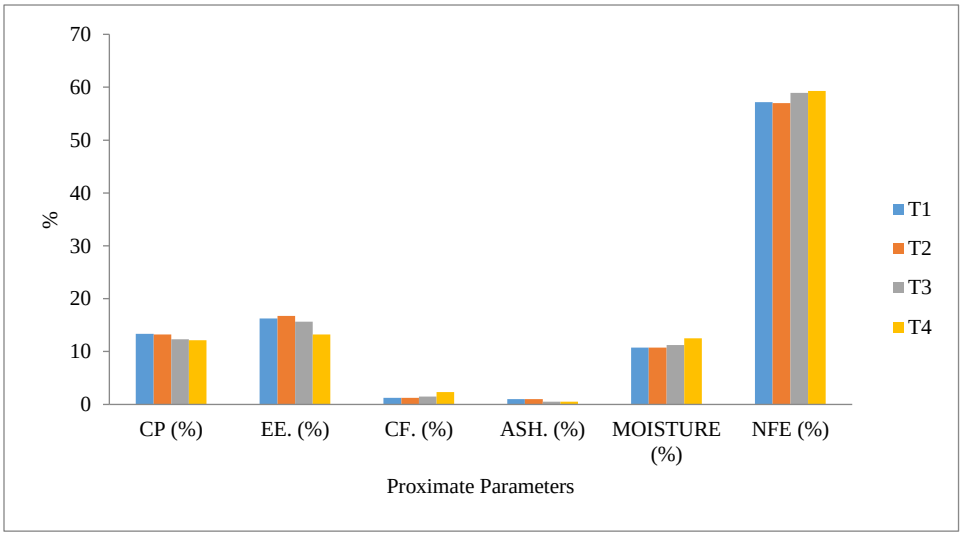

Figure 4. Proximate Analysis Chart

3.3 Effect of Magnetic Water on Nutritional Quality

Proximate analysis was employed to determine the nutritional composition, encompassing the major constituents of the feed, employing standard compositional parameters. The nutritional values assessed included crude protein, Ether Extract, crude fiber, ash content, moisture, and Nitrogen-free Extract. The mean values obtained from the proximate analysis table indicated the following results for different treatments: For crude protein, T1 displayed the highest value at 26.65%, surpassing T2, T3, and the T4 control, which had values of 26.56%, 24.64%, and 24.24%, respectively. Ether Extract showed T2 having the highest value at 16.75%, exceeding T1, T3, and the T4 control, with values of 16.28%, 15.67%, and 13.25% respectively. Crude fiber values were consistent across T1 (1.25%) and T2 (1.25%), while T3 and the T4 control exhibited values of 1.5% and 2.34%, respectively. Notably, the T4 control had the highest value. Ash content values for T1 and T2 were both 1.00%, whereas T3 and the T4 control showed values of 0.50%. This indicates that T1 and T2 had higher values compared to T3 and the T4 control. Moisture content revealed T4 control having the highest value of 12.5%, while T1 and T2 shared the same value of 10.75%, and T3 had a value of 11.25%. This suggests that the T4 control had the highest moisture

content. Nitrogen-free Extract showcased T4 control with the highest value at 59.30%, followed by T3 (58.94%), T2 (56.97%), and T1 (57.18%). The application of magnetically treated irrigation water had an impact on crude protein, Ether Extract, and ash content, resulting in higher values compared to the control. This outcome might be attributed to the nutrient absorption of popcorn seed plants irrigated with magnetically treated water, as previously indicated by [21, 22]. Conversely, non-magnetically treated irrigation water led to higher values for crude fiber, moisture, and Nitrogen-free Extract compared to magnetically treated irrigation water.

4 CONCLUSIONS

The utilization of magnetized irrigation water led to an augmentation in the popcorn seed yield. Additionally, the nutritional attributes of the popcorn seeds were enhanced by magnetized irrigation water, resulting in elevated proportions of crude protein, ether extract, and crude fiber when irrigated with magnetized water. In contrast, ash content, moisture levels, and nitrogen-free extract exhibited higher values when irrigated with non-magnetized water.

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