DETERMINATION OF OPTIMUM WATER REQUIREMENT FOR MAIZE PRODUCTION UNDER BASIN IRRIGATION SYSTEM AT LAKE GERIYO IRRIGATION PROJECT YOLA, ADAMAWA STATE NORTHEASTERN NIGERIA

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Abstract: Maize constitutes one of the most widely consumed food sources in northern Nigeria. Water requirement is a key parameter in obtaining maximum yield for maize. The study aimed at determining the optimum water requirement of maize under basin irrigation system at Geriyo irrigation scheme. Six different amounts of water (30, 45, 60, 75, 90 and 105 mm) designated as A, B, C, D, E and F was applied to six different basins of the same size of 3× 3 m. Maize (*Zea mays*) hybrid variety (Azam) was used as a trial crop. It was replicated three times in a randomized complete block design. Irrigation interval of seven days was used throughout the period. Three plots were established according to the slope variation of the land with each unit having a different land slope. Double ring infiltrometer was used to determine the infiltration rate of the plots and the value of 48 mm/hr obtained indicated that the soil in Geriyo irrigation scheme is suitable for irrigation due to its moderate intake rate couple with the soil textural classification which is found to be Silt-clay-loam. The rooting depth of the maize was found to be 1.65 m. The optimum water requirement for the crop under study was obtained to be 510 mm/total growing period, which gave the maximum yield of 2.36 t/ha (Treatments C). Peak evapotranspiration of 80.99 mm/week was obtained in treatment C indicating a fairly good result. The lowest yield of 1.64 t/ha was obtained in treatment E. An average yield of 1.88 t/ha was obtained for all the treatments. Irrigation water cost of ₦6,350 per hectare per season ₦529.20 per hectare per irrigation) was obtained for treatment C which was moderate as such more economical since maximum yield, highest income and profit were obtained. Thus, treatment C with an optimum water requirement of 510 mm/total growing period is the most suitable and appropriate amount of water to be applied for maximum crop yield, self-sustenance and profit making in basin irrigation system using 3 x 3 m basin sizes. Similar study is also recommended for other crops in the irrigation schemes.

Keywords: Water requirement; maize; basin irrigation; Lake Geriyo; infiltration, treatment

Introduction

Maize (*Zea mays* L.) is grown in some various environments, and is a basic food grain in many areas and several cultures across the globe (Huang *et al.*, 2006). Maize constitutes one of the most widely consumed food sources and a basic raw material for feed mill and beverage industries in northern Nigeria. Its sustainable production promotes adequate food supply; job opportunities, increased family income and foreign exchanges (Tekwa and Bwade, 2011). Optimum water requirement is the quantity of water needed by a crop for normal growth regardless of its supply source for a given period of time under field condition(Arora, 2004). Under normal conditions, four to seven irrigations are recommended for optimum maize production (Su *et al.*, 2002; Mao *et al.*, 2003; Chuanyan and Zhongren, 2007). Climate is one of the main environmental determinants influencing crop yields, and could be used to estimate maize water requirement (Ezekial *et al.*, 2015). FAO (1992) stated that of the water supplied for irrigation are not effectively used for crop production. The estimates of Maize water requirement are essential in order to curtail excessive application of water, which could cause crop damage, poor trafficability, soil erosion, excessive leaching and the wastage of water, labor and energy. Arora (2004) stated that adequate water supply could influence an average maize yield of up to 4,000 kg per hectare in most tropical environments. This estimate could drop to as low as 1400 kg per hectare or lower when grown under inadequate water supply. Tya and Othman (2014) reported that minimum and maximum cultivated plots of 0.2 hectares were used by majority of the small-scale farmers in Nigeria. A wide variety of crops such as carrot, tomatoes, maize, sorghums were grown in the irrigated Fadama.

Full season hybrid variety maize was used in the research area because it can resist heat and moisture stress, it can respond to a break in the weather and also because of its high demand. It is one of the most staple food crops in Nigeria and is mostly cultivated in the Northern part of the country especially the research area. It constitutes an important source of carbohydrates, vitamin and minerals (Ishaku *et al.*, 2016). It is also a food crop for most Sub-Saharan Africans of which Nigeria is inclusive with per capital consumption of 40 kg/year (FAO, 2003). In Nigeria Maize is the third most important cereal crop after sorghum and millet (Ojo, 2000). Its production is quite common in all part of the country. The production of this crop is indeed poverty reduction tools in the country; for example, the annual requirements for maize has been estimated at about 14 million MT while the current production is about 7.7 million MT, which indicated a huge production shortfall of about 6.3 million MT (FAO, 2003). Irrigation farming in Nigeria particularly in the low-lying land near rivers, streams and ponds usually called "Fadama" has been in existence for centuries, but the proper utilization of the available water to boost crop yield has not been attained (Tya and Othman, 2014). An estimated area of two million hectares of Fadama soil along the country's water network has been identified as suitable for small-scale irrigation in Nigeria, half of which can easily be exploited.

Materials and Methods

The study area

The study area is located 2 km North of Jimeta metropolis, Yola, Adamawa State, within the savannah ecological zone of Nigeria (Fig. 1). The location lies between 9°17′ to 9°19"N and longitude 12°24′30" to 12°28′30"E with altitude range of 150-180 m above the mean sea level (Ankidawa *et al.*, 2015). The area has two major seasons; the rainy and the dry season. The rainy season lasts from the beginning of May to the end of October with annual rainfall of 958.99 mm, while the dry season lasts mainly from November to the end of April (Ankidawa, 2014). The driest months are January to April when the average minimum relative humidity is 13%. This is mainly due to the prevalent dry and desiccating north-east trade winds. The dry season is favorable for cultivation of many crops under irrigation since there is no rainfall during the period. The wettest months are August and September when depth of rainfall reaches up to 25% of total annual rainfall. The relative humidity in the area varies: the hottest month is April with monthly average maximum temperature of 39.7℃, while the coldest months are December and January with minimum average temperature of 16℃ (Ankidawa, 2015b).

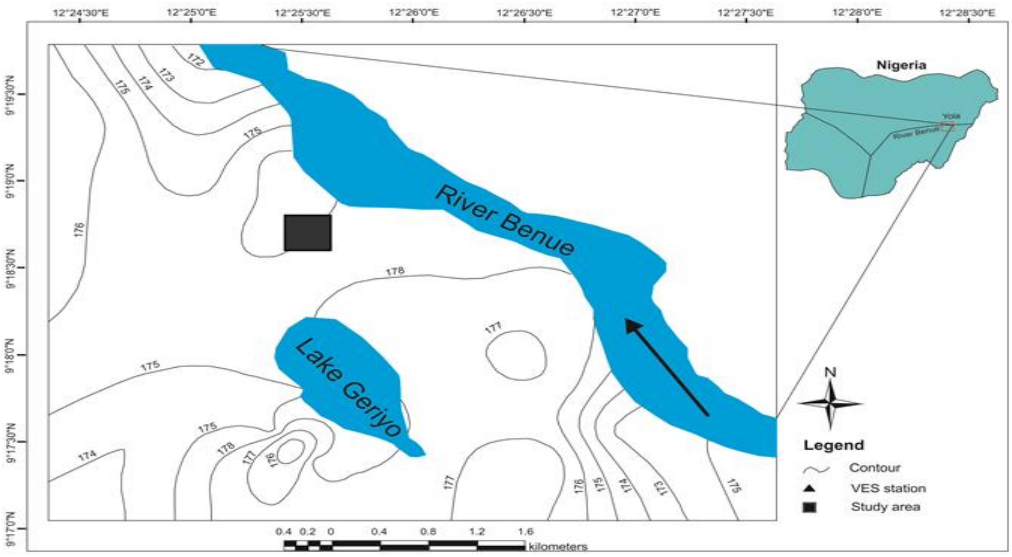

Fig. 1: Topographic map showing the study area (Ankidawa *et al.*, 2015)

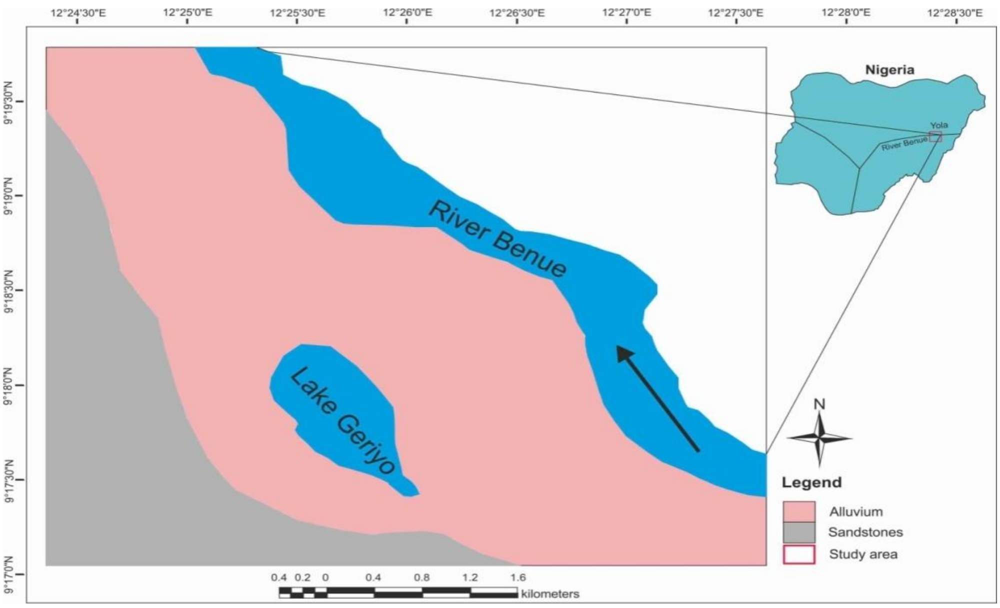

Figure 2: Geology of the study area (Ankidawa, 2015b)

Geology of the study area

The study area is underlain entirely by cretaceous and quaternary sedimentary deposits (Fig. 2). The Bima sandstone belongs to the cretaceous while the River Alluvium belongs to the Quaternary geologic period. The Bima sandstone is the oldest formation in the Upper Benue Trough and overlies the Basement Complex (Ishaku *et al.*, 2011; Ishaku *et al.*, 2003). The detail descriptions of Bima sandstone was provided by Carter *et al.* (1963). The Bima sandstone was derived from a granitic terrain (Carter *et al.*, 1963). Lithologically, the Bima sandstone consists of fildspathic sandstone, grits, pebbly beds and clays (Offodile, 1992). The Bima sandstone occurs in the southwestern and northwestern parts of the study area. The River Alluvium (recent) belongs to the quaternary age and is found along the main course of the River Dadin Kowa and consists more than half of the area (Fi. 2). It is composed of poorly sorted sands, clays, siltstone and pebbly sand (Ishaku and Ezeigbo, 2000; Yenika *et al.*, 2003). The research area is mainly silt-clay with alluvial soil found along the floodplain of River Benue. The estimated thickness of sediment in the area is 80 m depth (Ankidawa, 2015a). The soils are deep, with medium texture and have sandy loam or silt loam surface horizon. The soil is highly fertile and they are heavily cultivated through irrigation particularly during the dry season.

The field layout and experimental design

An experimental field plot of 0.108 ha sized with dimension 36 x 30 m was divided into three equal parts called plot units, and each plot unit was along the direction of predominant slope. The percentage slope of the plots was determined. The plot units were determined to be 1.7, 1.9 and 1.5% for plot unit one, two and three, respectively. Plot unit two was determined to be at the highest part. The plots were laid across the contours of the farm in order to have as much homogeneous soil as possible within and between the units. Each plot unit had an area of 0.0360 ha with dimension of 36 x 10 m which was further divided into three equal parts called blocks, along the direction of the predominant slope. The blocks, each with an area of 0.0119 ha with dimensions 36 x 3.3 m were divided into 12, 3 x 3 m basin sizes. Each block consisted of two treatments A; two treatments B; two treatments C; two treatments D; two treatment E; two treatments F. Though, each plot unit consist a total of six treatments. Randomized complete block design for a single factor experiment was used for the layout of the treatments within the three replications. Total area of land used for channels and levees was 0.0324 ha and the total land utilized in the study for the crop production was 0.0648 ha.

A double ring infiltrometer was used to measure the infiltration rate of the soil in the research area. The soil texture of the soil profile was determined using sieve analysis in accordance with the USDA Textural Classification. Digital Soil Moisture Meter with model number M0750 was used to determine the moisture content of the soil in the study area. The soil sample were taken at different depths of 150 to 750 mm using a soil sampling auger at six location randomized within the plot units and ensuring that each treatment is represented within each unit. The depth of water applied was calculated. The moisture content was usually taken before and two days after every irrigation.

Determination of irrigation stream size, advance and ponding time

A cut throat flume was used for this purpose. The flume was placed in a levelled channel. It was aligned straight with the channel longitudinally and laterally. A petrol engine pump was used to lift water from the hand drilled well to a delivery point located at a distance some meters from the pump. An earth stilling basin was constructed to store the water and maintain a constant flow rate in a 100 mm cut-throat metal flume as much as possible. The cut-throat metal flumes were installed at three different locations. One along the main canal, three meters away from the stilling basin. Another one along the distributing canal at the inlet of the plot. And the last one was installed at the inlet of the basin in the blocks. Stream sizes were determined using eq. 1 (Isrealsen and Hansen, 1980) for the three locations.

$$Qt = ad \qquad 1$$

where; Q = stream size, cm^3/s, t = time of irrigation, sec, a = area of basin, m^2, d = depth of irrigation, m.

The measurements were carried out on each irrigation day. Advance time for the water applied into the basins was measured using a stop watch and taken into consideration the time taken for the water to spread from the inlet to the end of the basin. This was done randomly, with good representation for each treatment. These measurements were taken on all irrigation days. When water was supplied to the basin, a stop watch was used to measure the time taken for the water to infiltrate into the soil from the soil surface, thus obtaining the ponding time. These measurements were taken on each irrigation day throughout the season.

Determination of crop evapotranspiration

The crop evapotranspiration of the study area was determined by using principle of the evaporation pan as used by Grismer *et al.* (2002). The E_{pan} is multiplied by a pan coefficient, K_{pan} and crop coefficient to obtain the ET_c.

$$ET_c = K_{pan} \text{ X } E_{pan} \text{ X } K_c \qquad 2$$

where ET_c = crop evapotranspiration, K_{pan}=pan coefficient, E_{pan} = pan evaporation, K_c = Crop coefficient

Cultivation of the maize crop

Maize seed (*Zea mays*), high breed variety obtained from Adamawa State Agricultural Development Programme was used during the research work. The crop was planted on the experimental plot at Lake Geriyo irrigation research farm on 2nd November, 2016. Water was applied to the farm before planting; this is to ease the planting and germination of the maize. It took about four days for the seed to germinate. Irrigation interval of seven days was used throughout the period of study. The number of irrigation applied throughout the period of study was twelve times. The first weeding and fertilizer application was done on the 16th November, 2016 at the rate of 50 kg/ha. And it was done manually. Thereafter another second weeding and application of fertilizer was done on 17th December, 2016 at the rate of 50kg/ha. Harvesting of the crop was done manually on the 15th February, 2017.

Experimental design and data analysis

The optimum water requirement for maize was studied using a randomized complete block design (RCBD) for six basins of the same size with different amount of water applied. Preliminary field data were processed using Excel word 2007 and the graphs were developed using MATLAB 2007. The data collected were also subjected to analysis of variance (ANOVA) at 5% level of significance.

Results and Discussion

Table 1 shows the textural class and the mean bulk density of the soil determined in the study area. From the table, the textural class of the soil in the study area was found to be silty-clay-loam, which indicates that the soil is suitable for maize production under basin irrigation system in Geriyo irrigation scheme because of its high water holding capacity. The mean bulk density of the soil was found to be 1.62 g/cm^3, these indicate that the soil is suitable for maize production.

Table 1: Soil textural classification and bulk density of the field

Depth of Soil (m)	% Sand	% Silt	% Clay	Mean Bulk Density (g/cm^3)	Textural Class)
0.00 - 0.15	20	45	35	1.6	Silty-clay-loam
0.15 - 0.30	18	44	38	1.64	Silty-clay-loam
0.30 - 0.45	19	42	39	1.6	Silty-clay-loam
0.45 - 0.60	16	43	41	1.63	Silty-clay-loam
0.60 - 0.75	18	40	42	1.61	Silty-clay-loam

Table 2: Soil moisture holding characteristics of the field

Depth of Soil (m)	Field Capacity (% by Weight)	Wilting Point (g/cm^3)	Mean Bulk Density (g/cm^3)	Available Moisture (mm)
0.00 - 0.15	27.30	13.5	1.60	21.7
0.15 - 0.30	26.20	13.8	1.64	19.7
0.30 - 0.45	29.00	16.0	1.60	20.8
0.45 - 0.60	29.35	16.2	1.63	18.1
0.60 - 0.75	28.70	16.0	1.61	22.6
Average	28.31	15.1	1.62	20.58

Table 2 gives the summary of the soil moisture holding characteristics in the study area. From the table, it was concluded that the mean field capacity, wilting point, and available moisture, were found to be 28.31%, 15.1 g/cm^3 and 20.58 mm, respectively. These indicate the suitability of the soil for maize production under basin irrigation system.

The performance of different water applied was based on the quantitative analyses. The parameters considered include; the amount of water applied, crop water used for maize, yield, production cost and net returns. Average maize yield for the various amounts of water in terms of how much water was utilized and revenue generated were determined and compared. All the parameters mentioned above were ranked among the six treatments and the optimum water requirement to produce the maximum crop yield was obtained. The most economic water charge for the various amount of water applied and the respective profits made were determined.

The application depth of 30, 45, 60, 75, 90 and 105 mm of water was applied to treatment A, B, C, D, E and F, respectively. Table 4 shows the water flow rates measured at three locations in 100 mm cut-throat flumes. The table shows that average flow rate decreases along the channel. At station 1, that is 3 m away from the constructed stilling basin (flow rate for plot 1), the average water flow rate was 6.06 l/s, at station 2, that is at unit inlet along the distributaries channel (flow rate for plot 2), the average flow rate was 4.96 l/s. At station 3, the flow rate decreases to 4.91 l/s as it moves along the channel being the basin inlet within the blocks (flow rate for plot 3): this is due to the seepage of water as it moves along the channels. The results on the analysis of the infiltration rate characteristics of the soil shows that the soil has a moderate intake rate, thus, stream size available were adequate. The little differences in the advance time could be due to slight variation in the slopes of the plot units. Table 6 shows the ponding times for the treatments. The table indicates that ponding times were almost the same within the plots units for the same treatments, but increases with increase in amounts of water applied for all the treatments in the plot units. The sum of advance time and the ponding time gives the total irrigation time. Table 3 shows the seasonal amount of water applied and the total time of irrigation for all the treatments. Here, it was observed that the time of irrigation varied with the amount of water applied for the stream size and the basin sizes used due to the increase in the amount of water applied leading to increase in ponding times. Thus, there is increase in the time of irrigation and fuel consumption as more water is applied.

Table 3: Flow rate measured at three stations

Irrigation Number	Measured flow rate (l/s)			Supply time	Elapsed time(hrs)
	Plot 1	Plot 2	Plot 3		
1	5.12	4.1	2.65	6am-9am	3
2	6.21	4.52	3.68	6am-9am	3
3	7.53	5.26	4.91	6am-9am	3
4	5.43	4.91	3.82	6am-9am	3
5	6.23	5.52	5.15	6am-9am	3
6	6.17	5.54	4.82	6am-9am	3
7	6.71	4.44	3.66	6am-9am	3
8	5.61	4.61	3.9	6am-9am	3
9	5.66	4.76	3.3	6am-9am	3
10	5.27	4.86	4.35	6am-9am	3
11	6.62	5.4	4.81	6am-9am	3
12	6.18	5.8	5.31	6am-9am	3
Average	6.06	4.96	4.19		3

Table 4 shows the values of the crops water used per treatment for the maize under study. The table shows that crop water used varied for all the treatments due to the differences in the amount of water applied and the soil texture. The amount of water applied was found to be higher than the water holding capacity of the soils. However, the moisture content of the soil taken two days after irrigation show that the moisture content was very close to the value of the field capacity. That is, the excess water was completely disposed of by deep percolation. Treatment F (719.59 mm) has the highest crop water use per growing season, followed by treatment E (646.72 mm), D (593.62 mm), C (510.38 mm), B (407.64 mm), A (343.61 mm) in that order, which were in line with the amount of water applied, respectively.

Table 4: Estimated results for the crop water use of maize in the research area

Treatments	Irrigation number												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
A	26.34	27.8	27.93	28.5	28.54	28.9	28.94	28.96	29.74	29.72	29.24	28.99	343.61
B	30.65	31.6	32.26	32.7	33.54	33.7	34.01	34.67	37.27	36.12	35.6	35.53	407.64
C	49.49	41.5	41.8	42	42.08	42.4	42.82	42.96	43.68	43.43	43.12	43.02	510.38
D	48.09	48.1	49.01	49.2	49.23	49.3	49.53	49.75	50.79	50.75	50.11	49.86	593.62
E	28.21	38.7	39.91	40.2	43.71	49.8	52.45	62.35	79.08	74.93	64.08	62.35	646.72
F	24.01	28	34.13	42.5	48.7	65.8	68.98	75.88	90.69	80.39	80.39	80.39	719.59

Table 5: Estimated crop evapotranspiration mm/day

Treatments	Irrigation Number												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
A	1.48	1.46	1.06	2.21	1.10	2.07	3.66	0.26	0.28	0.76	1.04	1.01	16.39
B	12.74	13.42	9.4	14.35	8.88	12.31	7.73	9.47	10.33	11.46	10.99	11.28	132.36
C	16.88	17.04	17.18	17.59	17,92	17.97	18.42	18.20	18.51	16.67	16.57	16.32	209.62
D	24.89	25.47	26.89	25.29	24.25	24.21	25.72	25.14	25.85	26.91	25.77	25.99	306.38
E	51.35	50.09	40.2	49.85	25.91	27.65	15.07	10.92	16.61	37.55	46.29	61.79	433.28
F	80.99	77.04	70.87	62.53	56.3	24.61	24.61	39.18	24.83	14.31	29.12	36.02	540.41

Table 5 shows that evapotranspiration values were low at the initial stage of the crop that is just after the crop germination. In treatment C, the values increase to a peak of 18.51 mm/week and then decreases at maturity to a value of 16 mm/day. This is mainly due to the fact that at the initial stage, the roots of the crop were not fully developed and in that case small water was used, but as the crop developed, the rate of water usage increases up to the peak and there after decreased at maturity, as crop did not require much water at that stage. The evapotranspiration value of 18.51 mm/day had a net water use of 510.38 mm/total growing period as obtained by Adeniran *et al.* (2010) which was found to be 416.10 mm and 504.56 mm/total growing season respectively. Similar trend was reported by Tya and Othman (2014) for Kadawa soils in Kano State. Similar trends were also reported by Dagdelen *et al.* (2006); Igbadun *et al.* (2006); Panday *et al.* (2000); Gulay and Mustafa (2008).

Table 6 shows the amount of land area used for each treatment with the percentage of relative land loss. Land loss through making field canals and levees constructions was estimated as a loss in income and additional production cost. This was done by quantifying and costing the expected maize yield from the stated loss of land. These losses were found to be the same for all the treatments since the same basin sizes were used for the experiment. It was observed that since the same basin sizes were used for the experiments, the same loss in income was estimated for each treatment.

Table 6: Percentage of land utilization for treatment

Treatments	Cultivated Area (ha)	Wasted Area (ha)	Percentage of Relative Land Loss (%)
A	0.0108	0.0054	5.56
B	0.0108	0.0054	5.56
C	0.0108	0.0054	5.56
D	0.0108	0.0054	5.56
E	0.0108	0.0054	5.56
F	0.0108	0.0054	5.56
Total	0.648	0.0324	33.36

Crop harvested was classified into marketable and non-marketable yields. The yields were measured with a weighing balance at the site immediately after harvest. Marketable yield implies those harvested crops that were obtained from the experimental farm and conveyed to the market with minimum damage and at the prevailing market price. Non marketable yield are those crops obtained from the experimental farms as damaged maize crops and/or those that could not be sold when taken to the market. Table 12 shows the average marketable yield for all the harvests for the treatments and plot units. The highest average marketable yield of 2.36 t/ha was obtained for all the treatments. This quantity was sold at a market price of one hundred and forty Naira (₦140) per kilogram giving the highest average revenue of forty-nine thousand eight hundred and forty Naira (₦49,840) per hectare or thirty-two thousand two hundred and ninety-six naira (₦32,296) for 0.0648 ha being the actual area used**.** The range of crop grain yield obtained in this study were similar with one reported by Lyocks *et al.* (2013) being 2.05 to 3.78 t/ha for Samaru, Zaria. Garba and Namo (2013) also reported grain yield of 3.88 and 3.49 t/ha of Saminaka (lowland) and Vom, which differ with this study. However, similar trend was also obtained by Sefer *et al.* (2011) who obtained grain yield from 1.93 to 10.4 t/ha under clay loam soil with the use of drip irrigation system in the Eastern Mediterranean climatic conditions of Turkey.

Table 7 presents the average maize yield, which is made up of marketable and non-marketable component. Total maize yield of 11.30 t/ha was obtained in the entire plot. Average maize yield of 1.71, 1.88, 2.36, 2.01, 1.64, and 1.70 t/ha were obtained for treatments A, B, C, D, E, and F, respectively. Treatment C gave the highest yield of 2.36 t/ha. This is followed by mean yield of treatments D (2.01 t/ha), B (1.88 t/ha), A (1.71 t/ha) and F (1.70 t/ha). Treatment E, had the lowest average yield of (1.64 t/ha). The differences in yield among the plot units may be due to soil water holding capacity of the soil that is, as a result of the high percentage of silt and clay size particles. When these mean yields were compared to the average amount of water applied, it shows that treatment C gave the optimum water use, followed by treatments D, B, A, F and E in that order. Thus treatment F had the highest water utilization, while treatment A had the lowest water utilization considering the yield obtained for the treatment.

Table 7: Maize yield distribution for treatments and plot unit (t/ha)

Treatments	Plots Units(s)			Mean
	1	2	3	
A	0.663	0.539	0.498	1.70
B	0.504	0.776	0.600	1.88
C	0.892	0.788	0.790	2.36
D	0.713	0.670	0.620	2.01
E	0.840	0.500	0.300	1.64
F	0.630	0.600	0.440	1.70

Table 8: Analysis of variance for maize yield distribution and treatment

Sources of Variation	DF	SS	MS	CF	Tabulated F (5%)
Replication	2	24.6853	12.3427	10.5855*	4.1
Treatment	5	26.0722	5.2144	4.472*	3.33
Error	10	11.6602	1.166		
Total	17	13.0471			

Plot unit 1 has the highest mean yield of 0 .707 t/ha, followed by the mean yield for plot unit 2 (0.645 t/ha) and plot unit 3 (0.541 t/ha). The differences in yield among the plot units may be due to slope variation and variation in irrigation in the plot units. The data obtained for maize yield from plot 1, 2 and 3 (Table 7) were subjected to statistical analysis. Since the F-calculated is greater than the F-tabular, it is concluded that there is a significant different between the maize yields of the treatment at 5% level of significant (Table 8). Similar trend was reported by Hamid *et al.* (2011); Tya and Othman (2014).

Table 9 shows the amounts of water used and the mean yield for the treatments. It indicates that crop yields increased with the amounts of water applied and thereafter, declined as more water was applied. Treatment C with 510.38 mm total amount of water consumed gave the highest average yield of 2.36 t/ha. This was followed by treatments D, C, B and F. Treatment E with 646.72 mm gave the lowest average yield of 1.64 t/ha. Fig. 6 gives the graph of the maize yield against the gross amount of water applied. The graph indicates that maize yield increases to maximum at an optimum amount of water applied and decreases from the maximum yield with further increase in the amount of water applied. This might be due to high deep percolation losses associated with high amount of water applied, thus leaching the required crop nutrients, resulting in yield reduction. The regression model equation and coefficient of determination r^2 (Fig. 3) are expressed as;

$$y = 1.042 + 5.074x - 52.72x^2 \qquad 3$$

where y is the yield, x is the water applied

The regression model equation is an expression predicting the yield y of maize when there is a change in the applied water x. while the r^2 of 85% indicates a high coefficient of determination.

Table 9: Crop water use and mean maize crop yield for treatments

Treatments	Water (mm)	Mean Maize Yield (t/ha)
A	343.61	1.71
B	407.64	1.88
C	510.38	2.36
D	593.64	2.01
E	646.72	1.64
F	719.59	1.70

Table 10 gives a total cost of production of crop under cover. This was obtained by summing the fixed cost and the Variable costs for all the treatments. However, it was also observed from the Table, that the total cost of production for treatment F was the highest, while the lowest was recorded in treatment A. These differences in cost of production among the treatments were due to varied amounts of water applied to the basins and irrigation labour.

Table 10: Total cost of production for all the treatments

Cost	Treatments (₦/ha)					
Depreciation	**A**	**B**	**C**	**D**	**E**	**F**
Fixed Cost	15,000	15,000	15,000	15,000	15,000	15,000
Variable Cost	38,010	38,410	38,560	38,690	38,700	38,705
Total	53,010	53,410	53,560	53,690	53,700	53,705
Gross Total						321,075

Table 11: Analysis of variance of water charge for treatments

Sources of Variation	DF	SS	MS	CF	Tabulated F (5%)
Replication	2	79899956	39949978	4.99*	4.1
Treatment	5	80444329	16088866	2.01^{ns}	3.33
Error	10	79900006	7990001		
Total	17	80444278			

Table 12: Overall performance for all treatments

Treatments	Yield (t/ha)	Water Charged (₦/ha)	Profit (₦/ha)	C/B
A	1.70	6,080	38,490	0.73
B	1.88	6,250	47,590	0.90
C	2.36	6,350	72,740	1.40
D	2.01	6,495	54,110	1.01
E	1.64	7,100	37,000	0.70
F	1.71	7,600	39,795	0.74

The assessment of the amounts of water applied considered based on the maize yield, gross income from maize sales, irrigation water charge, profit made and cost- benefit ratio for each treatment are provided in Table 12. A crop yield with an average of 1.70, 1.88, 2.36, 2.01, 1.64 and 1.71 t/ha were obtained for treatments A, B, C, D, E and F, respectively. It was observed that the difference between the treatment mean yields were very significant. Treatment C has the highest mean yield of 2.36 t/ha, followed by treatment D with a mean yield of 2.01 t/ha, then follow by treatment B with mean yield of 1.88 t/ha, then followed by F (01.71 t/ha), A (1.70 t/ha). The lowest mean yield of 1.64 /ha was obtained for treatment E. This may be due to these high percolation losses associated with large amount of water applied to the basins resulting in lower field.

Irrigation water costs of ₦6,080, ₦6,250, ₦6,350, ₦6,495, ₦7,100 and ₦7,600 per hectare were obtained for treatment A, B, C, D, E and F, respectively. Here, it can be observed that irrigation water costs increase with the amount of water applied to the basin. Treatment F gave the highest water charge of ₦7,600 per hectare, followed by water cost of treatment E, D, C and B. Treatment A had the least water cost of ₦6,080 per hectare. The mean profit made for treatments A, B, C, D, E and F were ₦38,490, ₦47,590, ₦72, 740, ₦54, 110, ₦37,000 and ₦39,795 per hectare, respectively. Here, it can be observed that treatment C gave the highest mean profit of ₦72,740 per hectare, followed by treatment D, B, F and A. the lowest mean profit of ₦37,000 per hectare was obtained from treatment E.

Figure 3 shows the relation of the irrigation water charge, net return and the amount of water applied. It was observed that profit realized was at the maximum at an optimum amount of water applied and then thereafter tends to decline with either decrease or increase in the amount of water applied. However, irrigation water charge increases with the amount of water applied to the basins. Also, from the figure it can be observed that, for optimum profit, water application of 510.38 mm/total growing period is required which is within the FAO standard, and water charged in the range of ₦6,080.00 to ₦8,500.00 per hectare is required. Beyond these ranges, farmers may not be able to pay for the amount of water applied. The amount of water applied will be too much such that it tends to reduce yield with high water charge which will result to low profit. However, for maximum profit the figure indicates that an optimum yield of 2.36 t/ha with optimum water application of 510.38 mm per hectare per season, with adequate water charge of ₦6,350 per hectare per season that is an average of ₦529.20 per hectare, per irrigation is required. This average irrigation water charge of ₦529.20 per hectare is close to the cost of hiring an irrigation water pump by farmers at the rate of ₦500 per hectare as reported by Tya and Othman (2014).

The cost/benefit ratios were determined as: 0.73, 0.90, 1.35, 1.01, 0.69 and 0.74 for treatments A, B, C, D, E and F, respectively. Treatment C had the highest cost benefit ratio of 1.35. This indicates that, the ratio is viable. Hence it has greater benefits than cost. It is then followed by treatment D, B, F, A and E. Table 12 indicate that cost-benefits ratios for the amount of water applied were low and that the ratios tend to rise with increase in the amount of water applied, which shows that smaller amount of water applied had better costs recovery than large amount of water applied. This confirms the relationships obtained on maize yield for the treatments.

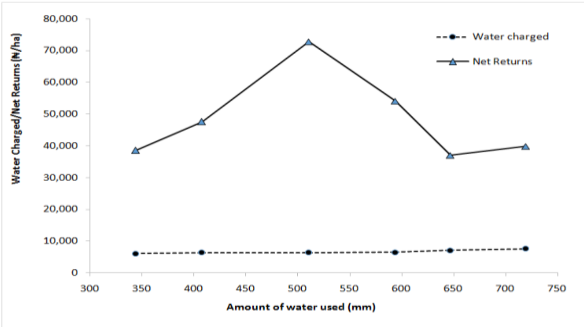

Fig. 3: The relation of water charge, net returns and the amount of water applied

Combining the performances of the treatments based on water requirement, crop yield, income, water charge and cost-benefit ratio, it was observed that treatment F which has the highest amount of water applied recorded the highest crop water use. Treatment C had the best performance in terms of crop yield and revenue generated, and it had the least cost-benefit ratio. Treatment E recorded the lowest yield, but had the highest cost- benefit ratio. Treatment A recorded the lowest performances in terms of water cost and labour utilization. Therefore, treatment C performed above average in terms of water requirement, economic evaluation and yield. Thus, treatment C with 510.38 mm average amount of water applied per growing season and irrigation water charge of ₦529.16 per hectare per growing season was selected as the most suitable and appropriate amount of water to be applied at the most economic water charge for maize production in a small scale irrigation farming in Geriyo irrigation project Yola, Adamawa State.

Conclusions

Maize yield and net returns increases with the amount of water applied up to a maximum of 510.36 mm/total growing period and thereafter decreased as more water was applied. Thus, crop yield, net returns and water charge were found to influence the amount of water applied. Peak consumptive use of 18.51 mm/day was obtained for treatment C. An optimum water requirement of 510.36/total growing mm is required to produce a maximum yield of 2.36 t/ha at an economic water charge of ₦6,350 per hectare per season that is ₦529.16 per hectare per irrigation which is adequate for farmers to adopt for effective crop production and profit making under small scale irrigation farming using a 3 × 3 m basin size. Average crop yield obtained ranged from 1.70 to 2.36 t/ha. Treatment C gave the highest crop yield and profit, while treatment E produced the lowest crop yield and lowest profit. Irrigation water charge varied from ₦6,080 to ₦7,600 per hectare among all the treatments. Therefore, treatment C had the best cost recovery among all the treatments.

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