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COMPARATIVE ANALYSIS OF PERFORMANCE OF IRRIGATION METHODS ON MAIZE PRODUCTIONIN MAIDUGURI, NIGERIA

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ABSTRACT

Rainfall in Maiduguri, Nigeria is extremely irregular to the extent that the amount and distribution in space and time has not been ideal to optimally support maize production. This necessitate irrigation to meet up with food demand for the growing population.This research was aimed to compare performance of different irrigation methods on the growth, yield and yield parameters and quality of maize kernelon sandy loam soils. The experiment consisted of furrow, drip, and sprinkler irrigation methods. Growth, yield and yield parameters of maize were recorded during the crop growth and development. Maize kernel quality, performance of irrigation systems used in terms of uniformity of water distribution, water savings and their irrigation efficiencies were evaluated. The result of the study revealed that the growth, yield and yield parameters were significantly affected by irrigation methods in both growing seasons with better performance from drip compared to sprinkler and furrow irrigation methods. The drip irrigation method has resulted in water savings of 17.31% and 31.75% when compared with sprinkler and furrow irrigation methods, respectively. The uniformity of water distribution was higher in the drip irrigation method with emission uniformity of 91.2% compared to a sprinkler with a coefficient of uniformity of 75% and furrow with distribution uniformity of 75%. The irrigation efficiencies of the drip, sprinkler and furrow irrigation methods used were 80%, 76% and 64%, respectively. Maize crops irrigated using the drip irrigation method had the highest contents of carbohydrates, ash and fibre of 73.04%, 2.40%, and 2.56%, respectively.The study revealed that the drip irrigation method is the most viable alternative in maize production for the semi-arid region environment of Nigeria for improved yield, higher water savings and higher maize kernel quality.

Keywords: Irrigation methods, maize production, yield, Maize kernel quality, irrigation performance, uniformity of distribution.

1. INTRODUCTION

Nigeria,themost populous nation with an estimated population of about 200 million is overwhelmingly dependent on agriculture, where more than 70% of its population is involved (Adeniji, 2002). The prosperity of agriculture provides the impetus to establishing or strengthening the industrial base of the country and thereby raising the overall prosperity of the nation. The majority of farmers in Nigeria, as in other developing countries, are at subsistence levels and hence cannot meet their food and fibre requirements. FA0 (2015) reported that food insecurity and poverty are still on the increase in many sub-Saharan countries, including Nigeria. The report revealed that the region recorded the highest prevalence of hunger compared to any other region with about 220 million hungry people between 2014 to 2015. The gap between the domestic food supply and demand in Nigeria is unfortunately on the increase. The Human Development Report by United Nations (Malik, 2014) shows that about 84.5% of the population of Nigeria lives below $2 per day. This economic condition is worse in rural areas. Efforts should therefore be geared to increase food production to meet the demand of the increasing population.

The climate of most parts of Borno state, Nigeria is predominantly arid or semi-arid.Irrigation, the highest contributorto increasing global food production, is one of the alternative solutions to the problem of food insecurity (Adeniji, 2002) since the rainfall in the area is low and erratic.Irrigation is an agricultural practice designed to supplement the water available from precipitation and the contribution to soil moisture from groundwater by providing the required quantity of water at the time needed to replenish soil moisture to the required level for optimum crop production (Zwart and Bastianssen, 2004; Hoffman *et al.*, 2007 and Nagy, 2008). Irrigation is therefore a risk management tool for agricultural production. Yields from irrigated land are higher and more consistent than the yields from rain-fedcrop production. Irrigation,therefore,plays a significant part in sustaining food production for the ever-increasing population.

The technique of replenishing the soil water deficit by applying irrigation water is referred to as an irrigation method (Drastig*et al*., 2016). Irrigation methods are broadly classified into the surface, sprinkler, trickle and subsurface irrigation based on the modes of water application and their associated overall efficiencies (Adeniji, 1992; Ali, 2011). Irrigation methods have specific applications that are based on several factors, among which the most relevant are the crop, soil type, topography and water availability and quality. The application efficiencies of the methods vary and depend on their design, management, and operation (Holzapfel *et al*., 2009).In the face of the dwindling availability of water resources in the 21st century (Turral*et al*., 2011), prudent use becomes inevitable.Irrigation methods are thus under pressure to increase productivity with declining water supply (FAO, 2011; Levidow*et al*., 2014).

Maize is commonly irrigated using the furrow irrigation method in the semi-arid region of Nigeria due to insufficient rainfall (Ahmad *et al*., 2000). But due to its low application efficiency of 54% (Aljamal*et al*., 2001), only 1.8 t/ha of maize is obtained compared to the world average of 5.3 and to 7.8 and 9.1 t/ha in Egypt and Mauritius, respectively (FAOSTAT, 2014). Bashir and Akande (2017) reported a wide gap in maize yield from the use of furrow irrigation compared to the drip irrigation method, with 2630 kg/ha from furrow irrigation compared to the yield of 5684kg/ha obtained from the drip irrigation method in the semi-arid region of Nigeria. Similarly, Usoh*et al*. (2017) reported a 36% drop in furrow-irrigated maize yield relative to those obtained using the drip irrigation method in Nigeria. In similar research, Kharrou*et al*. (2011) reported that furrow-irrigated wheat yield was 28% less relative to drip-irrigated wheat in the semi-arid region of Morocco. Erdem*et al.* (2006) also found a 40% drop in furrow-irrigated tuber yield relative to those obtained under drip irrigation. In terms of water use efficiency, furrow irrigation method has lower irrigation water use efficiency compared to the drip irrigation method as confirmed by the work of Ghamarnia*et al.* (2013) that reported a significant increase in maize irrigation water use efficiency of 1.29 kg/m^3 and water savings of 36% from drip irrigation method compared to irrigation water use efficiency of 0.99 kg/m^3 from furrow irrigation method. Similarly, Cetin and Bilget (2002) reported higher water use efficiency of 4.87kg/m^3 in drip irrigation compared to 3.87kg/m^3 in the furrow irrigation method. Yavuz *et al*. (2012) reported a 24% drop in irrigation water use efficiency under furrow irrigation relative to the drip irrigation method.

The focus of this study is to determine the proper and most economically viable irrigation methodfor optimum maize production to meet the increasing demand for food, livestock feeds and biofuel for the growing population.

2. MATERIALS AND METHODS

2.1 Study Location

Field experiments were carried out in the 2014 and 2015dry seasonsat the Teaching and Research Farm of Ramat Polytechnic Maiduguri, Borno State located at latitudes 11° 46'18"N to 11° 53' 21"N and longitudes 13° 03' 23"E to 13° 14' 19"E in the semi-arid region of NortheastNigeria.The meteorological data recorded during the period of the experiment showed that the maximum and minimum air temperatures were 42.2 to 43.5° C and 24.5 to 25° C, respectively. The relative humidity ranged from 22.3 to 44.3%. The wind speed and evaporation rate were 123 to 135 km/h and 10 mm, respectively.

2.2 Treatment and Experimental Design

The experiment consisted ofirrigation methods at three levels namely:furrow, sprinkler, and drip irrigation methods. The treatments were randomly assigned to plots and replicated 3 times in a randomized complete block design in plot sizes measuring 5 m by 3 m.The overall field layout for the experimental farm hasatotal area of 5500 m^2

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(0.55hectares). The area occupied by the drip and furrow-irrigated plots was1000 m^2 each, while the sprinkler-irrigated plots used an area of 3500 m^2 (0.35 hectares).The entire area was harrowed and the plots under the different irrigation methods were marked out.

2.3 Cultural Practice and Data Collection
Farm operations relevant to maize cultivation from land preparation to harvesting were strictly followed according to good agronomic practice. Collection of data was done at two, four, six, and eight weeks after planting. Growth and yield parameters recorded during the crop growth and development were the number of leaves per plant, leaf area index, stem girth, plant height, cob length, cob diameter, number of rows per cob, cob weight, number of seeds per row, the weight of seeds per cob, 1000 seeds weight and total yield per hectare using standard procedures.

2.4 Irrigation Methods Used

2.4.1 Drip Irrigation System
The system of irrigation used is the gravity drip irrigation system. The system consisted of a reservoir, mainline, laterals and drippers which were all made from plastic materials. The reservoir was raised to a height of 1m from the ground surface to provide water pressure for the flow of water by gravity. The average flow rate of the drippers was 0.43l/h. Each experimental plot was 15 m^2 with four (4) laterals of 5m length which were laid on the ridges at a spacing of 0.75m. Each lateral consisted of a control valve for regulating water application based on the different irrigation schedules used. The internal diameters of the mainline and laterals were 19 mm and 12.7 mm, respectively. The drippers were spaced at 0.5m along the laterals as shown in figure 1. The spacing of 0.75m and 0.5m were chosen based on the recommended spacing for growing maize.

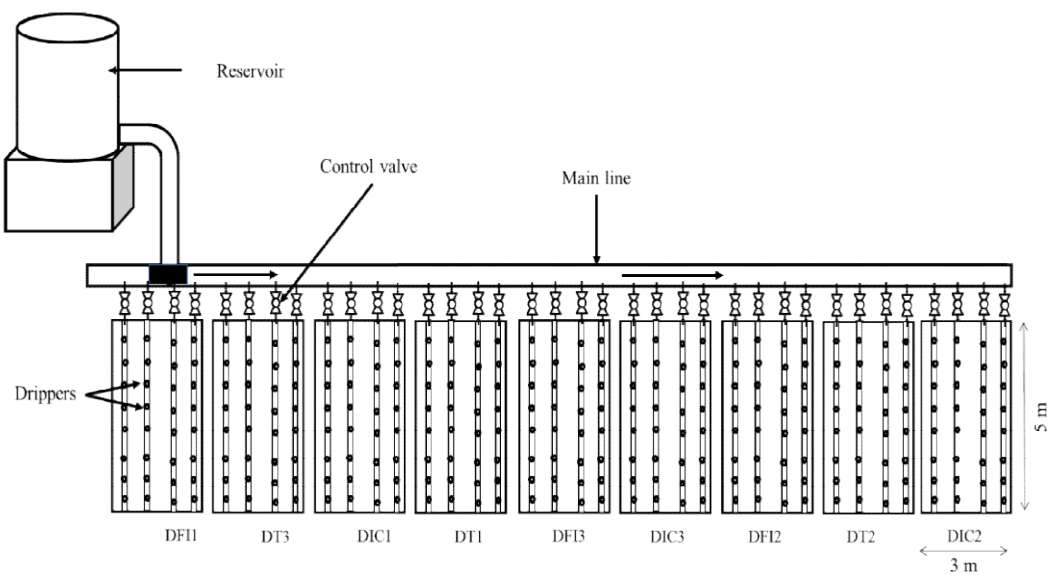

Figure 1: Field layout of Drip irrigation

2.4.2 Sprinkler Irrigation System
The sprinkler irrigation system used consisted of a reservoir, mainline and six laterals spaced 12 meters apart. Each treatment was irrigated using two laterals and each lateral has a control valve for regulating the flow of water. Each lateral consisted of three double nozzle sprinklers spaced 6 meters apart along the lateral. The laterals were provided with control valves for regulating irrigation based on the schedules. The diameters of the mainline and the laterals were 101.6 and 31.75mm, respectively as shown in figure 2. The area irrigated by the sprinkler system was cleared and marked out into plots of sizes 15 m^2.

3.4.3 Furrow Irrigation System
The field layout for the furrow irrigation used for the research is presented in figure 3. The field was harrowed, and ridges were constructed manually using a furrow opener at a spacing of 0.75m based on the recommended spacing for maize production in the region. A total of nine (9) experimental plots were marked out for the experiment. Each experimental plot was 15m^2 consisting of 4 ridges

5m long each. A ridge was used to separate a plot from the one adjacent to it. The lengths of the furrows were limited to 5m because of the size and shape of the experimental field as shown in figure 3 below.

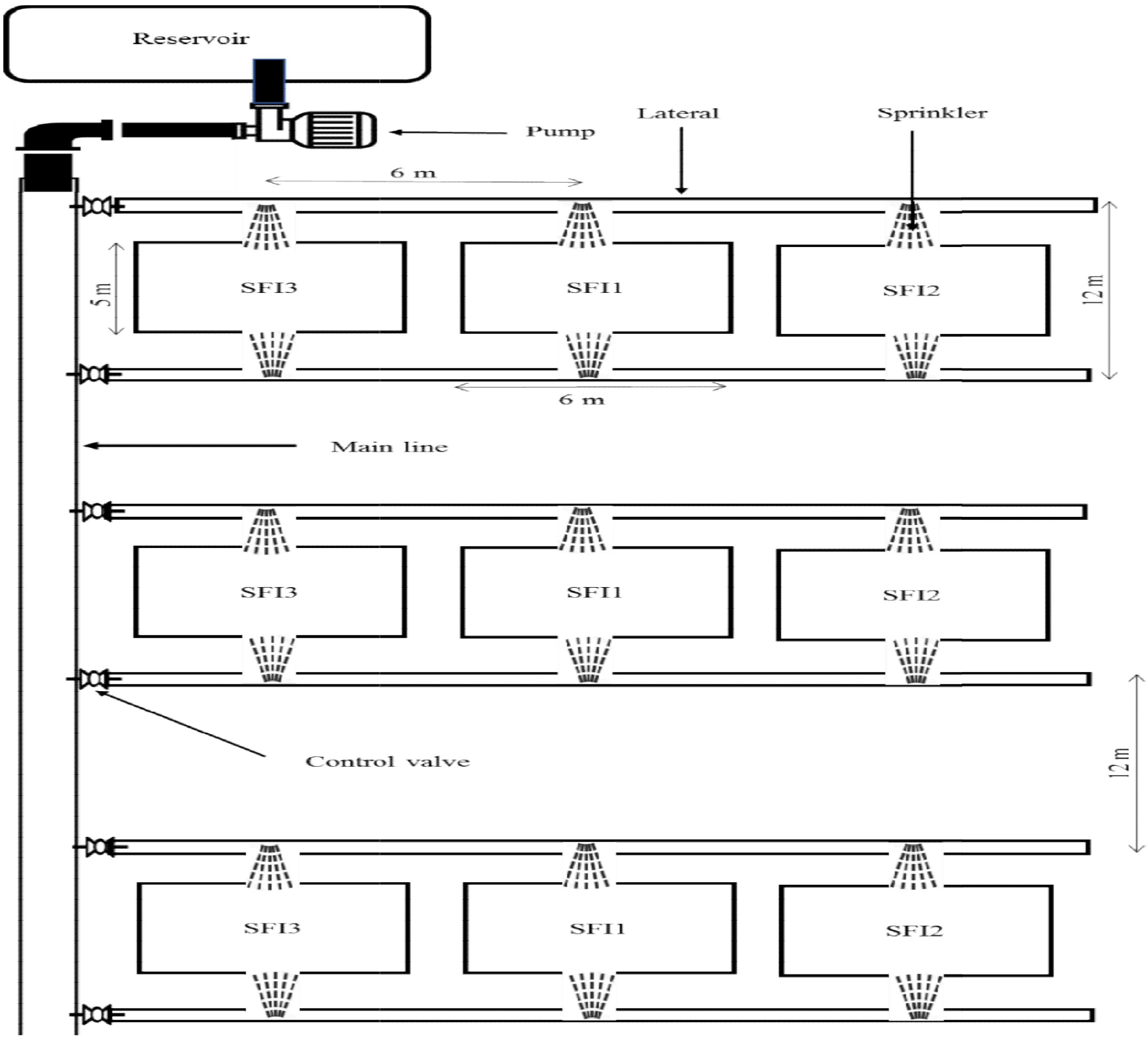

Figure 2: Sprinkler irrigation system layout

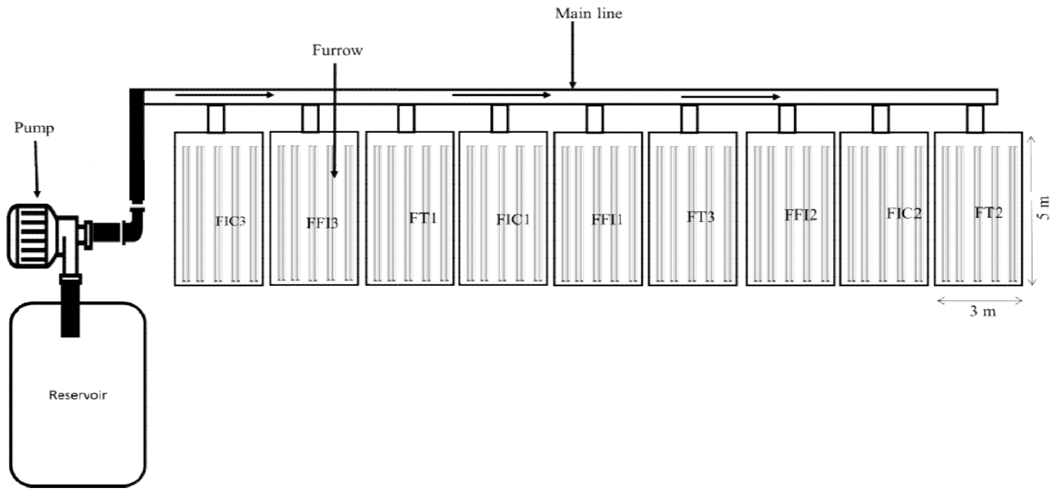

Figure 3. Field layout of furrow irrigation method

2.4.4 Measurement of Furrow Stream Size, and Application Ratesof Sprinkler and Drip Irrigation Systems

The size of the furrow stream was measured using a flume which estimated the discharge by measuring the loss of head caused by forcing a stream of water through a throat or converged section of the flume with a depression bottom. The discharge was obtained from equation 1.

$Q = \mathrm{CWh}^n$……………………………(1)

Where:
Q = discharge in l/s
W = width of the throat in cm
h = height of water in the convergent section in cm
n = exponential coefficient of discharge.

The application rate of the sprinkler and drip irrigation systems were determined by first calculating the flow rate of nozzles or emitters. The flow rate was calculated by collecting the flow of water from the nozzles or emitters in a container of known volume for a measured period.

$\text{Flow rate} = \frac{\text{vol of water in the container (l)}}{\text{time required to fill the container } (s)}$…………….(2)

$\text{Application rate} = \frac{Q}{S_L * S_M}$……………..(3)

Where:
Q = flow rate,
S_L= spacing of the sprinkler or emitter along the laterals
S_M= Spacing of the laterals along the main

2.4.5 Performance of Irrigation Methods
The performance of the irrigation methods was evaluated by determining the distribution uniformity of furrow irrigation, the coefficient of uniformity for sprinklers, emission uniformity for drip irrigation, and overall irrigation efficiency.

2.4.6 Furrow irrigation distribution uniformity
The distribution uniformity of the furrow irrigation method was evaluated using inflow and outflow measurements following the procedure used by Horst *et al.* (2005). This was done by determining the infiltration rate along a segment of the furrow lengths by taking the difference between the measured flow rate at the beginning and at the end of the segment using a flume measuring device. The distribution uniformity was then evaluated using the equation below:

$D_u = \frac{d_{zq}}{d_z} \times 100$………………………...(4)

Where:
D_u = distribution uniformity (%),
d_{zq}= average depth of water infiltrated in the low one-quarter of the field (cm)
d_z=average depth of water infiltrated over the field (cm).

2.4.7 Sprinkler coefficient of uniformity
The sprinkler coefficient of uniformity was evaluated using catch cans.Twenty-four (24) catch cans were placed in between the laterals in equal grid spacing on the field. The sprinkler system was operated for 30mins and the amount of water collected by each can was measured and recorded.

The coefficient of uniformity of water for the sprinkler system was computed using the Christiansen (1942) equation presented in equation 5 below:

$$C_u = \left[\frac{1-\sum(X_i - X_m)}{\sum X_i}\right] \times 100 \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where:
C_u = coefficient of uniformity (%)
X_i = depth of water collected in each of the equally spaced cans (mm)
X_m = mean depth of water collected in all the cans (mm)
$\sum$ = summation of all the measured depths

2.4.8 Drip emission uniformity
The emission uniformity for drip irrigation was evaluated based on emitter discharges using the mathematical equation used by Keller and Karmali (1974),Heermann*et al*. (1990), Irmak *et al*. (2011) and Tagar*et al*. (2012) expressed in equations6, 7 and 8.

$$E_u = 100 \left[1.0 - 1.27 \frac{C_v}{n^{1/2}}\right] \frac{q_{\min}}{q_{av}} \ldots\ldots(6)$$

$$C_v = \frac{\delta}{q_{av}} \text{ x } 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

$$\delta = \sqrt{\frac{\sum_{i=1}^{n}(q_i - q_{av})^2}{n}} \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Where:
EU=emission uniformity
C_V =coefficient of variation
n =number of emitters
$q_{\min}$ = minimum emitter discharge
q_{av} = average emitter discharge
δ = standard deviation

2.5 Overall Irrigation Efficiency
The overall irrigation efficiencies of the irrigation systems were computed using the expression recommended byAljamal*et al*. (2001) as shown in equation 9.

$$\text{IE} = \frac{\text{ET}_c}{I} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Where:
IE= Overall Irrigation efficiency (%)
ET_c =Crop evapotranspiration (mm)
I =Irrigation water applied (mm)

3. RESULTS AND DISCUSSION

3.1 Growth Parameters of Maize

3.1.1 Plant height
A significant effect ($P \leq 0.01$) of irrigation methods on the number of leaves of maize plants was observed (Table 1). The drip irrigation method led to a significant increase in plant heights of 178.8 cm in 2014 and 185.2 cm in 2015 compared to the plant heights of 114.0 and 148.0 cm from the sprinkler and 118.6 and 124.7cm from furrow irrigation methods in the 2014 and 2015 growing seasons, respectively.

Table 1: Effect of irrigation methods on a number of leaves of the maize plant.

Irrigation	2014				2015				Combined means			
Schedules	W2	W4	W6	W8	W2	W4	W6	W8	W2	W4	W6	W8
Drip	43.7[a]	71.0[a]	112.1[a]	175.8[a]	52.4[a]	85.7[a]	117.8[a]	185.2[a]	48.1[a]	78.3[a]	114.9[a]	180.6[a]
Sprinkler	36.0[b]	56.4[b]	89.9[b]	141.0[b]	45.0[b]	68.2[b]	94.6[b]	148.0[b]	40.5[b]	62.3[b]	92.2[b]	144.6[b]
Furrow	29.9[c]	47.6[c]	75.9[c]	118.6[c]	35.9[c]	57.2[c]	79.6[c]	124.7[c]	32.9[c]	52.4[c]	77.7[c]	121.9[c]
SE±												

Means in a column followed by the same letter are not significantly different according to Duncan Multiple Range Test at 5% level of probability.

Similarly, the combined analysis result for the two seasons also showed that the plants from drip-irrigated plots were significantly taller by 24.9% and 48.2% compared to plant heights obtained using sprinkler and furrow irrigation methods respectively. The favourable soil moisture condition created by the drip irrigation method through the application of water directly to the root zone of the plants led to enhanced growth with taller plants. This result is supported by Kahlon and Khera (2016) who reported a taller maize plant height of 251.4 cm under the drip irrigation method compared to a plant height of 225.2 cm from the furrow irrigation method. Similarly, the result obtained from this study is also in agreement with the findings of Sahu*et al*. (2005) and Usoh*et al.* (2017) which reported an increase in plant height of baby corn from the use of drip compared to the furrow irrigation method.

3.2 Yield and weight of 1000 kernels

Figures4 and 5 present the results of the yield and weight of 1000 kernels of maize. The result revealed that the yield and weight of 1000 kernels were significantly ($P \leq 0.01$) affected by irrigation methods.The drip-irrigated plots led to a significant increase in yields of 4054 kg/ha in 2014 and 4304 kg/ha in 2015 followed by sprinkler (3737 and 3968 kg/ha) and the least from furrow (3401 and 3611 kg/ha) in the 2014 and 2015 growing seasons, respectively. Similarly, the combined data analysis also showedahigher yield of 4179 kg/ha fromdrip-irrigated plots compared to yield values of 3853 and 3506 kg/ha obtained from the sprinkler and furrow-irrigated plots, respectively (Figure 4).

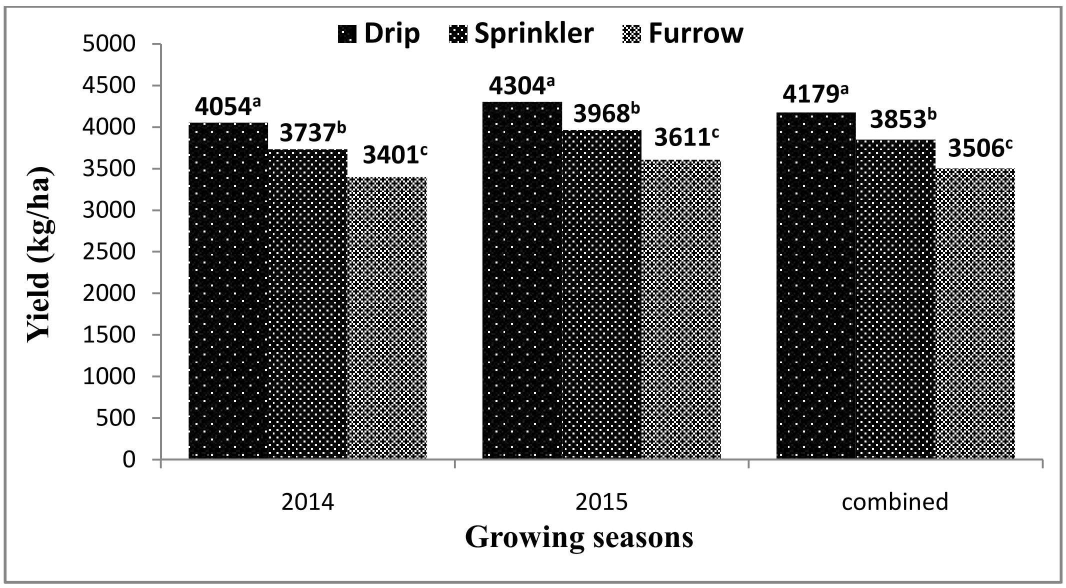

Figure 4: Effect of irrigation methods on maize yield

The significant increase in yield from the drip-irrigated plots was due to the favorable soil moisture condition created through the direct application of water to the root zone of plant which enhanced vegetative growth that resulted inayield increase. The result of this study is in agreement with the findings of Usoh*et al.* (2017) on the effect of drip and furrow irrigation systems application on the growth and yield of sweet maize under sandy loam who reported the yield of 5941.2 kg/ha of maize from drip and 3782 kg/ha for the furrow irrigation system. Similarly, the outcome of this study was supported by the findings of Powel *et al*. (2004), Humphreys *et al.* (2005), Hassanli*et al.* (2009), Abdel-Waheed and Ali (2012) and Couto *et al.* (2013) who all reported a significant increase in maize yield from drip compared to sprinkler and furrow irrigation methods.

Figure 5 showed the significantly higher weight of 1000 kernels of 252.2 g and 273.2 g from the drip-irrigated plots followed by 194.0 and 210.2 g from the sprinkler and the least values of 150.9 and 163.5 g from furrow irrigation plots in the 2014 and 2015 seasons, respectively. Similarly, the combined result followed the same trend with a significantly higher 1000 kernels weight of 262.7 g from drip followed by 202.1 g from sprinkler and the least 1000 kernels weight of 157.2 g was from the furrow irrigated plots.

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The significant increase in the 1000 kernels weight in the drip-irrigated plots can be attributed to the optimum soil moisture due to a lower rate of evaporation from the soil surface which enhanced growth that culminated into increased kernels weight. The findings of this study is supported by the result of Kahlon and Khara (2016) on the effect of irrigation methods and regimes on maize growth who reported the highest 1000 kernels weight of 255 g fromdrip-irrigated plot compared to 242 g from furrow irrigated plot. Karimi and Gomrokchi (2011) also reported similar findings.

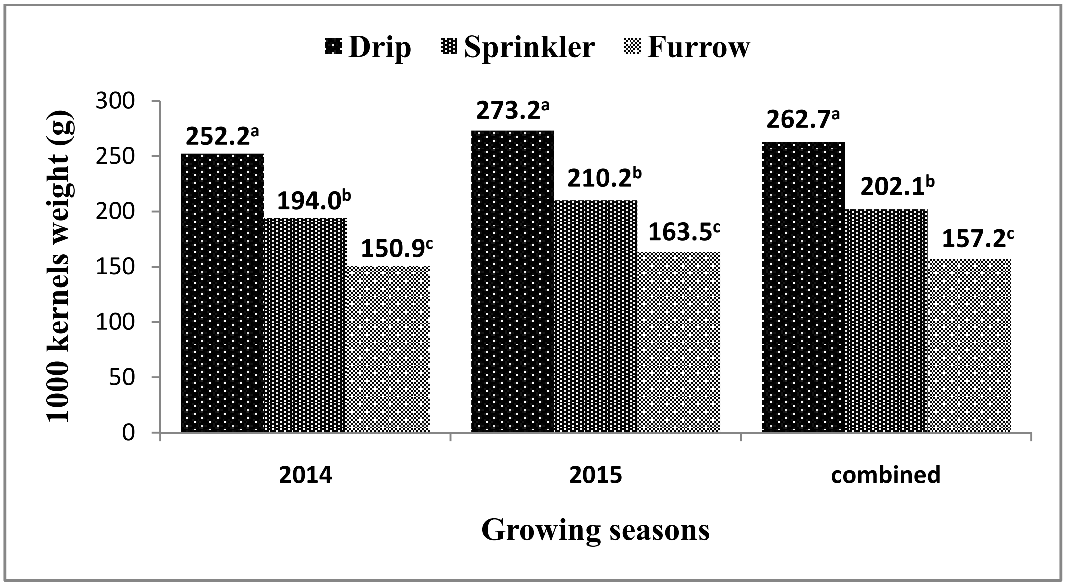

Figure 5: Effect of irrigation methods on weight of 1000 kernels.

3.3 Cob Length and Cob Diameter

Cob length and cob diameter were significantly ($P \leq 0.01$) affected by irrigation methods (Figure 6 and 7).The result revealed that the plots irrigated with drip produced the maximum cob lengths of 17.8 and 19.3 cm followed by sprinkler with 17.10 and 18.52 cm and the least cob lengths of 16.0 and 16.7 cm were obtained from plots irrigated using furrow irrigation

method in the 2014 and 2015, respectively.

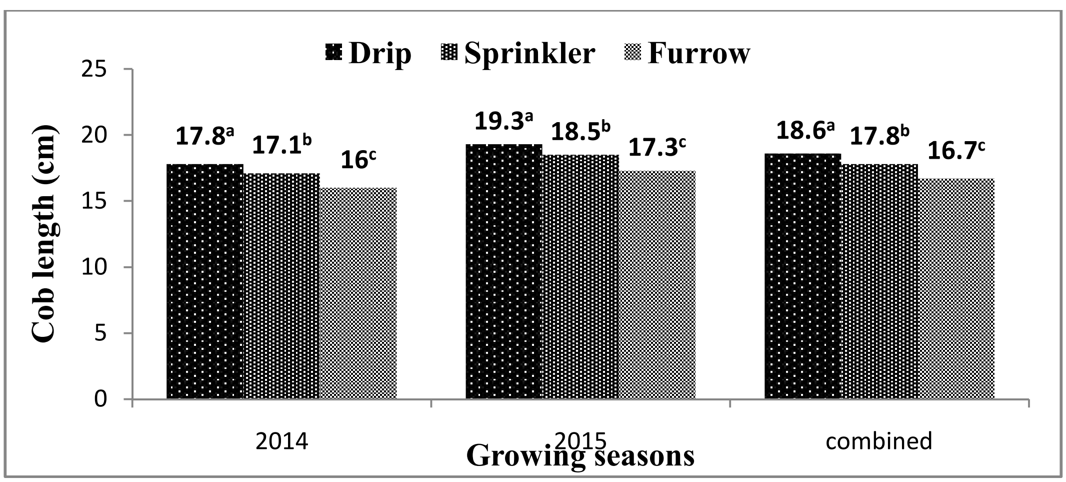

Figure 6: Effect of irrigation methods on cob length

Similarly, the combined analysis for the two growing seasons also showed that the maximum cob length of 18.6cm was from drip and the cob lengths of 17.8 and 16.7 cm were from sprinkler and furrow irrigated plots (Figure 6). This can be attributed to the drip irrigation methods' uniformity in water distribution and lower evaporation rate. The result obtained is in agreement with the findings of Sahu*et al*. (2005) who reported higher cob length from drip-irrigated plots compared to cob length obtained using the furrow irrigation method.

Figure 7 showed significantly increased cob diameter (4.60 cm in 2014 and 5.18 cm in 2015) fromthedrip irrigation method compared to 4.01 and 4.52 cm from the sprinkler and 3.49 and 3.71 cm from the furrow irrigated plots in the 2014 and 2015 growing seasons, respectively. Similarly, the combined (2014 and 2015) results also showed that the drip-irrigated plots had the highest value of cob diameter of 4.80 cm followed by 4.27 cm from the sprinkler and the least cob diameter of 3.71 cm from the furrow irrigated plots. The result obtained is similar to the findings of Sahu*et al.* (2005) who reported higher cob diameter from the use of drip compared to the furrow irrigation method.

3.4 Number of Rows per Cob and Cob Weight

The effect of irrigation methods on the number of rows per cob and cob weight is presented in Figures8 and 9. The results revealed that the number of rows per cob and cob weight was significantly ($P \leq 0.01$) affected by irrigation methods in both the 2014 and 2015 growing seasons.

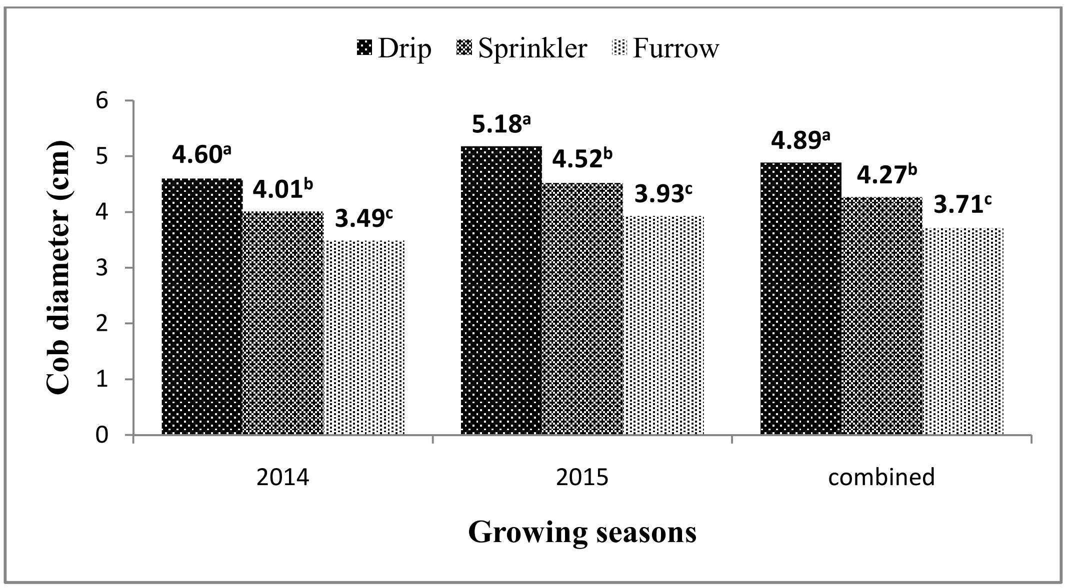

Figure 7: Effect of irrigation methods on cob diameter

The drip produced the highest (14.6 and 16.7) number of rows per cob compared to 13.8 and 15.8 from the sprinkler and 12.9 and 14.4 from the furrow irrigated plots in the 2014 and 2015 growing seasons respectively. Similarly, the combined result also showed that the drip irrigation method gave the highest number of rows per cob at 15.5 followed by 14.8 from the sprinkler and the least number of rows per cob of 13.7 was obtained from the furrow irrigated plots. This can be attributed to the favourable moisture condition in the soil which was made possible by the direct application of water to the plant root zone by the drip irrigation method. This result is supported by the findings of Bashir and Akande (2017) who reported that drip irrigation significantly increased the number of rows per cob to 16 compared to 13 obtained from the furrow-irrigated plots.

Figure 9 revealed that the drip-irrigated plots gave the highest cob weight of 116.9 g in 2014 and 108.1 g in 2015 compared to cob weights of 94.5 and 107.5 g from the sprinkler and 79.5 and 75.3 g from the furrow irrigated plots in the 2014 and 2015 growing seasons respectively. The combined results of the seasons also showed the drip-irrigated plots gave the highest cob weight of 120.5 g compared to cob weight values of 97.4 and 81.9 g obtained from the sprinkler and furrow irrigated plots.

The result obtained from this study is similar to the findings of Roja*et al*. (2017) who reported a significant increase in cob weight of 198 g from the drip irrigation method compared to cob weight of 117 g from furrow irrigated plots. Hanson *et al.* (2007) also reported that the drip irrigation method was more advantageous over other methods in increasing the grain weight of cob due to a reduction in the incidence and severity of weeds and diseases in dry row middles and nutrient loss through deep percolation.

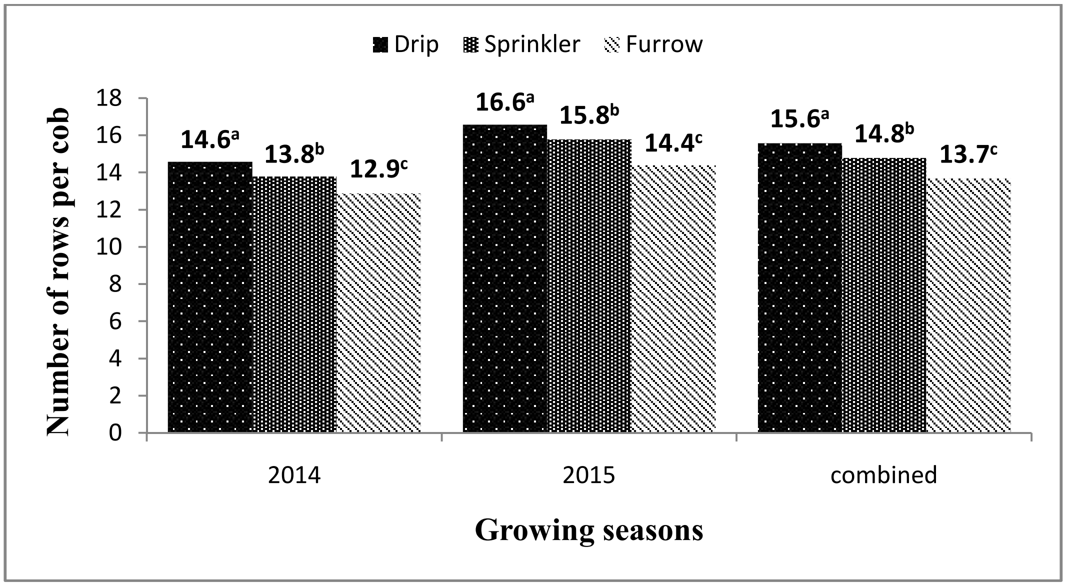

Figure 8: Mean comparison effect of irrigation methods on the number of rows per cob

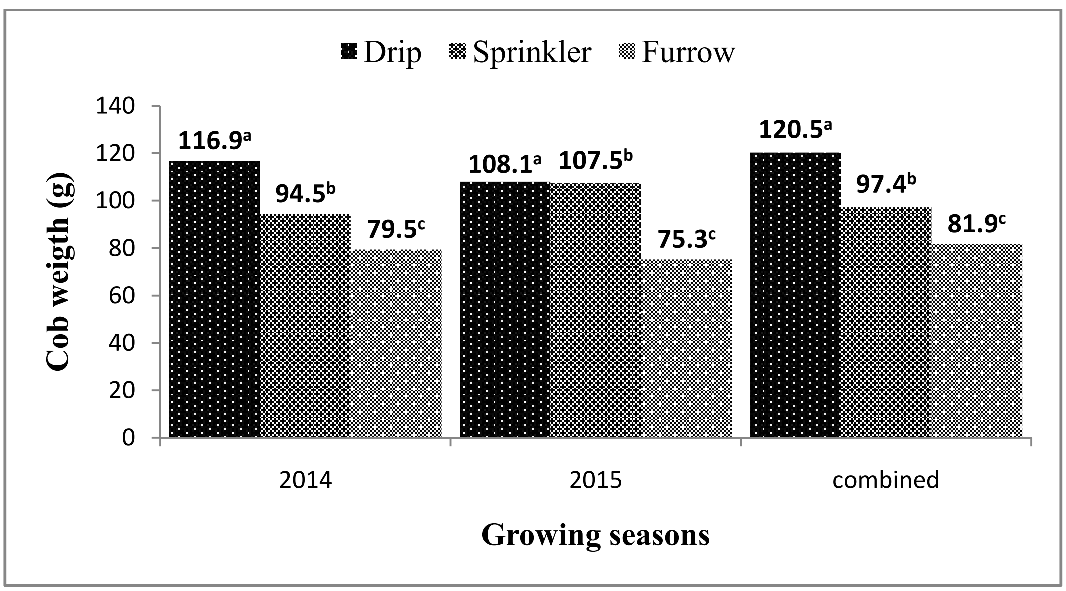

Figure 9: Mean comparison effect of irrigation methods on cob weight

3.5 Water distribution uniformity and irrigation efficiencies of irrigation methods

The uniformity of irrigation water distribution for the furrow, sprinkler, and drip irrigation methods was evaluated based on the concept of distribution uniformity and emission uniformity to ascertain how evenly the water is distributed within the experimental field. The sprinkler coefficient of uniformity and furrow water distribution uniformity was found to be 85% and 75%, respectively. While the emission uniformity for the drip irrigation method was found to be 91.2%. A distribution uniformity value of 75% indicates that 25% of the field received water less than the required depth for crop requirement. Similarly,thedistribution uniformity value of 85% shows that 15% of the field received less water. While distribution uniformity of 91.2% revealed that only 8.8% of the field received less water compared to the depth of water required. The result obtained shows that, drip irrigation has higher (91.2%) uniformity of water application compared to sprinkler and furrow irrigation methods. The higher value of emission uniformity of 91.2% and lower coefficient of variation of 5.3% as shown in Table 7 indicated the excellent performance of the drip irrigation method in supplying water evenly to plants and this translates to higher crop yields. The values obtained are within the limit suggested by Merriam and Keller (1978) for good irrigation methods performance in terms of uniformity of water application. This result is also supported by the findings of Pramanik and Patra (2015) who reported emission uniformity coefficients of 90 to 93% for the drip irrigation method.

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3.6 Quality of Maize Kernel

Percentages of fat, ash, protein, fibre, carbohydrate and moisture content of maize kernel under the different irrigation methods during the 2014 and 2015 growing seasons are presented in Table 8. The result shows significant differences ($P < 0.05$) in the nutritional properties of the maize kernel concerning irrigation methods (drip, sprinkler and furrow) in both the 2014 and 2015 growing seasons. Based on the result, maize crops irrigated using the furrow irrigation method had the highest fat, protein and moisture content values of 5.39, 10.72 and 16.65%, respectively in 2014 and 5.29, 10.34 and 17.67%, respectively in 2015 growing seasons. This

The irrigation efficiencies for the drip, sprinkler and furrow irrigation methods were found to be 80%, 76% and 64%, respectively. The irrigation efficiency of drip irrigation was the highest based on the fact that drip irrigation applies water directly to the root zone of the plant thereby significantly reducing the conveyance, evaporation and percolation losses. The medium sprinkler irrigation efficiency value recorded was because there was no runoff and deep percolation losses, but the water applied by the sprinkler system is intercepted by the maize leaves thereby resulting in higher losses. The lowest irrigation efficiency obtained from furrow could be due to the non-uniformity of water distribution with considerable losses due to differences in infiltrated water volumes at the top and end of the irrigation run. A non-uniform distribution of water denies some crops the water applied to meet their needs and can also lead to over-irrigation of some parts of the field resulting in waterlogging, injury to plants, salinity problems and leaching of nutrients beyond the root zone of plants among others.

The drip irrigation efficiency value of 80% obtained in this study is within the range of drip irrigation efficiencies of 80 to 91% reported by Battikhi and Abu-Hammad (1994). The sprinkler irrigation efficiency value of 76% is equally in agreement with values of sprinkler irrigation efficiencies of 54 to 80% reported by Zalidis*et al*. (1997). Similarly, the furrow irrigation efficiency of 63% obtained in this study is also within the efficiency values in the range of 50 to 73% for furrow method reported by Oster *et al.* (1986), Abu-hammad (1994),Zalidis*et al*. (1997). The values obtained were found to be acceptable because efficiency of 100% is not desirable because they do not maximize profit.

concurred with the findings of Amiri *et al.* (2009) who reported higher values of fat and protein contents of maize produced using the furrow irrigation method. Drip irrigation produced the highest carbohydrate ash and fibrecontents with values of 72.50, 2.41, and 2.56%, respectively in 2014 and 73.02, 2.39, and 2.51%, respectively in 2015. This can be attributed to the sufficient amount of water applied directly to the plant'sroot zone by the drip irrigation method which resulted in higher photosynthetic activity and the production of more carbohydrates. This result conforms with the findings of Amiri *et al* (2009) and Ghamarnia*et al*. (2013).

Table 2: Quality of maize kernel (%) under different irrigation methods

Treatments	Fat	Ash	Protein	Fiber	Carbohydrate	Moisture
			2014 season			
Drip	3.34[b]	2.41[a]	7.76[c]	2.56[a]	72.50[a]	11.43[b]
Sprinkler	3.39[b]	2.21[b]	8.70[b]	1.91[b]	71.21[b]	12.54[b]
Furrow	5.39[a]	1.32[c]	10.72[a]	1.43[c]	64.50[c]	16.65[a]
SE±						
			2015 season			
Drip	3.31b	2.39a	7.56c	2.51a	73.02a	11.17b
Sprinkler	3.33b	2.07b	8.58b	1.88b	72.78a	11.36b
Furrow	5.29a	1.27c	10.34a	1.37c	64.06b	17.67a
SE±						
			Combined means			
Drip	3.32[b]	2.40[a]	7.66[c]	2.56[a]	73.04a	11.03[c]
Sprinkler	3.36[b]	2.14[b]	8.64[b]	1.89[b]	71.24b	12.71[b]
Furrow	5.33[a]	1.29[c]	10.52[c]	1.40[c]	64.28c	17.16[a]
SE±						

4. CONCLUSION

The drip irrigation method led to a significantly higher maize yield of 5056 kg/ha compared to yields obtained from the sprinkler (4641kg/ha) and furrow (4215kg/ha) irrigated plots in the region. The drip irrigation method also had the highest water savings of 17.31% and 31.75% when compared with sprinkler and furrow irrigation methods, respectively. Higher application efficiency and uniformity of water emission were found with the drip irrigation method at 80% and 91.2%, respectively, followed by sprinkler with application efficiency of 76% and a coefficient of uniformity of 85%. The least water application efficiency of 64% and distribution uniformity of 75% were found with furrow irrigation method. Furthermore, the drip irrigation method produced maize kernel with ahigher carbohydrate content of 73.04%, fibre content of 2.56% and ash content of 2.40%. Maize kernel with the least percentages of carbohydrate, fibre and ash contents of 64.28%, 1.40% and 1.29% were obtained from the furrow irrigated plots.

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