PERFORMANCE EVALUATION OF DRIP IRRIGATION SYSTEMS AND SURFACE IRRIGATION SYSTEMS ON PRODUCTION OF OKRA (*HIBISCUS ESCULENTUS*) IN SOUTHWESTERN, NIGERIA

ABSTRACT

This study was carried out to evaluate the performance of drip irrigation systems on production of okra (Hibiscus esculentus) in southwestern, Nigeria. Application of water to crops in an area of scarcity of water is very important to meet the food demand of the ever-increasing population and modified irrigation techniques that can assist the okra farmers to have affordable irrigation systems that will get them great yields at the end of the season was evaluated in this paper. A field experiment was conducted at Teaching and Research farm of Agricultural and Bio- Environmental Engineering Department, School of Engineering Technology, The Federal Polytechnic, Ado, Ekiti - State, Nigeria. The field area of 150m by 400m was properly cleared, stumped, ploughed and harrowed. The topography of the land was flat with its suitable soil structure, texture, retention capacity and loamy clay soil. The cultivated area of land was divided into three and on each experimental plot, highly yield and disease resistant okra variety seeds obtained from a research institute (IITA) were carefully selected and planted at a regular interval of 0.6m. Drip laterals were laid in between rows of okra plants with inline drippers at a spacing of 20 cm. The parameters measured include okra seed germination, plant height, stem girth, number of leaves and yield production. The study also includes soil properties, crop water requirement and crop water use efficiency. There were no significantly difference in the okra agronomic parameters at each experimental plots under drip irrigation system. The water applied to crop was greater than the actual crop water requirement and the efficiency of the drip irrigation was 68.5%. There is high in seed germination percentage in with 3.5%, 3.6 % and 3.8% at each experimental plot respectively. The selected okra agronomic parameters showed that okra performed very well under drip irrigation systems. Based on the results, water application through drip irrigation has positive impact on growth and vegetative development of okra.

Keywords: *Drip Irrigation, Surface Irrigation, Okra, Evaluation , Performance*

1.0 INTRODUCTION

Agriculture utilizes globally about 70% of all the water managed by man, and about 80% of the water used in the developing world. Water supply is important for crop growth and production particularly in arid and semi-arid areas. The increased competition for water among agricultural, industrial and domestic consumers creates the need for continuous improvements in techniques for judicious use of water in crop production. Oshunsanya, Aiyelari, Aliku and Odekanyin (2016) analyze that the competition among the various sectors-agriculture, communities, industry, nature, etc. as becomes stiffer and agriculture is most under pressures for scarce water resources, as the output per unit water is significantly lower than in the other economic sectors.

The majority of the population in sub-Saharan Africa makes their living from rainfed agriculture and depends to a larger extent on smallholder, subsistence agriculture for their livelihood and food security (Maisiri, Senzanjem Rockstorm and Twomlow, 2005). However, when rainfall is scarce and in order to make water available to the farmers throughout the dry season to ensure food security there is need for irrigation systems. Irrigation is the artificial application of water to the soil or plant, in the required quantity and at the time needed, is a risk management tool for agricultural production. FAO (2014) has estimated that irrigated agriculture uses more than 70% of the water withdrawn from the earth's rivers; whereby the proportion exceeds 80% in developing countries. So it is important to judiciously use the already existing water resources by using suitable irrigation technology that not only increases vegetable production per unit area but also per unit of water used. Efficient water use is becoming increasingly important and alternative water application methods such as drip irrigation may contribute substantially in making the best use of the scarce available water for crop production. Drip irrigation is a technique that provides crops with water through a network of pipe lines at a high frequency but with a low volume of water applied directly to the root zone in a quantity that approaches consumptive use of the plants (Salunkhe, Bhamare and Mavale, 2015). Drip irrigation does not only conserve water, but also improve productivity and quality of the produce even utilizing poor quality waters. Paul, Mishram, Pradhan and Paniggrahi (2013) discovered that drip irrigation has considerable advantages over other irrigation systems in terms of water application efficiency is capable to small and frequent applications of water has created interest among the farmers because of less water requirement, increased production and better quality production. Okra, a widely distributed crop is one of the oldest cultivated crops in many parts of the world with its origin from Ethiopia and Sudan (Oyelade, Ade-Omowaye and Adeomi, 2003). It is an important vegetable because it is rich in vitamins, folic acid, carbohydrates, phosphorus, magnesium, calcium, potassium and other minerals and it belongs to the genus *Abelmoschus* family (Dilruba, Hasanuzzaman, Karim and Nahar ,2009). Okra is a type of vegetables that can be planted on all types of soils but the soil should be friable (Ayeni, Ale and Kayode, 2015). Drip irrigation system along with mulching can make the yield of okra to increase up to 61% higher than other irrigation method with same quantity of irrigation water applied (Paul, *et. al.,* 2009). Okra is a high water crop use despite having considerable drought resistance (Fasina, 2008). During the year 2009 and 2010, 13.6 and 14.8 percent higher okra yield was observed under drip irrigation in comparison to other irrigation method as reported by Birbal, Rathore, Nathawat, Bhardwaj and Yadav (2013). Drip irrigation may help in producing more water applied and allow crop cultivation in water scarce area but there is limited numbers of study conducted in South western, Nigeria to assess and ascertain its utility and suitability under different situations for production of okra. This study is aimed at to evaluate the performance of improvised drip irrigation systems in production of okra in south western, Nigeria in order to maximize profit and at the same time reduce the cost of production.

2.0 MATERIALS AND METHODS

2.1 Study area

The experiment was conducted during year 2015-2016 at the Teaching and Research Farm of Department of Agricultural and Bio-Environmental Engineering, School of Engineering Technology, The Federal Polytechnic, Ado Ekiti, Ekiti State, Nigeria. The area is located around Latitude 6˚N and Longitude 16˚E and is a low relief with elevation about 185m above the sea level which is enveloped by rocky and hilly outcrops. Geologically, the region lies entirely within the pre-Cambrian basement complex rock group, which underlies much of Ekiti State. The temperature of this area is almost uniform throughout the year; with little deviation from the mean annual temperature of 270ºC. The hottest period is between February and March with temperature between 280ºC and 290ºC respectively while the coolest period is June with temperature of 250ºC. The mean annual total rainfall is 1367mm with a low co-efficient variation of about 10%. Rainfall is highly seasonal with well-marked wet and dry season. The wet season lasts from April to October, with a break in August (Ogundele and Jegede, 2011).

2.2 Treatments and Experimental Plot Layout

The ruggedness of the topography of the experimental plot is characterized by slopes, valleys, and some planes at the suburbs of the area which are used for agricultural purposes. The area is chosen for its suitable soil structure, texture, water retention capacity, loamy fertile soil, nearness to water source (well) and availability of power supply to operate the electric water pump. To characterize the soil at experimental plot, physico- chemical analysis of soil sample from 0-30cm depth was carried out and presented in Table 1. Land preparation involved the use of tractor for ploughing and harrowing. The leveling was done manually by using simple farm implements to make it suitable for undisturbed, unobstructed free flow of water and good crop management. The leveling of the experimental plot was done to avoid stagnate of water in the depressions area whereas higher parts of the area may lack necessary water. This may eventually results to uneven water distribution, uneven crop emergence and uneven early growth, uneven fertilizer distribution and possibly unwanted weeds. Total experimental plot of 150m by 400m was used and the area was divided into three experimental plots.

Table 1

Physico-chemical properties of soil at the experimental plot area

Soil depth Cm	Sand %	Silt %	Clay %	Textural class	Bulk density gcm^{-3}	Water retention at, $cm^3\,cm^{-3}$		Saturated Moisture content cm^3	K_s, $cm\ day^{-1}$	EC dS/m	pH
						0.33 bar	15 bar				
0-30	17	32	43	Clayey	1.38	0.38	0.19	0.42	22.40	4.06	8.8

2.3 Irrigation Layout

The purpose of irrigation layout is to transmit information from engineering plans to the irrigation field. The drip irrigation system employed includes discharge valve, flushing valve, pressure regulator, screen filter, sand filter and filter injection. Centrifugal water pump with

5.5horse power (hp) capacity driven by an electric motor was used to draw irrigation water from the two storage tank (iron) at elevation of 12m as shown in plate 1. The storage tank serve as water reservoir where the main pipeline is connected to sub main pipelines 240, 40m long and 63mm, 38mm in diameter respectively, and made of Polyvinyl Chloride (PVC). It was buried at a depth of 20cm. The lateral pipes are made of black Linear Low Density Polyethylene (LLDPE). The twenty laterals is each 40m long and 16mm inside diameter. The laterals were joined to the sub-main at 1m spacing. The discharge from each emitter's is between 2-4 l/h as recommended by (Al-Harbi, Al-Omran and El- Adgham, 2008). Emitters were fixed in each lateral at 20cm spacing that coincides with the plant spacing. Drip laterals were laid in between two rows of okra plants with inline drippers at a spacing of 20 cm. The spacing between plants on the ridges is 20cm as shown plate 2. The drip irrigation system components were laid according to experimental design.

Plate 1: Storage Tank Serves as Reservoir to Supply Water to the Main Pipeline

Plate 2: Supply of Water through Emitter to the Root of the Okra

2.3 Irrigation Requirement and Uniformity Distribution

Climatic data were source from Nigerian Meteorological Agency office, Ado Ekiti which was used in determine the amount of rainfall and other climatic data that were favorable for the crop production. Crop water requirement was calculated using the following formula (Allen, Pereira, Raes, and Smith, 1998)

$$ET_C = ET_O + K_C$$

where: ETc: Crop water requirement (mm/day); ET_o: Reference crop evapotranspiration (mm/day); K_c: Crop coefficient.

Reference crop evapotranspiration (ET_o) was calculated according to Penman-Monteith, as calculated by Allen *et.al*, 1998

$$ET_O = \frac{0.408\Delta(Rn-G)+\alpha\frac{900}{T+273}U\,2(ea-ed)}{\Delta+\alpha(1+0.34U_2}$$

Where: ET_o: Reference crop evaporation (mm/day); Rn: Net radiation at crop surface ($MJ/m^2/day$); G: Soil heat flux ($MJ/m^2/day$); T: Average temperature at 2m height (ºC); (ea-ed): Vapour pressure deficit for measurement at 2m height; U_2: Wind speed at 2m height (m/s); Δ: Slope or vapour pressure Curve (KpaºC); 0.34: Wind coefficient for the reference crop (S/m); Y: Psychometric constant (KPaºC).

The net crop water requirement (N_{CWR}) was calculated by subtracting the monthly effective rainfall (R_{ef}) from crop water requirement (CWR) as:

$$N_{CWR} = CWR - R_{ef}$$

The R_{ef}, (mm) was calculated from the total rainfall (TR) mm, using empirical formula according to USDA Soil Conservation Service;

$$P_e = C \times P_{tot} + d \ ,$$

where: P_e: Effective rainfall (mm/month); P_{tot}: Total rainfall in a given month (mm/month) and C, d are respectively, fixed percentage that accounts for losses from rainfall and deep percolation.

The uniformity distributions of drip irrigation system were determined by using the equation according to Nakayama and Backs, 1981. The rate of discharge (q) was measured 70 emitter's chosen for each system, volumetrically using catch cans, and a stop watch.

$$En = \frac{q_n}{q_{ave}} \ x\ 100$$

The pressure for the drip irrigation was adjusted at 2bar for all the laterals. The discharge rate measurements were repeated three times and the average was taken. A regression analysis was used to analyze the rate of flow reduction. Three (3) representative experimental sites were used for measuring water infiltration in cm/hr following the procedure. Water use efficiency of the crop for each treatment was computed from yield and water requirement data.

2.4 Yield Data and Data Analysis

The okra seeds (3) were planted at 2cm depth with 0.6m interval from each hole. The same amounts of water were applied through drip irrigation to the crop at the same time on the same day to avoid bias. The interval between irrigations was three (3) days for the drip irrigation. The pesticide and fertilizer were applied to control the diseases and increases the quality and quantity of okra yields. The moisture content and soil temperature was measured by means of soil moisture and soil thermometer respectively from the day of planting to the maturity stage of the plants. After one (1) month of sown, data was collected for okra yields include plant height (cm), plant diameter (cm), root length (cm), root weight (g), number of leaves, flowers and buds. Okra yield (kg/ha) was estimated considering the mean yield obtained from the replicated plots under the treatments using sensitive balance. The data collected (height, stem girth, canopy of okra plant and quantity of water used) was analysis using one – way Analysis of Variance (ANOVA) methods. Differences between means were considered significant at $P < 0.05$.

3.0 RESULTS AND DISCUSSION

3.1 Crop Water Requirement and Water Use Efficient

Climatic data and Reference crop Evapotranspiration (ET) is shown in the Table 2. The monthly mean reference of crop evapotranspiration (ET_C) was 6.77mm/day and the water consumption is about 8mm/day for full-grown cup (Sorapong, 2012). Table 3 shows the water requirements for okra for four months which is length of the growing season and the mean okra ETC was 5.31mm/day which agree with that of Abubaker, Alhadi, Shuang-En and Guang-Cheng, 2014 which show a linear relationship between okra production and the amount of water supplied. There was no rainfall during the period that this research was carried out, this make the okra net crop water requirements (N_{CWR}) coincided with $ET_{C.}$ The drip irrigation showed high crop water use efficiency (WUE) of 68.5% as shown in Table 4 during the period that this research was carried out and it was due to moisture conservation under irrigation which is probably due to prevention of deep percolation and evaporation from soil surface at the experimental plots.

Table 2: Mean Monthly Meteorological Data and Mean of Reference Crop Evapotranspiration

Month	Mean temperature°C		Relative humidity %	*WS (m/h)	Sunshine (hrs.)	ET_O mm/day
	max	Min				
Oct	38.25	22.79	39	2.88	11.05	7.65
Nov	34.98	20.88	35	2.56	9.95	6.55
Dec	32.00	13.95	32	2.22	9.80	6.10
Jan	35.20	15.90	29	2.90	9.70	6.78
Mean	35.10	18.83	33.75	2.64	10.13	6.77

*wind speed at height at 2m.

Table 3: Okra Water Requirement and Net Crop Water Requirement

Month	Oct	Nov	Dec	Jan	Mean
ET_O mm/day	7.65	6.55	6.10	6.78	6.77
Kc	0.67	0.71	1.22	0.90	0.88
ET_C mm/day	4.40	4.85	6.25	5.75	5.31
ET_C mm/month	132	145.5	187.5	172.5	159.5

Table 4: Crop WUE of the Okra crop grown under drip irrigation systems

Irrigation method	Yield kg	Total amount of water m^3	WUE kg/m^3
Drip Irrigation	17280	595.5	31.50

3.2 Growth Parameters

3.2.1 Seed Germination

The germination of seed of okra under the conditions of drip irrigation system at experimental plots shows that the higher rate of seed germination at the experimental plots as presented in Table 5. Moreover, there was no significant difference in the germination percentage but there is higher in seed germination percentage in with 3.5%, 3.6 % and 3.8% respectively. According to Oshunsanya *et.al,* 2016, this could have happen because the amount of water flowing from the drip nozzle was completely utilized by the sown seeds without any waste as a result of direct discharge of water at the planted spot in form of droplets with easy absorption by the soil in those experimental plots.

Table 5: Analysis of okra Seed Germination using drip irrigation systems

Experimental Plot(EP)	Seed Germination (Mean) (%)	Standard deviation	Standard error	95% confidence interval mean	
				Lower limit	Upper limit
EP1	94.88a	81.55	16.31	81.20	96.98
EP2	94.4a	78.88	15.78	77.56	95.44
EP3	95.55a	80.66	16.13	79.66	97.45

***** Means with the same alphabet(s) in the same column are not significantly different at P = 5%

3.2.1 Plant Height

The mean plant height of okra under the drip irrigation systems was presented on Table 6. Okra plant height from drip irrigation systems experimental plots shows there was no significant in respect to plant height on the plots at weeks after planting. The height of okra is getting high as the plant is growing every week and there were no significant difference in respect of the height of the plant at all experimental plots where the research were carried out as shown in figure 1. On the average , the plant height on all experimental plots using drip irrigation is around 38.8cm which is in the same trend as report by Oshunsanya *et.al,* 2016; Choudhary *et al.,* 2012. The result justified the fact that the water supplied was available for okra plants under drip irrigation to utilise maximally since water was discharged directly to the root of the plants at low pressure. Also, drip irrigation kept the root zone at the field capacity and this to avoid lack of water for the physiological functions of the plant.

Table 6: Analysis of variance of Plant Height at the Experimental Plots

	Sum of Squares	Df	Mean Square	F	Sig.
Treatments	5917.269	2	2958.635	9.827	.000
Error	10838.426	36	301.067		
Total	16755.695	38			

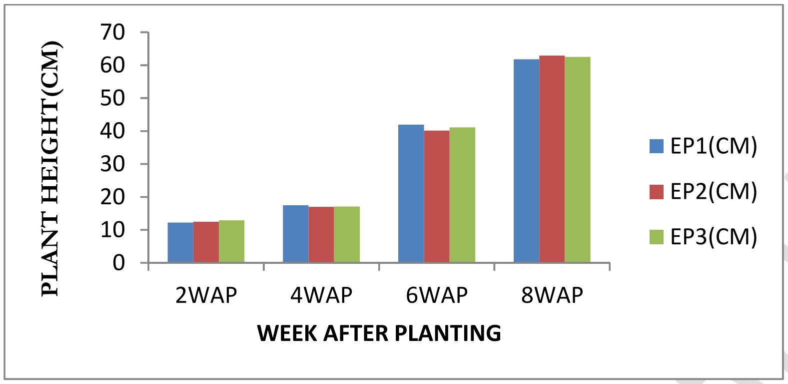

Figure 1: Plant Height at the Experimental Plots

3.2.2 Stem Girth and Number of Leaves

The mean stem girth and number of leaves for various weeks were consistently higher under the drip irrigation method at the experimental plots as shown in Figure 2 and 3 respectively. The numbers of okra leaves are significantly high and they are not different significantly as shown on Table 8 and Figure 3, they are range between 20 and 70 as respect to the weeks after planting. The higher in the number of okra leaves is as a result of photosynthesis under drip irrigation compares to other irrigation systems which could determine to a large extent the assimilates for growth and yield. The significant increase in the stem girth of the plant as shown in Figure 2 by drip irrigation method can be attributed to the conserved soil moisture, seedling emergence and improved emergence. There were no significant difference in stem girth at different experimental plots as shown on Table 7 and this as a result positive significant correlation with yield under drip irrigation methods. The results achieved was similar results reported by Singh and Rajput, 2007 that okra plant grown under drip irrigation had more number leaves and branches than any other irrigation methods and this could be as a result of carbon dioxide exchange rates varied considerably under the drip irrigation methods due to irrigation timings and quantity of water applied (Oshunsanya *et.al,* 2016)

Table 7: Analysis of Variance of Stem Girth at the Experimental Plots

	Sum of Squares	Df	Mean Square	F	Sig.
Treatments	.286	2	.143	2.236	.122
Error	2.303	36	.064		
Total	2.589	38			

Table 8: Analysis of Variance of Number of Leaves at the Experimental Plots

	Sum of Squares	Df	Mean Square	F	Sig.
Treatment	1636657.042	2	818328.521	29.480	.000
Error	1249124.438	45	27758.321		
Total	2885781.479	47			

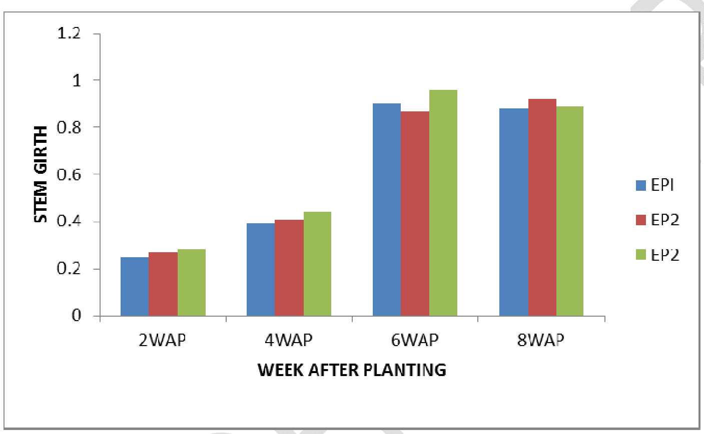

Figure 2: Stem Girth at the Experimental Plots

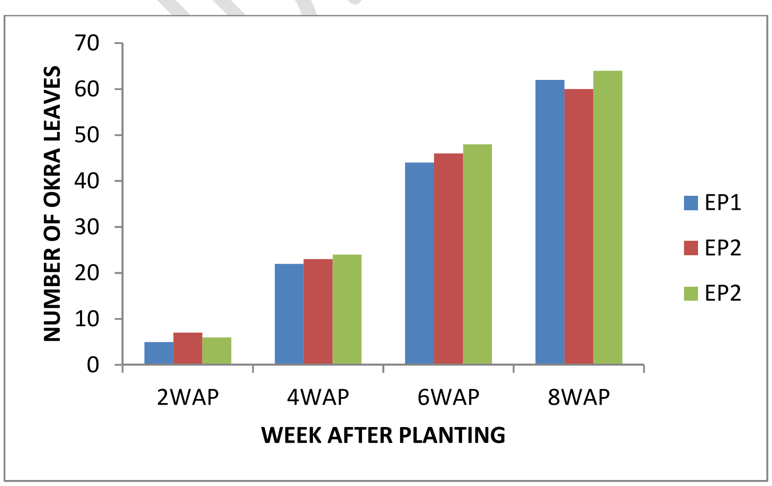

Figure 3: Number of Okra Leaves at the Experimental Plots

3.2.3 Okra Yield (Kg/Ha)

The results of okra yield for sixteen days picking show that there is no significant difference as shown on Table 9. Higher significant fresh okra fruit weight was obtained under drip irrigation between 6th and 8th day of picking as shown on Figure 4. This is because drip irrigation provides a consistent supply of water to the entire root area on a continuous basis so that drench and dry out stress are reduced. This is in agreement with the findings of Anthony and Singandhupe, 2003 who reported that okra yield increase under drip irrigation systems by 20.69% with the water saving of 44.92% which further says that the plants receive drip irrigation than any other irrigation systems. Regular and often use of drip irrigation results in maintaining moisture conditions in the crop root zone leading to higher water as well as nutrient availability to the plant (Sharma *et al.*, 2016)

Table 9: Analysis of Variance of Okra Yields at the Experimental Plots

	Sum of Squares	Df	Mean Square	F	Sig.
Treatment	1636657.042	2	818328.521	29.480	.000
Error	1249124.438	45	27758.321		
Total	2885781.479	47			

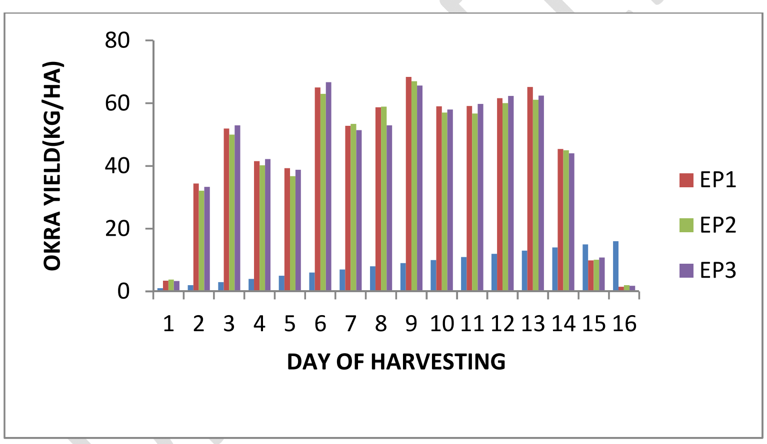

Figure 4: Okra Yield at the Experimental Plots

CONCLUSION

The hydraulic performance of drip irrigation system was evaluated and the performance of the system in terms of average uniformity coefficient, field emission uniformity, absolute emission uniformity and manufacturing coefficient of variation were within the acceptable limit. Drip irrigation method play a significant role in okra production by maxima land utilization and as well as water in the production of okra. The study revealed better plant growth, high water use efficiency and enhancement in the yield under drip irrigation. The drip irrigation system is more economical and it could be used in places and periods of water scarcity for the production of okra throughout the year by small, medium and large scale farmers. The drip irrigation system also has the tendency to make large quantity of water available to the plants gradually such that there will be no runoff and deep percolation. Although drip irrigation can be tedious in its installation as compared to other irrigation method but it saves time, energy, labour and water during the process of water supply to plants after the drip lines have been laid out. The drip kit irrigation is highly affordable for subsistence farming for sustainability of livelihood.

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