INFLUENCE OF DEFICIT IRRIGATION ON DEVELOPMENT, YIELD AND WATER CONSUMPTION OF OKRA (*Abelmoschus esculentus*) IN OWERRI, NIGERIA.

C. I. OBINECHE[1x], A. P. ORIAKU[2], B.O.UNANKA[3], C.C. Emekachris[4], S. N. AKANDE[5], ,

[1*,3]Department of Agricultural Engineering Technology, Federal College of Land Resources Technology Owerri, Imo State Nigeria
[2]Department of Soil Science Technology, Federal College of Land Resources Technology Owerri, Imo State Nigeria
[4] Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture Umudike, Nigeria
[5]Department of Agricultural Extension and Management Technology, Federal College of Land Resources Technology Owerri, Imo State Nigeria
([*]): Corresponding author. Email: ikechiobineche@gmail.com Tel: (+234) 0803 622 1412

ABSTRACT
This research was conducted on sandy loam soil at Federal College of Land Resources Technology, Owerri Imo State during 2016 dry season planting, to relate evapotranspiration data to yield, and to estimate the yield response of okra using different regimes of deficit drip irrigation. A plot measuring 5 m × 6 m was cleared and subsurface drip irrigation installed. Okra seed was sown 1.5 — 2.5 cm deep, plant distance of 30 x 8 cm, 16 crops per lateral, to ensure proper growth. Four treatments T1, T2, T3 and T4 were used which was connected to a reservoir, supplying water to the emitters under uniform pressure head of 1.5bar. The effects of four different irrigation water management levels on the growth and yield response along each lateral were studied using randomized complete block design (RCBD) with four treatments four replicates. Highest yield was observed under T2 irrigation rate which recorded 2.707 tons ha^{-1}, followed by T3 which had 2.081, T4 had 1.734 and T1 had 1.633 tons ha^{-1}. Results revealed that T2 (80%) application rate recorded the highest yield. This indicates that excess irrigation water in the farm does not increase crop produce, but its application at the correct period and in accurate quantity. Though, water production aimed at okra yield against ET was moderately linear. It shows that 20% of water can be saved by irrigating okra under T2 irrigation regime.
***Keywords**: Irrigation deficit, okra, water use, yield, evapotranspiration.*

INTRODUCTION

In crop production, water supply is a major challenge especially during the dry season in eastern part of Nigeria. It is therefore important to enhance the supply of water for improved crop production using alternative water application methods like drip and sprinkler irrigation. The recent development has been to ensure a more effective delivery system aimed at converting gravity irrigation to drip irrigation system (Abd E-Kader *et al*., 2010). Excessive irrigation water application retards yields, while its insufficiency leads to water stress and hence, reduction in output. Therefore, to attain the greatest of drip irrigation system water scheduling application is vital (Abd E-Kader *et al*., 2010). According to Tiwari et al., 1998 and Zotarelli *et al*., 2009, drip irrigation minimises soil loss due to seepage, through the systematic injection of daily soil water requirement to the root zone of each plant, which results in a balance of soil matric capability in the rhizosphere thereby relieving plants of water stress .The yield, growth of most vegetables are influenced by water stress (Sasani *et al*., 2004). This however impacts on the growth and quality of the crop. It is thus imperative that irrigation technologies and irrigation scheduling are used to optimize inadequate water supply. Using improved irrigation techniques to improve water use proficiency in agricultural sector is of great importance (Punthakey and Gamage, 2006). Another way through which water use efficiency can boost harvest per unit of moisture is through deficit irrigation.

Abelmoschus esculentus L. Moench okra is a plant widely grown around the world. It may either be grown as a single crop or inter-cropped with another crop (Emuh *et al*. 2006). Okra as a vegetable is found to exist as a malvaceae clan. The origin of okra has been traced to Africa and Asia (Konyeha and Alatise, 2013). It is said to content some nutrients such as carbohydrate, protein, fats, minerals and vitamins in the human diet (Abd E-Kader *et al*., 2010). The interest in the commercial production of okra was reawakened by the nutritional values of the crop. Abd E-Kader *et al*. (2010) reported that the appropriate temperatures of okra ranges from 18 — 35˚C. In Nigeria, okra crop is also widely cultivated throughout the country either as a single or in mixed cropping systems probably as a result of its high adaptability to different soil types and general acceptability for use as vegetable (Konyeha and Alatise 2013).

The localized application of water to the plant roots in drip irrigation system reduces surface evaporation, runoff and deep percolation which usually lead to about 60% savings in water use compared to the conventional irrigation (Santiniketan and Bharati, 1994). Considering the current demand of agricultural produce and okra crop being a very important agricultural product there is need to make it available in and out of season. Normal consumptive water use is the evapotranspiration that occurs when crops produce average yields which is to be determined by plotting the average yield on crop-production functions. The major basis of irrigation is to supply appropriate moisture for plant growth. The yield (y) and responses on varying levels of water input are used to describe relationships in crop water management application. Vaux and Pruitt (1983) reviewed several works were ET production functions (ETPF) were derived for different species of agricultural crops. They concluded that the produce of a particular crop can be described as a linear function of cumulative ET generally; they quoted some literatures were Y and ET curvilinear relationships were discovered. Igbadun *et al*. (2007) reported crop water production functions as an important tool in irrigation water application management. Crop water production functions vary among crop varieties and climatic zone. The relationship and interaction between crop yields and water applied are found through water production function (Mao *et al*., 2003). Many decisions on irrigation management are made without due consideration on the effect of limited Irrigation on crop yield. Hence, the relationships between crop yield and water availability need to be utilized. Therefore the relationships between crop water requirement, crop water deficit, maximum and actual crop yield can be determined through quantifications. Water stress in crops can be estimated by the relationships between the rates of actual evapotranspiration (ETa) against the rate of maximum evapotranspiration (ETm). When crop water requirements are met completely, through water supplied, therefore ETa = ETm; though, when the supplied water is deficient, Eta < ETm. The cop water –production (CWP) is the relationship between crop water use/yield, the effect of both timing and the amount of available moisture. Influences of interactions on plant stress are complex; they include periods of the developing period. The aim of the study is to determine the effect of deficit irrigation on growth, yield and water use ok okra. The above development formed the basis for this research work in Owerri south-eastern Nigeria.

MATERIALS AND METHODS

Federal College of Land Resources Technology Owerri (FECOLART) demonstration farm is located at Oforola, Owerri west local government area of Imo State. It lies on latitude 5° 12′N and longitude 6° 38'E. The study area is about 7km from Owerri the Imo State capital. The area has mean annual rainfall ranging from 2000 mm to 2500 mm, a mean temperature of 27℃ and humidity of between 70 % and 80 %. The climatic condition of the area favours the production of vegetables (okra, scent leaf) cassava, pineapple and plantains. The average slope of the area is 2 % (Chukwu, 2009). Owerri is in the humid tropical climate region and is characterized by two distinct seasons (wet and dry season). The wet season occurs between April and October, while the dry season is experienced during the remaining months of the year (October to March), though most times wet season encroaches into the month of November and beyond. The area is known to be endowed with sandy loam type of soil (Chukwu, 2009)

The randomized complete block design (RCBD) was used, four rows, four treatments (T1, T2, T3 and T4) and four replications (R1, R2, R3 and R4). The drip irrigation system was installed and the soil wetted overnight at field capacity. It was left for 48 hours to permit full drainage. The *Abelmoschus esculantus* L. (Pusa Sawani) was planted on the plot area marked 5 x 6 m, distance between each lateral was 1.2 m. Okra seed was sown 1.5 ─ 2.5 cm deep and planting distance 30 x 8 cm. Each treatment plot was connected to the same tank, which supplies water to the emitters under uniform pressure head of 1.5 bar. There were four treatments namely T1 (100 %), T2 (80 %), T3 (70 %), and T4 (60 %) of the total water requirement of okra, obtained at 30, 25, 15 and 10 mins irrigation water application, respectively. The analysis of variance of each treatment was done using Genstat version 2008 statistical software package. A significance level of probability ($P<0.05$) was used for all analyses. Relationship between the yield and the amount of water was presented using graphical analysis. Graphical plots and their statistics were generated using Microsoft Excel version 2010 and Genstat version 2008 software packages.

Results of the soil textual class shows that loamy sand at soil profile depths from 0 ─ 15 cm and 15 ─ 30 cm, and sandy loam at 30 ─ 45 cm. It shows no available phosphorus at depth 30 ─ 45 cm. The planting was on January, 2016. Four seeds were sown directly per hole, later thinned to a plant each when about 5 cm tall. The cropped area was applied with a hand full of fertilizer (N P K 15:15:15) 4th weeks after planting to enhance the fertility of the soil. Weeding was done once a week during the course of this study.

The commencing of irrigation application was centered on plant monitoring, the growth stages of the plant, soil type, the rate of evapotranspiration, and the water quality. The Irrigation interval calculated was

Irrigation Procedure

based on evapotranspiration rate, water requirement of the crop, soil-water holding capacity and crop-root depth. Irrigation was effected all through in the project. For estimating purposes generally, the crop growth was divided into four stages as follows initial stage (kc = 0.2), Growing stage (kc = 0.4), intermediate stage (kc = 1.0), and final stage (kc = 0.9) (Allen *et al*., 1998). The land water budget was not used during the experiment. Kc was utilized in the calculation of Etc. A GP tank which collects water through groundwater tapped through borehole supplies the water at uniform head, a pressure gauge was installed to check the pressure of water flowing through the laterals.

Calculation of Amount of Water Irrigated at the Different Growth Stages

A two day application of irrigation regime was used; the amount of water to apply was derived from the calculated reference crop evapotranspiration and the kc of the crop at different growing stages using the formula:

$$PET = \mathrm{rf}\frac{(0.45t+8)(520-R^{1.31})}{100}$$

BMN (Duru, 1984) (2)

Hence, PET = ETo = Potential evapotranspiration (mm day^{-1})

$P =$ Maximum sunshine hour ratio's for the period of interest to the annual maximum.

T = Temperature °C

R = Relative humidity %

Where p can be replaced with rf which is maximum possible radiation ratio to annual maximum.

y represent yield (g ha^{-1}) and C_u represent cumulative water use (mm)

RESULTS

The result of the climatic data in table 1, shows that the ETo during January recorded the highest values when compared to other months of the year 2016. It could be said that evapotranspiration was very high with minimal or no rainfall.

Hydraulic System Efficiency:

The rate of discharge recommended for different online emitters lies between 2 to 4 l hr^{-1} (Sankara and Reddy, 1995; Abd El-Kader *et al*., 2010). Hence, 3.515 l hr^{-1} was calculated under field condition at pressure of 1.5bar. Therefore, the rate of discharge calculated lies between the recommended. The emitters are confirmed to be suitable for the field conditions.

$$ETc = ET = kc.ETo \quad (1)$$

Where: ETc is the evapotranspiration of the crop sample, mm; ETo is the evapotranspiration of reference crop, mm; kc is the coefficient of crop sample.

But ETo was derived from the formula;

The climatic data was collected from the monitoring system and was used in computing evapotranspiration using the Blaney Morin model. Some weather parameters included in the study were total rainfall, relative humidity, sunshine hours and data. The evapotranspiration rate was calculated for the *Abelmoschus esculentus* crop using christened Blaney- Morin evapotranspiration model. The crop water use efficiency was determined using the equation.

$$water\ use\ efficiency\ (WUE) = \frac{y}{C_u} \quad 3$$

Table1. Climatic Data of Federal College of Land Resources Technology Owerri, Imo State, January March, 2016.

No. of Days	Total Rainfall (mm)	Max. Tempt. (°C)	Monthly mean 2016	Relative Humidity (%)	Sunshine Hours	ETo mm $month^{-1}$
31	**0.0**	**34.6**	**January**	**56.9**	**6.2**	**5899.212**
28	**29.4**	**36.8**	**February**	**63.3**	**2.0**	**2157.582**
31	**183.9**	**33.9**	**March**	**81.6**	**4.6**	**4139.832**

Water Use Efficiency (WUE)

The result from Table 2 shows the water use efficiency in the season under review.

Table 2. Water use efficiency (WUE)

Treatment (mm)	Season2 relative yield (tons ha^{-1})	Water use efficiency g ha^{-1} mm^{-1}
T4 (60)	1.73	2.87
T3 (70)	2.08	2.97
T2 (80)	2.71	3.38
T100	1.64	1.63

The height Okra

Table 3 and Figure 1, presents the effect of irrigation application rate result on the height of okra. Plant height increased at $P< 0.05$ of significance on minimum (moderate) irrigation. A 70 mm application obtained at 15mins gave the highest okra height (29.0 cm); 60 mm obtained at 10mins (27.0 cm); 100 mm obtained at 30mins (25.7 cm) and 80 mm obtained at 25mins (24.4 cm), respectively. Graph of crop evapotranspiration (ETc) against total average of okra height in weeks, in the planting season presented in Figure 5.shows that at 8 weeks, 102 cm of okra height was obtained and ETc was highest at 2 weeks

Table 3. Effect of irrigation rate on the height of okra

Amount of Water Applied(mm)	Number of Replication				Average (cm)	ETo mm/weeks	ETc mm/weeks
2nd week	**Rep1**	**Rep2**	**Rep3**	**Rep4**		1179.84	235.968
100	5.0	5.0	5.0	5.0	5.0		
100	5.0	5.0	5.0	5.0	5.0		
100	7.0	7.0	7.0	7.0	7.0		
100	8.0	8.0	8.0	8.0	8.0		
4th week						359.597	143.839
60	9.0	9.2	9.2	9.4	9.2		
70	9.7	9.3	9.5	9.5	9.5		
80	9.0	9.0	9.0	9.0	9.0		
100	10.0	10.0	10.0	10.0	10.0		
6th week						350.00	350.000
60	13.0	13.0	13.0	13.0	13.0		
70	15.0	15.0	15.0	15.0	15.0		
80	15.2	15.4	15.1	15.0	15.18		
100	15.0	15.0	15.0	15.0	15.0		
8th week						827.97	745.173
60	24.0	26.0	27.0	23.0	25.0		
70	28.5	27.5	29.0	27.0	28.0		
80	23.6	24.0	24.4	24.0	24.0		
100	25.0	25.7	24.3	25.0	25.0		

Eto = Potential evapotranspiration, Etc = Crop evapotranspiration

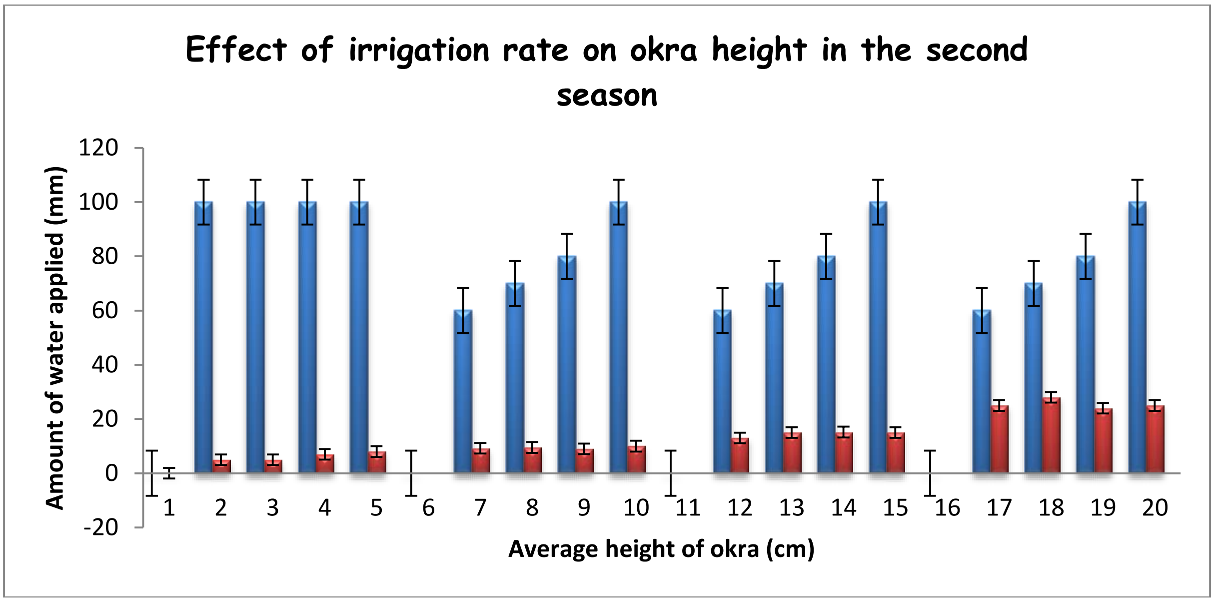

Figure 1: Graph of amount of water applied (mm) against average height of okra (cm) in the second season.

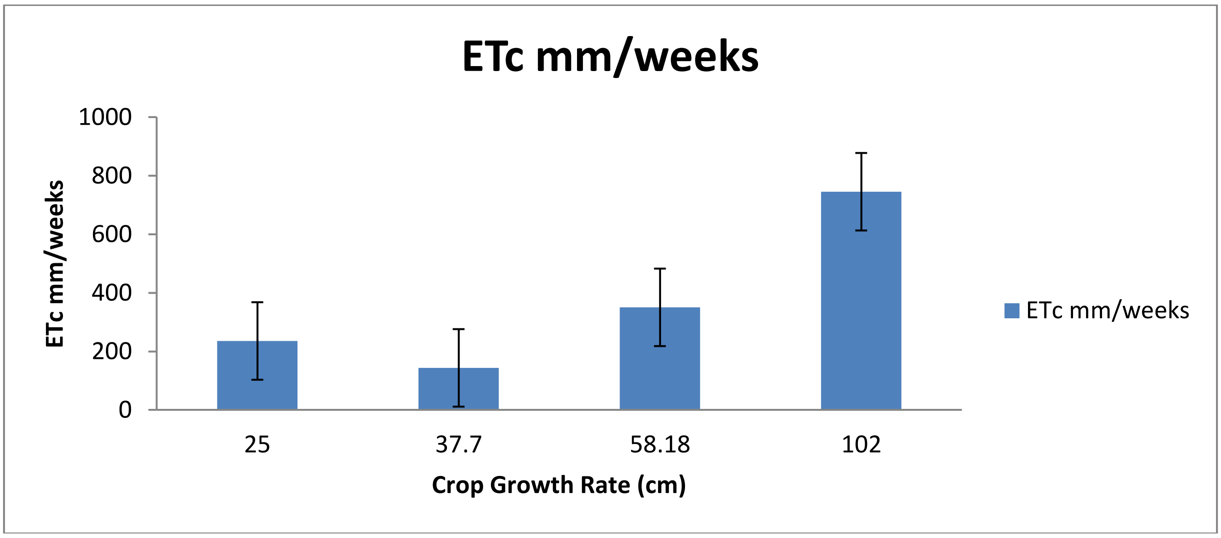

Figure 2. A graph of crop evapotranspiration (ETc) in weeks against total average of crop growth rate in weeks

Diverse levels of applications with respect to okra produce

Effects on diverse levels of irrigation on okra yield results are presented in Table 4A. T2 irrigation application rate records the highest yield of (2.71 tons ha^{-1}) while T3, T4 and T1 had 2.08, 1.73 and 1.63, respectively. This result shows that T2 termed high irrigation application recorded the highest yield. This increase in yield indicates that excess irrigation water in the farm does not compulsory boost crop yield, but its application at the precise time in the accurate amount. The results are in agreement with many investigators (Al Sadon *et al*., 1994; Fredric and Stab, 1989) who studied the effects of different drip irrigation rate application on vegetables (tomato) growth. Konyeha and Alatise (2013) who studied the harvest recorded on using different irrigation approaches in Nigeria, showed that yield response of okra to water use obtained has a great positive relationship range of 0.9584 to 0.997, while yield increase ranges between 1.08 to 2.78 t ha^{-1}, so also Owusu and Annan (2010), noted that treatment T2 (80%) application of ETc did better than the others and the lowliest result was from T4 (60%) application of ETc. Results of the analysis of variance (ANOVA) on okra yield are presented in Table 5. The graph of ETo against yield in the is presented in Figure 2 and 3

Table 4 A: Result of the relative yield of okra (January – March, 2016)

	Number of Replication				
Treatment (mm)	Rep1	Rep2	Rep3	Rep4	Total Yield (tons ha^{-1})
T4 (60)	38.9	46.8	40.8	46.9	1.734
T3 (70)	47.8	49.1	47.6	63.6	2.081
T2 (80)	75.4	65.0	74.0	56.3	2.707
T100	41.1	42.8	39.7	39.7	1.633

Table 5. Analysis of variance (ANOVA) for yield

Variate: Yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	3.4	1.13	0.04	
Rep.*Units* stratum					
Season	1	33.83	33.83	1.07	0.313^{NS}
Amount_of_water	3	2445.64	815.21	25.8	<.001*
Season.Amount_of_water	3	279.03	93.01	2.94	0.057^{NS}
Residual	21	663.58	31.6		
Total	31	3425.48			

*- Significant at P<0.05 level of significance

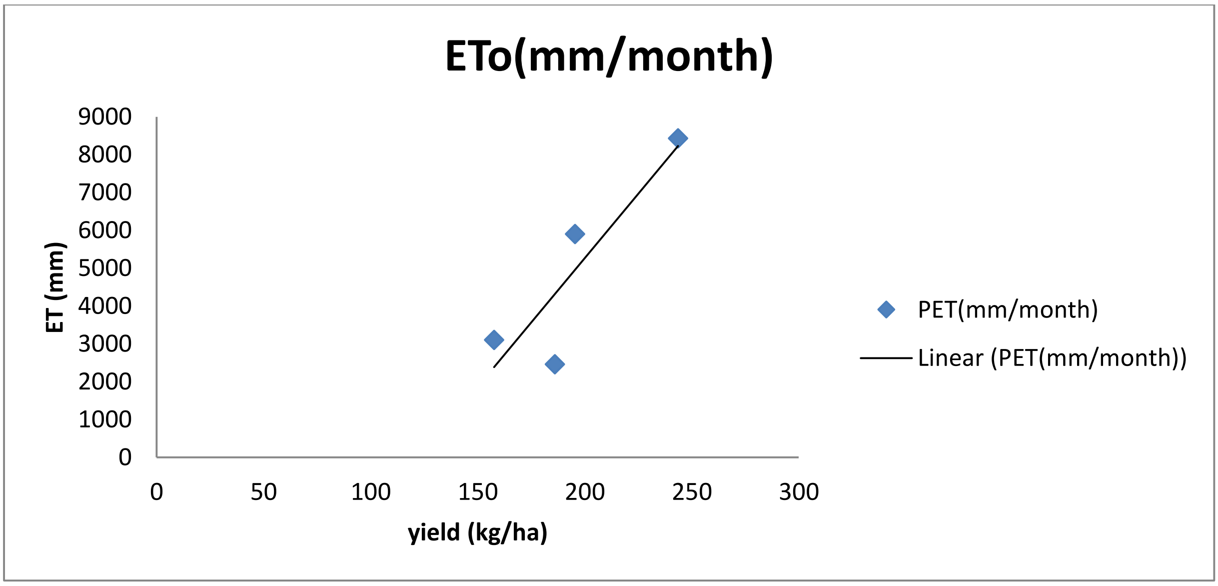

Figure 2: Graph of ETo against yield (kg ha^{-1})

The results of effect of crop evapotranspiration on yield are presented in Figure 2. The graph was linear; this shows that at maximum yield, evapotranspiration was highest.

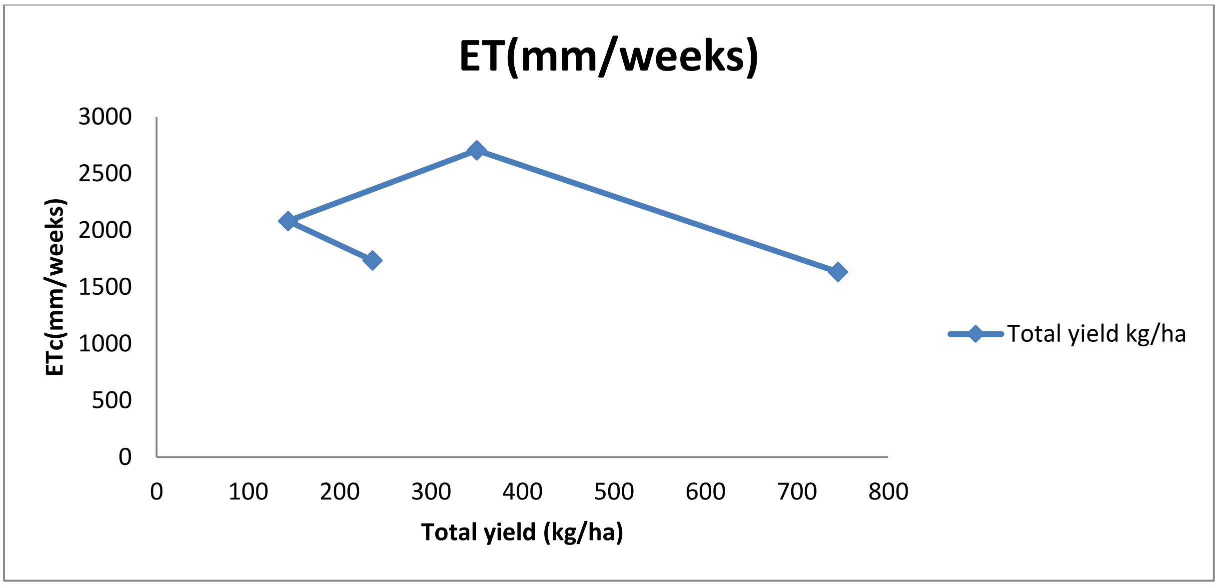

Figure 3. Graph of ETc (mm weeks^{-1}) against yield (kg ha^{-1})

The results from Figure 2 and 3, shows that the graphs were curvilinear, this is in agreement with Vaux and Pruitt (1983), who cited numerous studies in which curvilinear relationships between yield and ET were found. Effect of different irrigation water regime applied to yield in the season is as presented in table 4.

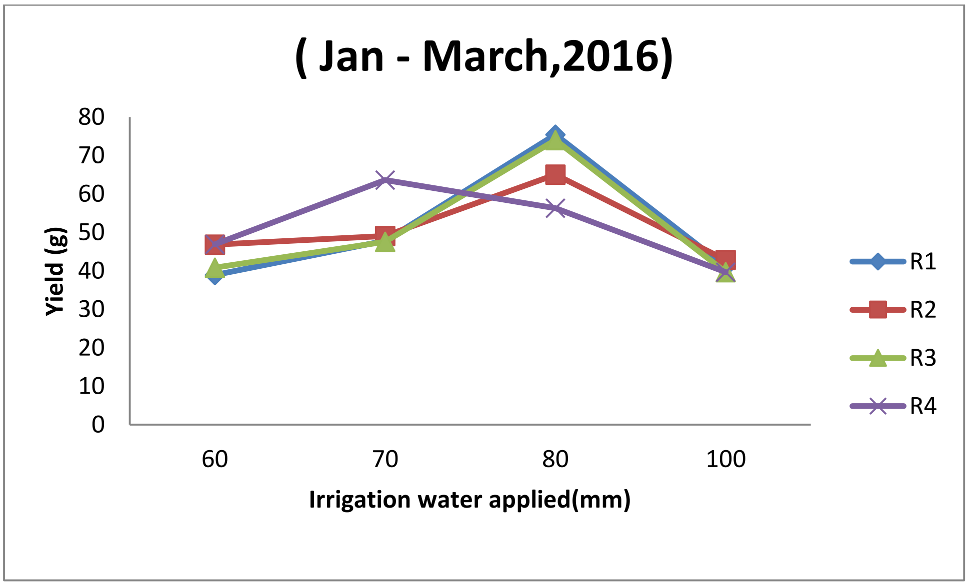

Figure 4: Effect of different irrigation water applied to yield in the season.

CONCLUSION

This study emphasizes on the complexity of the interactions which underlie the productive relationship between crop and water in irrigated agriculture. Due to the lack of a complete knowledge of the relationship between yield response of various crops to alternative levels of moisture stress, the capacity of moisture stressing as a means of economizing on the scarcity water supplies remain undefined, the interest of the article is to evaluate the influence of deficit of irrigation and the contributing factors which could retard the production of okra in areas were moisture supply is minimal or rare. Thus this work gives the confidence required. The above approaches are what this research tends to investigated. Treatment 2, 80% was highest when compared with (treatment 3) 70%, (treatment 1) 100% and (treatment 4) 60%, respectively. This surveillance can be due to the fact that most crops grown under high irrigation have adequate moisture accumulation (reserve) in the root zone so allowing moisture build- up at the crop root zone depth to help cover evapotranspiration and other biochemical requirements.

The water production function with respect to okra yield against ET is relatively curvilinear. This shows that once adequate moisture is available from rainfall or irrigation okra production will not be at risk. Lastly okra is likewise efficient in every unit of water utilized and the average value of water consumed is fairly constant over the wide variety of applications. In conclusion it could be stated that water would be used more efficiently in agriculture if it were priced according to its true scarcity value.

It is recommended for the best harvest of okra, treatment 2 (high) irrigation water application should be adopted were necessary, nevertheless anywhere moisture is abstemiously limited, medium (moderate) irrigation treatment should be utilized. This research is recommended as a guide to researchers who will want to work on different irrigation water management regimes; it will also be helpful in crop water production function to optimize okra water use under deficit irrigation.

REFERENCES

Abd El-Kader,A.A., Shaaban,S.M and Abd El-Fattah, M.S. (2010). Effect of irrigation levels and organic compost on okra plants grown in sandy calcareous soil. *Agriculture and Biology Journal of North America. ISSN* Print: 2151 - 7517.

Al Sadon, A.A.,. Wahdan, H.M and. Gab A.A,(1994). Yield potentiality of nine quashes cultivars grown in arid condition. Biological. Science. 3: 97-108.

Allen, R.G., Pereira,L.S., Raes,D. and Smith,M.(1998).crop Evapotranspiration. Guidelines for computing Crop water requirements. In: FAO irrigation and Drainage paper No.56.FAO, Rome.

Chukwu, I.L.(2009). Design and development of Bucket irrigation system for Dry Season Vegetable production at Oforola. HND Thesis, Agric. Engineering Department, Federal College of Land Resources Technology, Owerri.

Duru ,J.O. (1984). Blaney – Morin-Nigeria.Evapotranspiration *Model. Journal of Hydrology, vol. 70, pp 71-83.*

Emuh IF.N., Ofuoku, A.E and Oyefia, E. (2006). Effect of Intercropping Okra (*Hibiscus esculentus*) with Pumpkin *(curcubita Maxima Dulch ex Lam*) on Some Growth Parameters and Economic Yield Of Maize (*zea mays*) andMaximization Of Land Use in a Fadama Soil. Research *Journal of Biological Sciences* 1(1-4):50-54.

Fredric, L.R and Stab J.E. (1989). Combining ability analysis of fruit yield and Quantity in near-homozygous lines derived from cucumber.*Journal American. Society of Horticultural. Science,* 114: 332-338.

Igbadun, H.E., Tarimo, AK.P.R; Salim, B.A and Mahoo, H.F (2007).Evaluation of Selected crop water production functions for an irrigated maize crop Agricultural water management.94,pp1-10

Jayapiratha, V.,Thushyanthy, M. and Sivakumar,S.(2010). Performance Evaluation of Okra (*Abelmoshus esculentus*) Under Drip Irrigation System. Asia *Journal of Agricultural Research,* 4: 139 – 147.

Konyeha, S and Alatise, M.O. (2013). Yield and Water Use of Okra under Water Management Strategies In Akure, South- Western city of Nigeria. International *Journal of Emerging technology and advanced engineering. ISSN 2250- 2459,ISO 9001:2008 volume 3.*

Mao, X., Liu, M., wang, X., Liu, C., Hou, Z. and Shi, J. (2003). Effects of Deficit Irrigation on yield and water use of greenhouse grown cucumber in the North China Plain. Agric. Water Manage, 61:219-228.

Owusu –Sakyere, J.D. and Annan, E. (2010). Effect of deficit irrigation on growth And yield of okra (*Abelmoscus Esculentus*). *Journal of Science and Technology,* Vol 30. No.2,pp128.

Punthakey ,J.F. and Gamage, P.D.N. (2006). Coupled flow and salinity transport Modelling and Assessment of groundwater availability in the Jaffna peninsula, Sri Lanka. Proceeding of 32nd WEDC International Conference 2006, Colombo, Sri Lanka.

Sasani,S., Jahansooz, M.R. and Ahmadi, A. (2004) The effects of deficit irrigation On water use efficiency, yield and quality of forage pearlmillet.http://www.cropscience.org.au/icsc 2004/poster/1/5/1632_ shahryars.htm.

Santiniketan,M.R. and Bharati, V. (1994). Affordable Water Supply and Sanitation.Proceedings of the 20th WEDC international Conference Colombo, (ICC.94),Sri Lanka, pp:432-435.

Sankara,R.G.H. and Reddy, T.Y. (1995). Efficient use of irrigation water. Kalyani Publishers, New Delhi,pp:178-181

Tiwari K.N., Mal, P.k . Singh. R.M, and Chattapadhyay,A.(1998). Response Of Okra (*Abelmoschus esculentus* L. moench) to drip irrigation under Mulch and non-mulch condition. Agricultural Water Management 38.91-102.

Vaux Jr.H.J., and Pruitt,W.O.(1983). Crop Water Production Functions In Hillel,D.(Ed.), Advances in irrigation , Vol.2. Academic Press, New York, pp.62-97.

Zotarelli L., Dukes, M.D.. , cholberg, J.M.S., Munoz-Carpena, R. and Cerman, J.I. (2009).Tomato nitrogen accumulation and fertilizer use efficiency on a Sandy soil, as affected by nitrogen rate and irrigation scheduling. Agricultural water management 96, 1247-12