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Effects of Varying Levels of Irrigation on the Performance and Yield of Maize (*Zea Mays L*) in Selected Plots in Makurdi Metropolis, Benue State Nigeria

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Abstract

The paper examines the effects of varying levels of irrigation on the performance and yield of maize on a loamy sand soil of the Makurdi metropolis. The values of water parameters analyzed were within allowable limits for water used for irrigation. Computed irrigation stress levels (treatments) applied at 0%, 10%, 30%, and 50% were at 5days, 7days, 10days and 14days intervals respectively. Randomized Complete Block Design (RCBD) was adopted in the blocks which were 1m apart with the maize seeds planted at 60cm spacing. The results of the biophysical performance of the maize showed better performance in blocks kept at low stress levels, while those kept at high stress levels showed poor performance. The same trend of result was obtained in the mean yield of maize. The highest yield was 3394.44kg/ha in blocks with low stress levels and the lowest yield was 116.67kg/ha in blocks with high stress levels. The correlation, of the biophysical parameters with time using SPSS Software gave positive and linear result, while that between maize yield and irrigation stress levels gave negative correlation. ANOVA results showed that stress had significant ($p<0.05$) effect on the yield. Ducan Mean Separation was done. The results showed that the 10% irrigation stress level applied at 5days intervals performed best and are recommended as the economic irrigation stress level.

Keywords: Irrigation stress levels; irrigation intervals; maize; performance; yield

Introduction

Expensive supply of available water makes it very difficult to irrigate the entire irrigable land in an area. Therefore, farmers have to decide between fully irrigating a farm land which uncontrollably leads to waste of water, money and decreasing crop yield or varying/limiting the amount to be applied to save water, money and to increase crop. This is because irrigation, according (Hudson, 1975) should curtail excessive application of water than needed, which could cause crop damage, soil erosion, excessive leaching, and wastage of water, labor and energy.

Most research projects on field data such as crop yield, different levels of water use and irrigation management practices like varying interval of irrigation refer to the effect of irrigation on maize yield using sprinkle, furrow and drip irrigation (Filintas, 2003).

Maize cultivation requires large quantities of water seasonally if it is to yield a large crop (Filintas, 2003). The maximum production by a variety of medium maturity of the seed oscillates from 500m^3 to 800m^3 (Doorenbos and Kassam, 1986). Maize has a high water and nutrient demand with the flowering stage being the most sensitive to water stress during which grain yield maybe reduced by decreasing grain number and kernel weight (Pandey *et al;* 2000). Danalatos, 1992;Dioudis*et al* 2008) have made an extensive study of irrigation in the cultivation of maize drew the same conclusion that irrigation is of the utmost importance from the appearance of the first silk strands until the milky stage in the maturation of the kernels on the cop. Maize is a crop which is irrigated world-wide (Musick*et al* 1990; Filintas, 2003), the main maize producing country being U.S.A. Maize constitutes a stable food for large population groups particularly in the developing countries (FAO and ILO, 1997).

Maize is an important cereal crop with a wider range of uses than other cereals (Olaniyan, 2015). Its demand is increasing day by day because of diverse uses, include human consumption, livestock feed formulation, pharmaceuticals, textile industries and bio-fuel (Ali *et al*, 2010). However, the production capacity of maize is not adequate to meet the utilization demand. Therefore to meet increasing demands greater efforts should be taken under different environmental conditions (Karasu *et al,* 2015).

Maize is a necessary crop which is use as food, fodder, fuel, as well as in the manufacture of industrial products. Furthermore, oil of maize is also appropriate for human consumption due to the presence of unsaturated fatty acids. Among the abiotic factors, drought is one of the major environmental constrains, that limits the productivity of crops (Hossain *et al,* 2013; Hassan *et al*., 2016), through changing the growth, physiology and metabolism of plants (Lunde *et al.*, 2007; Islam *et al.*, 2011). Drought stress is a major constraint to agricultural production in many developing countries of arid and semi-arid regions of the world (Golbashy *et al*., 2010).

Material and Method

The study site was a 9m × 15m plot of land within Makurdi Metropolis, Benue State of Nigeria. Particle size analysis was done following the procedure of Lambe, (1951). The water sample used for irrigating the plots was analyzed at Benue State Water Board Central Laboratory. The physical soil parameters analyzed were Particle size analysis, Textural class, Hydraulic conductivity, Bulk density, Moisture content, and Infiltration rate, while the chemical soil parameters analyzed were PH, Organic carbon, Organic matter, Nitrogen, and Exchangeable cations (Ca, Mg, K, Na). The physical water parameters analyzed were Electrical conductivity, Suspended solids, Total dissolved solids, Total solids and Caliform count, while the chemical water parameters analyzed were PH, Nitrates, Sodium, Boron, Residual sodium carbonate, Hardness, Calcium, Nitrogen, Phosphate, Dissolved oxygen, Biochemical oxygen demand, and Carbon oxygen demand.

Basin irrigation was chosen because according to Larry, (1988), this type of irrigation is suitable for crops like Cotton, Grains, Orchards, and Pasture and that Maize can be successfully irrigated on soil with moderately high to high infiltration rate. The level of irrigation (how much water to apply), irrigation interval and net amount of water that was applied to bring the soil moisture back to the respective field capacity at the various stress levels were computed using the Soil Moisture Field Studies Method and the Irrigation Requirement Equation (Isrealson and Hansen, 1962).

The field was laid out into four equal blocks of 3m × 1.5m with a distance of 1m between each bock. The four irrigation stresses representing the treatment were 0%, 10%, 30%, and 50%, while the irrigation intervals were 5days, 7days, 10days and 14days respectively. The blocks were replicated four times. Randomized Complete Block Design (RCBD) was used to analyze the data for the performance and yield of Maize. Two maize seeds were planted per hole at a distance of 60cm spacing in the blocks. Organic manure, NPK and Urea fertilizer were applied to the soil uniformly to improve its fertility. At the commencement of stressing, four weeks after planting, one promising maize plant was per block representing each irrigation levels was identified and marked by tying a loose string around it in each of the blocks.

Crop performance parameters determined were plant height, leaf length and leaf width, measured at an interval of one week. This evaluation was done four weeks after planting when the roots were firmly established in the soil and could withstand stress levels and irrigation intervals. The data collection starts the fifth week after planting and ends the tenth week when the crop is matured. The cops were de-husked and dried properly before weighing.

The SPSS software package was used to carry out the analysis of variance (ANOVA) on the irrigation levels and the results of the maize yield. Correlation between irrigation levels and maize yield, and between plant height, leaf length and leaf width with time in each irrigation stress levels were determined.

Results and Discussion

Table 1, the analysis of the water sample showed that the value of PH, Phosphate, Nitrate, Total dissolved solids, Biochemical oxygen demand, Chemical oxygen demand and Suspended solids are within the allowable limits for water use for irrigation (Ministry of Water and Irrigation, Jordan 2006).

Table 1: Values of Water Parameters Analyzed

.			Acceptable values of irrigation water.Parameter for comparison	
S/No	Water parameter	Value obtained	FAO 1985	Ministry of water and irrigation .Jordan 2006
	A Physical			
1	Electrical conductivity(EC)	78.4µs/cm	0.7 – 3	NA
2	Suspended solid(SS)	36mg/L	NA	NA
3	Total dissolved solids(TDS)	31.8mg/L	450	500
4	Total solids(TS)	67.8mg/L	2000	50 - 150
5	Total coliform count(TCC) per ml of water	1600mg/L	1(max)	100 -1000
B Chemical				
6	pH	6.82		6 - 9
7	Nitrate	38.6mg/L	6.5 – 8.4	30 - 45
8	Boron(B)	2.60mg/L	50	NA
9	Sodium(NA)	48.60mg/L	NA	NA
10	Residual sodium carbonate($NaCo_3$)	16.0mg/L	NA	NA
11	Hardness	80.0mg/L	NA	NA
12	Calcium(Ca)	60.0mg/L	NA	NA
13	Magnesium(Mg)	20 mg/L	NA	30
14	Phosphate(P)	26 mg/L	NA	NA
15	Chemical oxygen demand(COD)	152 mg/L	65	100 - 500
16	Biochemical oxygen demand(BOD)	76 mg/L	< 100	30 - 300
17	Dissolved oxygen(DO)	5.7 mg/L day 1	NA	NA
18	Dissolved oxygen(DO)	4.5 mg/L day 5	NA	NA

NA = Not Applicable

Particle size analysis showed that the soil consists of 85.5% sand, 7% clay, 7% silt and the textural class is loamy sand (Table 2). The Chemical soil parameters show that the soil is poor in fertility because of the low values of Organic matter, Phosphorous, Nitrogen and Potassium. The Organic matter content of the soil was 0.14% which was in agreement with Morgan, (2001) that Sandy loam soil should have Organic matter content less than 2%.The infiltration capacity of the soil was 2.40cm/hr which was improved with the help of the Organic manure.

The irrigation interval for every 5 days in blocks subjected to 0% stress level and every 7 days in blocks subjected to 10% stress level recorded a greater and better grain yield than that of 10days and 14 days in blocks subjected to 30% and 50% stress levels respectively. The superiority of 5 days and 7 days over 10 days and 14 days frequency could be attributed to the fact that frequent irrigation would provide enough moisture in the layer of the soil in which the plant root exist, thus resulting to better crop nourishment and consequently higher yield. Water deficit affects the number of seed/cops thereby compounding the effects of final grain yield as reported by Ahmed and El Hag, (1999), and Ahmed (2002). They stated that prolonging irrigation intervals decreased plant's grain yield and grain yield per hectare. The 10% irrigation stress level (10725Kg/m^2) showed the most economical irrigation level from among other levels tested to irrigate the maize crop on the loamy sand soil.

Table 2: Values of Soil Parameters Analyzed

S/No.	Soil Parameters	Values/Unit
A	**Physical Characteristic**	
1	Percentage sand(sample from 0 – 90 cm depth)	85.52%
2	“ Silt “	7.28%
3	“ Clay “	7.20%
4	Textural class	Loam soil
5	Field capacity(F.C) moisture	17.39%(dry basis)
6	Wilting point(W.P)	8.70%(dry basis)
7	Available soil moisture(ASM)	8.70%
8	Bulk density(BD)	1.64g/cm^3
9	Infiltration capacity	2.40cm/hr
B	**Chemical Characteristic**	
10	pH	6.25
11	Organic carbon	0.08%
12	Organic matter	0.14%
13	Nitrogen	0.07
14	Phosphorus(P)	2.50ppm
15	Calcium(Ca)	2.81mg/L
16	Magnesium(Mg)	1.40 mg/L
17	Potassium(K)	0.20 mg/L
18	Sodium(Na)	0.62mg/L
19	Cation exchange capacity(CEC)	6.0

The mean weight (yield) of maize in grams was correlated with the varying irrigation levels show a very strong but negative correlation. This implies that as the stress level increases the yield of maize decreases (Fig. 1).The line graphs of maize height, leaf length and leaf width with time showed a perfectly positive linear correlation between both variables (Fig. 2).

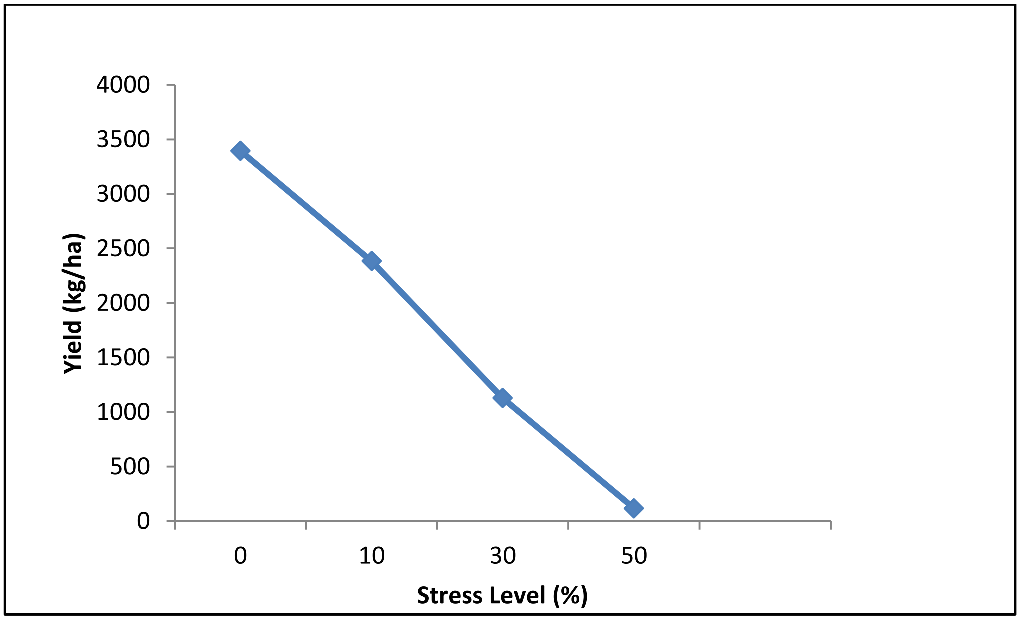

Figure 1: Graph of irrigation stress levels (%) with yield of maize in (grams).

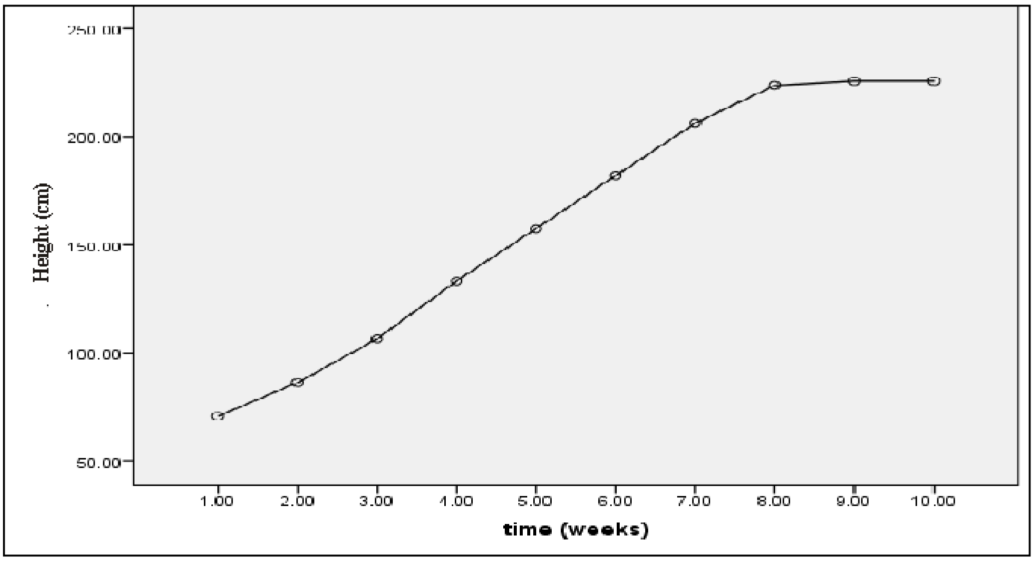

Figure 2: Graph correlation of Maize height (cm) with time (Weeks) for 0% irrigation stress level

The ANOVA results showed that stress levels had significant effect ($p < 0.05$) on the yield of maize, and as such Ducan means separation was used to separate the means. The mean yield of maize ranged from 116.67Kg/ha at 50% stress level to 3394.44Kg/ha at 0% stress level which is agreement with Ahmed and El Hag (1999) who reported that prolong irrigation intervals decreases plant grain yield and grain yield per hectare.

Conclusion

The study revealed that stress has a detrimental effect on the performance and yield of maize. The lower stress levels recorded a better performance in terms of maize height, leaf length, and leave width with time. The superiority of lower stress levels could be attributed to the fact that frequent irrigation would provide enough moisture in the layer of the soil in which the plant root exist, thus resulting to better crop nourishment and consequently higher yield. The mean weight (yield) of maize in correlation with the irrigation levels showed that, as stress levels increase the yield of maize decreases. The 10% irrigation stress level ($10725Kg/m^2$) showed the most economical irrigation level from among other levels tested to irrigate the maize crop on the loamy sand soil. Further study is recommended on different soil types and stress levels. This will help compare the effects that would be observed for optimal production of maize. Further research could be carried out with the same moisture stress levels using other crops. This will help to select the crops which best suit the moisture stress condition.

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