Effect of Magnetic Treatment of Irrigation Water on Growth and Yield of Maize under different Water Deficit Conditions

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Abstract- This study was conducted to determine the effect of magnetic treatment of irrigation water (MTW) on the growth and yield of maize under water deficit conditions. The maize was planted in a pot (2 stands per pot) in a transparent garden shed using Completely Randomized Design (CRD). A magnetic flux density of 443 gauss produced from electromagnet was used and measured inside the pipe using a gaussmeter Model GM-2 by Alpha Lab Inc. Water was allowed to flow through the magnetic field in a pipe for about 113 seconds. Four treatments used were 100 (2 litres at 100 %), 80, 60 and 50 % of water requirement labelled as T1, T2, T3 and T4 respectively and each treatment was replicated four times. A control experiment by non–magnetic treatment of water (NMTW) was also set up. The mean heights of maize plant with MTW at 29 days for T1, T2, T3 and T4 were 160, 184, 106, 103 mm while the yields after 86 days were 238.1, 281.6, 232.1 and 210.1 g/pot, respectively. The heights of maize plant with NMTW for T1, T2, T3 and T4 at 29 days were 124, 151, 91 and 90 mm while the yields after 86 days were 156.3, 209.6, 201.6 and 150.6 g/pot, respectively. The yield of maize from MTW compared to yield of maize from NMTW was statistically significant under the same water deficit condition by statistical pair t-test analysis.

Keywords- Deficit irrigation, Magnetic treatment of water, Magnetically treated water, Maize

1 INTRODUCTION

Water is indispensable for crop production. It is required for photosynthesis, transpiration and it acts as a solvent for plant nutrients present in the soil. Water is usually scarce during dry season for irrigation in Nigeria which makes crop production difficult during the season. Anand et al. (2012) pointed out that magnetic treatment of irrigation water could alleviate adverse effect of water stress in crop because it reduces free radicals production and antioxidant enzymes activity. Deficit irrigation is partial supply of water to crop especially at vegetative growth in order to reduce cost of water needed for irrigation to maximize profit. If water is partially supplied at flowering stage, the crop yield would be affected.

Magnetic treatment of water is a non-chemical method for agriculture and environmentally friendly that boosts crop yield, improves crop quality and increases water use efficiency (Selim, 2008; Maheswarli & Grewal, 2009; Babu, 2010; Hozayn & Abdul-Qados, 2010; Dhawi, 2014; El-Sayed & Sayed, 2014). When water flows through magnetic field at right angle to the field, the structure of the water is altered and reduction in surface tension of the water, increased minerals dissolubility of water and provide adequate nutrients for plant growth (Babu, 2010). Yusuf & Ogunlela (2017a) found out that magnetically treated water enhanced easy uptake of water for evapotranspiration by tomato plant which increased vegetative growth and yield of plant.

Some researchers pointed out that magnetic treatment of irrigation water could increase crop yield (Podlesny, Pietruszewski & Podleoeena, 2004; Moussa, 2011; Chern, 2012; Mohamed & Ebead, 2013). Moussa (2011) indicated that magnetically treated water which was treated with 300 G (0.003 T) improved yield and quality of common bean crop. Moussa (2011) stressed further that magnetic water could stimulate defense system, photosynthetic activity, and translocation efficiency of photoassimilates in common bean plants.

Noran et al. (1996) also pointed out that the interaction between soil particles and salts dissolved in ordinary water does not the same as the interaction between the soil particles and the salts dissolved in magnetically treated water. Magnetic fields can also influence the root growth of various plant species (Muraji, et al., 1992; Muraji, Asai & Tatebe, 1998). Kochmarsky (1996) indicated that the effective magnetic induction for water treatment ranging from 1,000 to 6,000 G and stated that 4,000 to 5,000 G could attain the efficiency of 60 to 80% when applied on heater and low-pressure boilers. Chern (2012) used permanent magnet with magnetic field strength of 5,500 G for treating water which was used to irrigate lady's finger moench plant (Okra) and the effect on plant growth and yield was statistically significant. The objectives of this study were to determine the effects of magnetic treatment of water and non magnetic treatment of water under different water deficit conditions on: (i) vegetative growth of maize plant; (ii) yield of maize and (iii) nutritional value of the maize.

2 MATERIALS AND METHODS

2.1 DESCRIPTION OF THE STUDY AREA

The study was carried out at the Demonstration farm of Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin, Kwara State, Nigeria. Ilorin lies on the latitude 8°30’N and longitude 4°35’E at an elevation of about 340 m above mean sea level (Ejeji & Adeniran, 2009). Ilorin is in the Southern Guinea Savannah Ecological zone of Nigeria with annual rainfall of about 1,300 mm. The wet season begins towards the end of March and ends in October while the dry season starts in November and ends in March (Ogunlela, 2001). The soil used was loamy sand taken from Demonstration farm of the Department of Agricultural and Biosystems Engineering, University of Ilorin. The soil was properly mixed together to have uniform soil fertility and then put into the 16 pots (16 buckets).

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2.2 MAGNETIC FIELD FOR TREATING THE WATER AND EXPERIMENTAL TREATMENTS FOR THE STUDY

Magnetic field used for the treatment of irrigation water in this study was produced from electromagnet. The electromagnetic device was developed using the readily available materials in Ilorin, Nigeria. The core of the electromagnet has 180 turns of coil with 2 cores facing each other which serves as permanent magnet as shown in Fig. 1 and Fig. 2. The mean magnetic flux density used in this study was 443 G measured inside the treatment pipe using a gaussmeter Model GM-2 by Alpha Lab Inc. The north and south poles of the electromagnetic cores on the treatment pipe were in alternate form for effective treatment of irrigation water by the magnetic field (Gabrielli et al., 2000 as cited by McMahon, 2009). The irrigation water was allowed to pass through the treatment pipe for duration of about 113 s.

The maize was planted in 16 buckets on 5th March, 2015, irrigated with MTW and a control experiment was set up adjacent to it inside the same transparent garden shed and irrigated with NMTW. The maize was harvested on 29th May, 2015. Four treatments used were 100 (T1), 80 (T2), 60 (T3) and 50 % (T4) of water requirement in order to subject the maize plant to different water deficit conditions and each treatment was replicated 4 times. The inside garden shed was warmer than the outside by 1°C with temperature varied from 24 to 40°C and relative humidity inside the garden shed varied from 50 to 60 % during the study.

![Fig. 1: Electromagnetic treatment device with a fan for cooling the unit](image)

![Fig. 2: Magnetically treated water from the electromagnet](image)

\[ E_{Tc} = K_c \times E_{T_o} \]  \hspace{1cm} (1)

\[ D_F = \frac{\rho_b}{\rho_w} \left( \frac{FC - \Theta_1}{100} \right) D_b \]  \hspace{1cm} (2)

\[ AW = \frac{\rho_b}{\rho_w} \left( \frac{FC - WP}{100} \right) D_b \]  \hspace{1cm} (3)

\[ WP = \frac{FC}{F} \]  \hspace{1cm} (4)

\[ d_n = P_n \times AW \]  \hspace{1cm} (5)

\[ I_v = \frac{d_n}{ET_c} \]  \hspace{1cm} (6)

\[ V_p = P_n \times A_p \times ET_c \]  \hspace{1cm} (7)

where \( E_{Tc} \) is the crop evapotranspiration (mm/day), \( K_c \) is the crop coefficient, \( E_{T_o} \) is the reference evapotranspiration (mm/day), \( D_b \) is the depth required to bring moisture content to field capacity at the beginning of the experiment (mm), \( \rho_b \) is soil bulk density (g/cm³), \( \rho_w \) is the density of water (g/cm³), FC is the field capacity of the soil (%), \( \Theta \) is the moisture content of the soil prior to irrigation (%), \( D_b \) is depth of the bucket (mm), AW is the available water (mm), WP is the wilting point (%), F is a factor ranging from 2.0 – 2.4 depending on the percentage of silt in the soil. The value of F used was 2.2 and wilting point was calculated to be 12.26 % when field capacity (FC) was 26.98 %. \( I_v \) is the irrigation interval (day), \( d_n \) is the net depth of irrigation (mm), \( V_p \) is the volume of water required by maize plant (litre/day), \( C_c \) is the crop canopy (%) and \( A_p \) is the area of the bucket (m²).

2.2 PAIRED T-TEST FOR THE MAIZE YIELD

The paired t-test was done to know if the yield of maize produced by magnetically treated water was statistically significant or not when compared to the yield of maize produced by untreated water.
by non-magnetically treated water. The difference between the two mean of the results was determined and then used to compute standard deviation, standard error and t-test value using equations (8), (9a) or (9b), (10) and (11) given by Montgomery, Runger & Hubele (1998),

\[ d = \sum_{n} d \]

\[ \delta = \sqrt{\frac{(d - \overline{d})^2}{n - 1}} \]

\[ \delta_{Er} = \frac{\delta}{\sqrt{n}} \]

\[ t_{cal} = \frac{d}{\delta_{Er}} \]

where \( \overline{d} \) is the mean of the difference from the data \( x_1 \) and \( x_2 \), \( \Sigma d \) is the summation of \( d \), \( n \) is the number of the treatments (observations), \( \delta \) is the standard deviation, \( \delta_{Er} \) is the standard error and \( t_{cal} \) is the calculated value of \( t \) which was compared with the Table value of \( t_{tab} \).

3 RESULTS AND DISCUSSION

3.1 VEGETATIVE GROWTH OF MAIZE PLANT

The results of this study showed that magnetically treated water (irrigation water treated by magnetic flux density of 443 G) had effect on vegetative growth of maize plant. The heights of maize plant measured during the vegetative growth for MTW and NMTW was shown in Table 1. The maize irrigated with MTW grew faster than the maize plant irrigated with NMTW. This was in agreement with the work done by some researchers that MTW increased vegetative growth (Babu, 2010; Moussa, 2011 & Dhawi, 2014). The pictures of the maize plant at flowering stage for both MTW and NMTW were shown in Fig. 3 and Fig.4.

Table 1. Mean heights of maize plant from the water stress experiment

| Date      | Days after planting | Treatment | T1 (mm) | T2 (mm) | T3 (mm) | T4 (mm) |
|-----------|---------------------|-----------|---------|---------|---------|---------|
| 02/4/2015 | 29                  | MTW       | 160     | 184     | 106     | 103     |
| 02/4/2015 | 29                  | NMTW      | 124     | 151     | 91      | 90      |
| 10/4/2015 | 37                  | MTW       | 208     | 250     | 135     | 160     |
| 10/4/2015 | 37                  | NMTW      | 181     | 231     | 143     | 131     |
| 17/4/2015 | 44                  | MTW       | 271     | 323     | 223     | 240     |
| 17/4/2015 | 44                  | NMTW      | 240     | 330     | 230     | 218     |
| 23/4/2015 | 50                  | MTW       | 350     | 373     | 285     | 320     |
| 23/4/2015 | 50                  | NMTW      | 318     | 385     | 290     | 295     |
| 05/5/2015 | 62                  | MTW       | 457     | 478     | 375     | 398     |
| 05/5/2015 | 62                  | NMTW      | 422     | 476     | 381     | 381     |
| 11/5/2015 | 68                  | MTW       | 495     | 524     | 412     | 430     |
| 11/5/2015 | 68                  | NMTW      | 469     | 520     | 410     | 412     |
| 16/5/2015 | 73                  | MTW       | 528     | 545     | 436     | 453     |
| 16/5/2015 | 73                  | NMTW      | 510     | 538     | 404     | 437     |

MTW = Magnetically treated water, NMTW = Non-Magnetically treated water, T1 = 100 % water requirement supplied, T2 = 80 %, T3 = 60 % and T4 = 50 %

3.2 YIELD OF MAIZE IN TRANSPARENT GARDEN SHED

The yields of the maize subjected to water stress (deficit irrigation) experiment for the treatments, T1, T2, T3 and T4 (100, 80, 60, and 50%) water requirements with MTW were 238.1, 281.6, 232.1, and 210.1 g/pot, respectively while the yields for NMTW were 156.8, 209.6, 201.6 and 150.6 g/pot, respectively as shown in the Table 2 and Fig. 5. The yield of maize was low for both MTW and NMTW probably because inside the garden shed was warmer than the natural open environment with relative humidity varied from 50 to 60% and this might not suitable for maize crop. The water requirement supplied at 80% gave the highest yield for both MTW and NMTW which might be the optimum water requirement by the maize. This could means that any increase or reduction in water supply to maize plant would affect the yield. The result revealed that magnetically treated water had a positive effect on maize plant and improved the yield under deficit irrigation (water stress or water shortage) as stated by Anand et al. (2012) that magnetic treatment of irrigation water alleviate adverse effect of water stress.
in crop because it reduces free radicals production and antioxidant enzymes activity. The quantity of water supplied at 100, 80, 60 and 50% of water requirement as the treatments were not statistically significant on the yield of maize because the calculated value of F for MTW was 0.41 while the Table value of F was 9.01 (Fcal = 0.41 < Ftab = 9.01) as shown in ANOVA Table 2. For NMTW, the calculated value of F was 0.85 and the value of F was 9.01 (Fcal = 0.85 < Ftab = 9.01) as shown in ANOVA Table 3 but the effect of water stress was more severe on the maize plant with NMTW than the maize plant irrigated by MTW from the values of Fcal obtained for MTW and NMTW. This means that maize was able to survive when the water requirement was reduced by 50% but there was a reduction in the yield of maize produced for both with MTW and NMTW which was statistically significant based on the quantity of water applied.

Moreover, the paired t-test statistical analysis was also used to compare the yield of maize produced by magnetically treated water to the yield of maize by non-magnetically treated water. The calculated value of t was 4.062 at α = 0.05 but for paired t-test, α = 0.05/2 = 0.025 while the table value of t was 3.182 (tcal. = 4.062 > ttab. = 3.182). This shows that, the effect of magnetically treated water was statistically significant on the yield of maize compared to yield of maize from non-magnetically treated water. The value of tTab was obtained from Montgomery et al. (1998). The result obtained in this study was in agreement with the work conducted by the previous researchers that MTW increased yield as shown in Figure 4 (Maheshwari and Grewal, 2009; Babu, 2010; Hozayn and Abdul–Qados, 2010; Dhawi, 2014 & Ogunlela, 2017b).

Table 2. Maize yield from magnetically treated water and non-magnetically treated water

| Row | Treatment | Yield of the maize irrigated with MTW and NMTW (g/pot) |
|-----|-----------|-----------------------------------------------------|
|     | T1        | T2        | T3        | T4        |
| 1   | MTW       | 39.40     | 58.50     | 74.50     | 65.60     |
|     | NMTW      | 37.30     | 45.90     | 64.30     | 50.90     |
| 2   | MTW       | 75.80     | 71.40     | 25.50     | 34.50     |
|     | NMTW      | 67.40     | 47.40     | 24.90     | 18.50     |
| 3   | MTW       | 45.70     | 101.30    | 77.60     | 83.80     |
|     | NMTW      | 18.70     | 74.80     | 79.10     | 43.70     |
| 4   | MTW       | 77.20     | 50.40     | 54.50     | 26.20     |
|     | NMTW      | 33.40     | 21.50     | 33.30     | 37.50     |
| Total| MTW       | 228.10    | 281.60    | 232.10    | 210.10    |
| Mean| MTW       | 156.30    | 209.60    | 201.60    | 150.60    |
| MTW, NMTW, T1, T2, T3, T4 are as previously defined in Table 1.

Table 3. ANOVA by CRD for the yield of maize in the water stress experiment with MTW

| SE | DF | Sum of square | Mean square | Cal. F | F Table at P ≤ 5 % |
|----|----|---------------|-------------|-------|-------------------|
| Treatment | 3 | 672.42 | 224.14 | 0.41 | 9.01 |
| Error | 12 | 7235.16 | 546.895 | | |
| Total | 15 | 6562.74 | | | |

SE = Source of error, DF = Degree of freedom

4 CONCLUSION

Magnetic treatment of irrigation water increased vegetative growth of maize plant and increased the yield of maize under the same deficit irrigation (water deficit condition) than the non–magnetically treated water. Magnetic flux density of 443 G inside the treatment pipe was appropriate for treating irrigation water and it
improved the carbohydrate and protein contents of the maize.

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