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Effect of varying water applications on growth, yield and water use efficiency of okra under drip irrigation in Akure, Ondo state, Nigeria

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Abstract

The conservation of water is crucial to sustainable agricultural production during dry season when there is little or no rainfall to improve crop production. Thus this study is aimed to estimate the effects of different levels of water applications on the growth, yield and water use efficiency of Okra under drip irrigation system during dry season. The sixteen plots consist of four treatments (2 m x 2 m) with four replicates in a complete randomized block design to determine the water consumptive use of Okra. The growth, yield and water use efficiency of Okra under four different irrigation management i.e irrigation water applied at 100FIT (full irrigation treatment), 80FIT, 60FIT and 40FIT were measured. Results showed highest growth parameters being observed at 100FIT and the least at 40FIT. The difference in the growth parameters in all the experimental blocks were not significant (p=0.05) for all the stages of development of okra. Using standard bar errors the yield obtained at 60 and 100FIT was not significantly different but significantly different when compared to other treatment blocks and it ranges from 2.05-3.60 tons/ha. The Irrigation Water Use Efficiency (IWUE) ranges from 0.024-0.041tons/ha.mm while the Crop Water Use Efficiency (CWUE) ranges from 0.0088-0.0139 tons/ha.mm. Okra crop irrigated with drip irrigation at 60FIT recorded the highest IWUE, CWUE and about 73% more yield than the 40FIT of 0.041 tons/ha.mm, 0.0139 tons/ha.mm and 3.56 tons/ha respectively. It was concluded that Okra crop irrigated at 60FIT should be adopted in order to save 40% water to irrigate additional land. Drip irrigation is encouraged during dry season for farmers to produce okra all year round.

Keywords: Okra yield, Water Use Efficiency, Irrigation, Drip irrigation

Introduction

Agricultural sector consumes about 83 per cent of water whereas, about 50-70 per cent of water is wasted through conveyance, evaporation, field application and distribution losses in conventional method of irrigation. These losses can be reduced by adopting drip irrigation method with efficient water management practices (Dahiya et al., 2005). Recently water supply has become major hindrance to crop production due to competing water demand from other sector of the economy such as rapid industrialization and high population growth (Konyeha and Alatise, 2013). Water is very essential in the growth and production of crop. It needs, thus, to ensure an appropriate growth of vegetable crops throughout the year most especially during dry season when there is little or no rainfall for production. This can be achieve by adopting the irrigation water management strategy to produce more crops per drop of water with the use of drip irrigation system (Panigrahi and Sahu, 2013). Properly managed irrigation increases crop

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yields, increase product value, reduce pest infestation, and precisely deliver and manage nutrients.

Okra (*Abelmoschus esculentus*) is one of the most well-known and utilized species of the family *Malvaceae* and originated from Africa (Abid et al., 2002). It is also a chief vegetable crop grown for its immature pods that can be consumed as a fried or boiled vegetable or may be added to salads, soups and stews (Kashif et al., 2008). Okra is a vegetable that has a lot of stored nutrient. The pods of okra plants should be harvested while young; as long as they are nearly 10cm long they are ready for picking. Okra plays, thus, an important role in human diet by providing carbohydrates, protein, fat, minerals and vitamins that are commonly deficient in basic foods. In spite of the high economic value of the crop and the available potentials for its high production in Nigeria, okra is extensively cultivated by farmers in the country during raining season. This is possible in the south-western Nigeria because of high rainfall for about two-third of the months of the year. Unlike tropical countries where a lot of researchers have studied the production of okra under different irrigation management (Abid et al., 2002; Panigrahi et al., 2011). The few researchers who worked on the production of okra in Nigeria (Ijoyah et al., 2010; Akanbi et al., 2010 and Iyagba et al., 2012). Akanbi et al, 2010 have studied on the response of okra to organic and inorganic source of nitrogen fertilizers using pot and field experiment. The researchers concluded that, small concentration of fertilizer being added to okra increases its yield. Ijoyah et al. (2010) also evaluated the response of okra to different intra-row spacing and they concluded that 30 cm intra-row spacing gives the highest yield. According to the few research carried out in Nigeria, response of okra to irrigation management have not been taking into consideration which implies that water has been added without proper consideration and this might have led to wastage of water most especially dry season.

In planning for irrigation system, it is important to calculate both the seasonal and peak water requirements of crop which is to be irrigated. Okra requires adequate water application and relatively humid soil throughout the growing season in order to have high yield. The flowering and the fruiting stage of okra are considered to be the most sensitive period in the entire growing season (Al-Harbi et al., 2008). Water shortage at this stage reduces the yield of okra. Therefore, to avoid reduced yield there is need for controlled irrigation system. According to Al-Harbi et al. (2008), controlled irrigation is important for high yields in okra field due to the sensitivity of the crop to both over and under irrigation. Therefore, the objective of this research is to evaluate the effects of water applications on the growth, yield and water use efficiency of okra under drip irrigation system in Akure South-Western city of Nigeria.

Materials and Methods

Description of the Study Area

The study was conducted during dry season of October 2017-March 2018 at Training and Research Farm of the Department of Agricultural and Environmental Engineering, Federal University of Technology, Akure. Akure is located within the humid region of Nigeria at Latitude $7^0$16'N and Longitude $5^0$13'E. Akure has a land area of about 2 303km^2 and is situated within the Western upland area. The study area has elevation between 300 and 700 meters above the mean seas level and mean rainfall ranges between 1300 mm to 1500 mm.

Soil Physical and Chemical Properties of the Experimental Site

The descriptive statistics of the soil properties at the experimental site before and after the experiment are presented in Table 1. The site has a mean soil texture (USDA method) of sandy clay loam in the top soil which forms mainly the agricultural layer required for the cultivation of shallow rooted crops. The soil is mainly sandy and it allows downward flow of water, which requires constant irrigation. Bulk density of the soil was determined by core method using 20 cm long by 4.4 cm diameter of cylindrical can. The soil moisture content was determined once in 2 weeks at 20 and 40 cm depth using gravimetric method. The soil chemical properties and particle size distribution were determined in the laboratory using standard procedures. Rainfalls were measured during the experiment with the aid of automated rainguage installed at the experimental site. The mean bulk densities of soil at the experimental site at depths 0-20 cm and 20-40 cm are 1.32 and 1.44 g cm^{-3} respectively.

Table 1. Physical and chemical properties of the soil at depth 0-40 cm

Parameters	Before planting	After planting
pH	4.76	5.07
P(mg/kg)	8.76	6.98
Na(cmol/kg)	0.53	0.43
Ca(cmol/kg)	3.10	2.90
Mg(cmol/kg)	1.30	1.10
K(cmol/kg)	0.60	0.24
CEC(cmol/kg)	12.14	9.26
O.C.(%)	1.21	0.88
O.M.(%)	2.08	1.52
N(%)	0.12	0.08
Sand(%)	52.80	52.80
Clay(%)	31.20	33.20
Silt(%)	16.00	14.00

P=Phosphorus; Na=Sodium; Ca=Calcium; Mg=Magnesium; K=Potassium; N=Nitrogen

C.E.C= Cation Exchange Capacity; O.C=Organic Carbon Content; O.M=Organic Matter Content

Experimental design and layout

An area of 10 m x 60 m was first slashed, ploughed and harrowed to ensure good soil tilth for crop growth and 10m x 10m of the prepared bed was divided into sixteen seed beds using drip irrigation system. A variety of Okra *(Abelmoschus esculentus)* was planted at equal distance of 90cm within rows and 50cm between rows. Cultural practices such as thinning, weeding and controlled of pests and diseases were carried out appropriately. The sixteen plots consist of four treatments (2m x 2m) with four replicates each in a complete randomized block design as shown in Figure 1. Each drip line was installed at a spacing of 90cm on the treatment blocks making a total of three drip lines on each treatment blocks. Each of the treatments blocks was connected to a main pipe which supplies water from the reservoir placed at higher elevation on the field. Catch-cans (2600 cm^3) were arranged in each treatment to harvest water from the emitter on the drip lines. The volume of water harvested over each treatment area with respect to the time considered was measured using a measuring cylinder. The irrigation water amount of 670.81 cm^3 was applied at irrigation interval of 2 days with average evapotranspiration of 4 mm/day. The irrigation time of 90 minutes was recorded for 100% FIT while 72 minutes, 54 minutes and 45 minutes were recorded for 80% of FIT (or 0.80 FIT), 60% of FIT and 40% of FIT respectively.

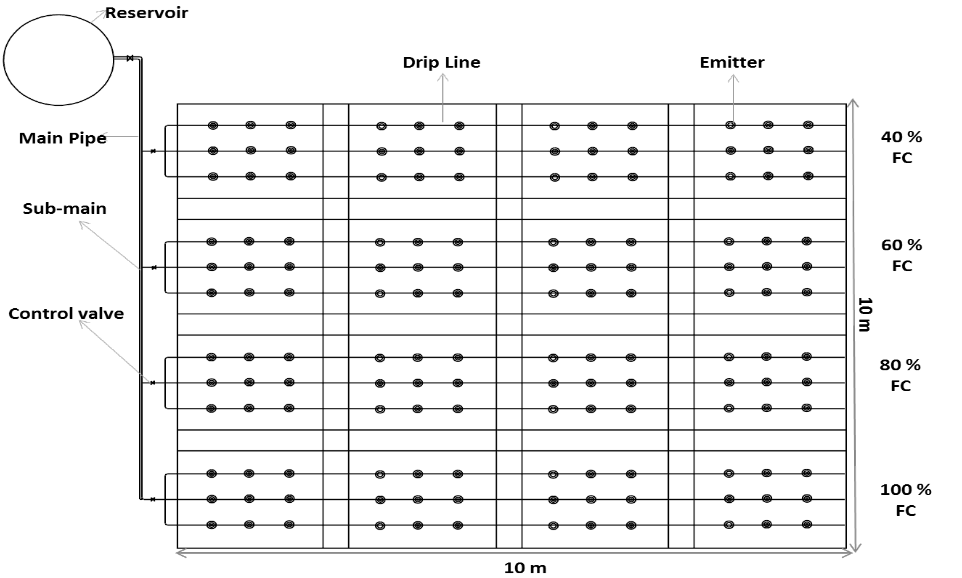

Figure 1. Experimental layout

Okra yield Measurement

Okra pod yield was determined at maturity. The yield was harvested manually in batches from the field and weighed using weighing balance of good precision of 0.01g. Water consumptive use was determined using soil water balance method (Hillel, 1998) and water use efficiencies were also calculated.

$$ET_c = I + P \pm \Delta S - R - DP \quad (1)$$

Where;

ETc=evapotranspiration (mm)

P=precipitation i.e. rainfall (mm); I=water applied by irrigation (mm)

DP=deep percolation (mm); R=runoff (mm); ΔS = change in soil water storage (mm)

Runoff and deep percolation were assumed negligible because of occasional rainfall were observed been inadequate enough to cause runoff and deep percolation into soil and only crop water requirement at the required depth was applied through drip irrigation system.

Water use efficiency/ Irrigation Water Productivity

Water use efficiency is defined as a ratio of biomass accumulation, which is usually expressed as carbon dioxide assimilation, total dry matter yield, or crop grain yield, to water consumed, expressed as transpiration, evapotranspiration, or total water input to the system. Water use efficiency can be divided into irrigation water use efficiency (IWUE) and crop water use efficiency (CWUE). Which is calculated using Equations 2-3;

$$IWUE = \frac{yield}{\text{amount of irrigation water applied}} \quad (2)$$

$$CWUE = \frac{yield}{\text{total crop evapotranspiration}} \quad (3)$$

Results and Discussion

The site has a mean soil texture (USDA method) of sandy clay loam in the top soil which forms mainly the agricultural layer required for the cultivation of most shallow rooted crops. The soil is predominantly sandy and it allows downward movement of water, which will require constant irrigation when use for cultivation. The source of irrigation water at the experimental site was from a borehole. The borehole has a capacity to supply irrigation throughout the growing season. The result analysis of agronomic response, crop and water productivity are discussed in this chapter.

Soil moisture content variation

It was observed that the soil moisture increases downward in the soil profile as shown in Figures 2. The fluctuations on the soil moisture might be attributed to different application of irrigation water, rainfall at different days after planting and evaporation at the soil surface (Konheya and Alatise, 2013). Figures 2 shows the relationship between the variations of soil moisture content stored under drip irrigation system in each treatment blocks at depth of 0-20cm and 20-40cm and their replicates. The moisture content at field capacity was high because the soil was fully saturated before planting okra. The reduction in the soil moisture content up to 40 days after planting was due to high demand of water by the crop during the flowering and fruiting stage when water is most required. At maturity and harvesting stage small amount of water is required by the crop thereby increases the moisture content of the soil up to 70days after planting. Figure 2a-2d shows that the highest moisture content was observed at first day and lowest at 40 days after planting for both depth (20 cm and 40 cm) for 100FIT, 80FIT, 60FIT and 40FIT treatments.

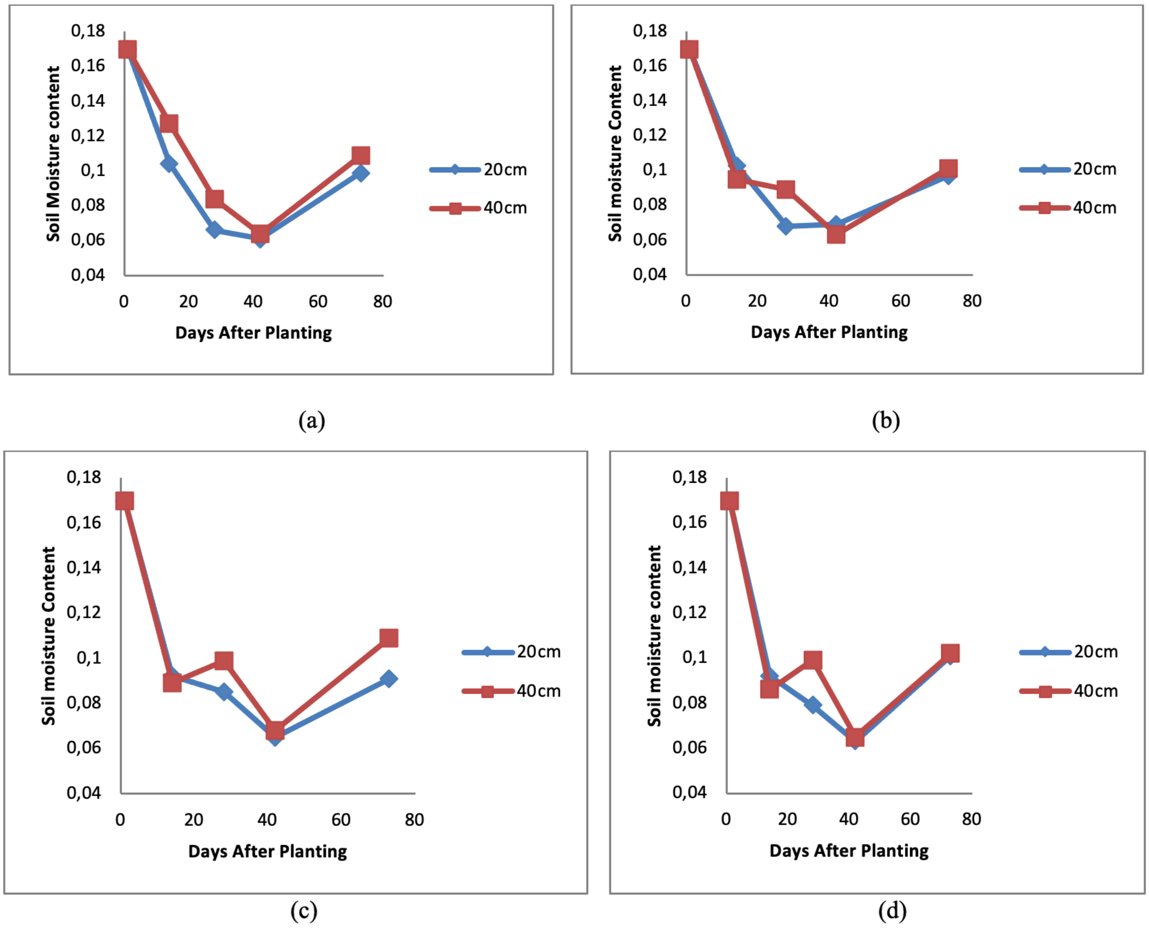

Figure 2. Variation of soil moisture content (a) 100FIT (b) 80FIT (c) 60 FIT and (d) 40FIT treatments block under drip irrigation system.

Agronomic response of okra

The relationship between the growth parameters with respect to days after planting in all the treatment blocks are shown in Figure 3. It was observed that there was no rapid increase in the mean of all the growth parameters during the emergence and the growing season of the crop until it gets to fruiting stage which was 35days after planting. This rapid increases were observed until the crop reaches maturity at 60days after planting when it no longer develop and the leave started dropping to add fertility to soil.

Figure 3a shows relationship between the mean stem girths with respect to days after planting. It was observed that at the emergence there was no different in the mean stem girth of all the treatment blocks. There was a rapid increase in the mean stem girth after the emergence stage to fruiting stage of the crop which occurs at 14 to 49 days after planting which later remain constant till maturity. From Figure 3b it was observed that there were no rapid increase in the mean height of the leaf during the emergence and the growing season of the crop until it get to fruiting stage which was 35days after planting. It was observed that there was no increase from 49days till maturity stage when the okra leaves started dying out and dropping on soil surface and add nutrient to the soil. Figure 3c shows the graph relationship between the mean numbers of leaves with respect to days after planting. It was observed that at the emergence and growing season there was no increase in the number of leaves in all the treatment blocks. There was a rapid increase in the number of leaves from the flowering to fruiting stage of the crop which occur at 28 to 49 days after planting. At maturity the leaves started dropping and add fertility to the soil. Figure 3d shows the graph relationship of leaf area against days after planting. It can be seen clearly from the graph that the control treatment (100FIT) which received adequate water supply has the highest leaf area. Figure 3e shows the relationship between leaf area index against days after planting. It can be seen clearly from the graph that the control treatment (100FIT) which received adequate water supply has the highest leaf area index. The leaf area index tends to increase up to fruiting stage in all the treatment blocks

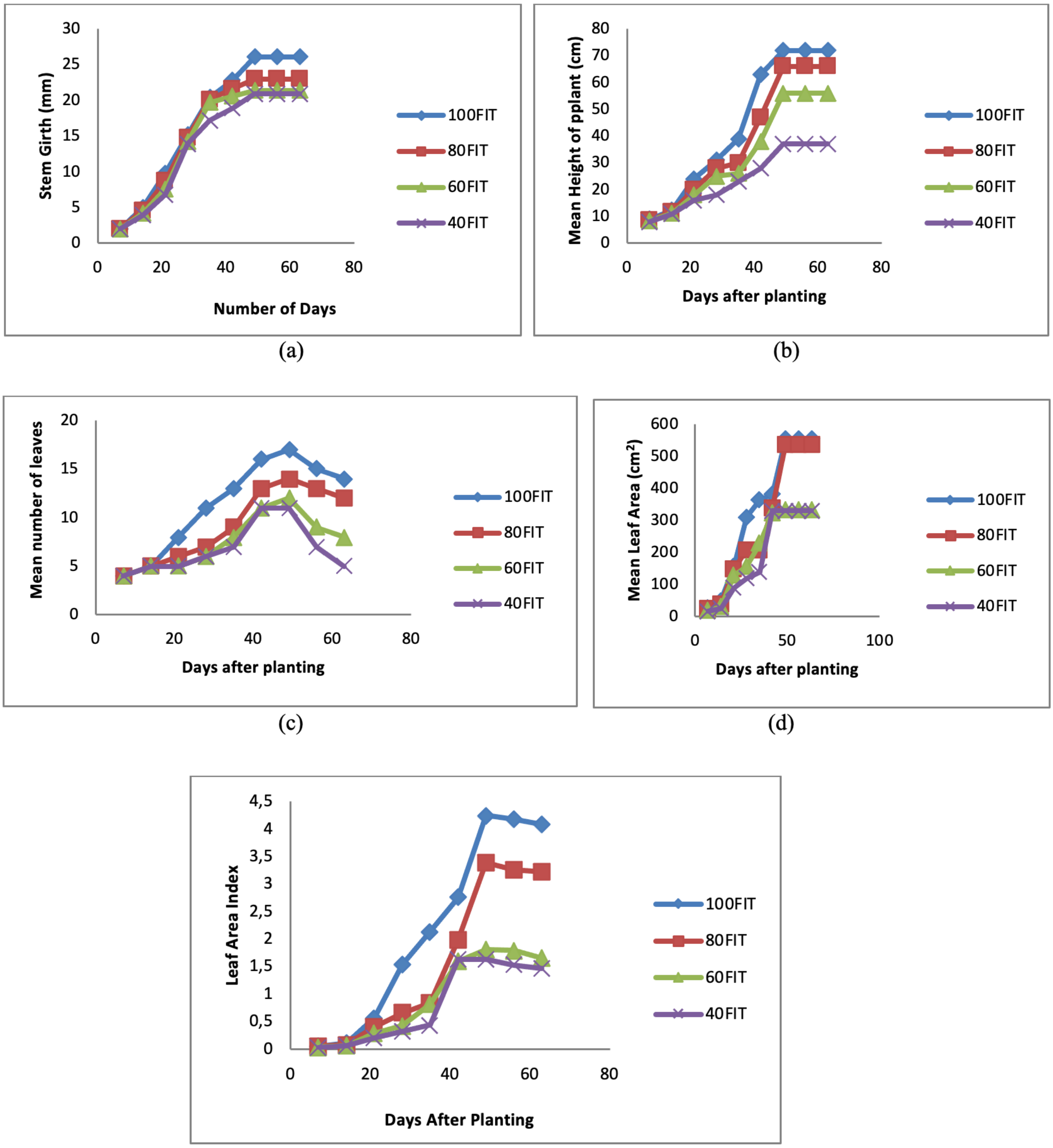

Figure 3. The graph of mean (a) stem girth (b) height (c) number of leaves (d) leaf area (e) leaf area index with respect to days after planting in all treatment blocks

Okra pod yield

The results of okra pod yield in tons per hectare is given in Figure 4. The average values of okra pod yield obtained was highest in the 100FIT treatment and lowest in the 40FIT treatment. The higher yield can be obtained due to the efficient application of water and proper aeration in the root zone which helps for the favorable conditions for growth of the plant. Standard error bars shows that there is no difference in the mean of the yield obtained in 100FIT, 80FIT and 60FIT. This implies that 40% reduction in crop water requirement has no negative effect on the yield of Okra. The yield ranges from 2.05 to 3.60tons/ha which is within the range obtained from that of Babu et al., 2015. Poor yield obtained in 40FIT was due to insufficient water application to meet crop growth requirement.

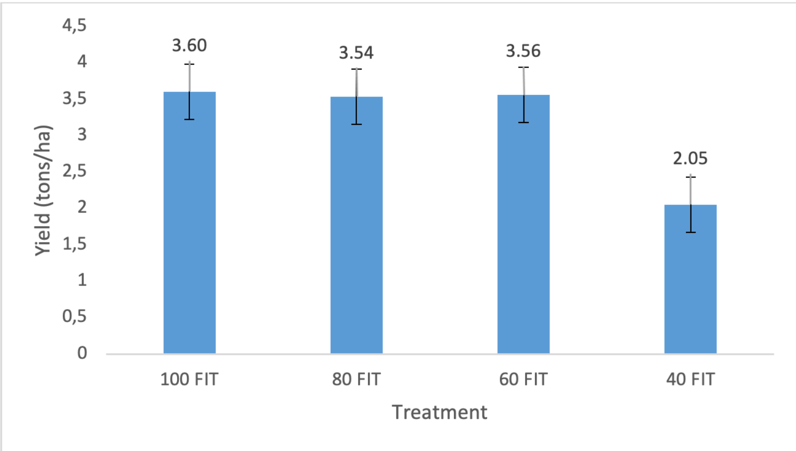

Figure 4. Yield response of Okra in all the treatment block.

Water use efficiecny/ Irrigation Water Productivity

Both the irrigation water use efficiency (IWUE) and crop water use efficiency (CWUE) were calculated and recorded in Table 2 and 3. Results shows that treatment 60FIT has the highest IWUE and CWUE of 0.041t/ha.mm and 0.00139t/ha.mm respectively compared to other treatment blocks and it was considered to be the best among all other treatments. There was significant difference in the IWUE at 5% levels of significance and this was caused by different irrigation water applied which in turn result to different yield being obtained. Reduction in the IWUE and CWUE for 80 and 100FIT shows that addition of water has no positive effect on the yield of Okra rather it only leads to wastage of water since the crop water requirement has been fully met at 60FIT. The arithmetic average (mean) of water applied in treatment block 100FIT, 80FIT, 60FIT and 40FIT are 25.32mm, 23.59mm, 21.60mm and 18.94mm at a time interval of 90mins, 72mins, 54mins and 36mins being considered for water application in each treatment blocks respectively.

Table 2. IWUE (tons/ha.mm) in all the treatment blocks

Treatments	IWUE (tons/ha.mm)				Average
	R1	R2	R3	R4	
100FIT	0.015	0.028	0.024	0.029	0.024
80FIT	0.017	0.031	0.029	0.040	0.029
60FIT	0.037	0.037	0.047	0.042	0.041
40FIT	0.031	0.035	0.031	0.039	0.034

Table 3. CWUE (tons/ha.mm) in all the treatment blocks

Treatments	CWUE (tons/ha.mm)				Average
	R1	R2	R3	R4	
100FIT	0.0072	0.0138	0.0115	0.0141	0.0116
80FIT	0.0069	0.0129	0.0118	0.0162	0.0120
60FIT	0.0127	0.0127	0.0159	0.0145	0.0139
40FIT	0.0081	0.0090	0.0080	0.0100	0.0088

Conclusion

A field experiment was carried out to investigate the effects of varying water application on the growth, yield and water use efficiency of okra. The yield obtained from all the treatment blocks was significantly different at 5% level of significance using standard bar errors and this was as a result of different levels of water applications. The irrigation water amount of 670.81 cm^3 was applied at irrigation interval of 2 days with irrigation time for full capacity for 90 minutes (100 FIT). The average evapotranspiration was 4 mm/day. The highest IWUE and CWUE were recorded at 60FIT as 0.041 and 0.0139 respectively. The yield obtained at 60FIT was 3.56tons/ha which has no significant difference to the yield obtained at 100FIT using standard bar errors. From this research; it was observed that Okra crop irrigated at 60FIT gives the highest thereby 40% of water to irrigate additional land. For farmers this research findings can help in planting and scheduling during dry season using drip irrigation if the amount of irrigation water amount and evapotranspiration are known.

Compliance with Ethical Standards

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal.
All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Not applicable.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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