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Nature and Science

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UTILIZING DEFICIT IRRIGATION TO ENHANCE GROWTH, YIELD AND WATER PRODUCTIVITY PERFORMANCE EFFICIENCY OF OKRA.

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Abstract: The research was conducted at the University of Cape Coast Teaching and Research Farm Cape Coast, Ghana, to investigate the effects of deficit irrigation on the growth and yield of okra in a field experiment. The Randomized Complete Block Design was used for the experiment with four (4) treatments (100%ETc, 90% ETc, 80% ETc, 70% ETc) replicated three (3) times. A two-day irrigation regime was used. Data collection was carried out on plant height, stem girth, number of leaves, leaf area, number of fruits per plants and average fruit weight. One-way analysis of variance was carried out to test for significant ($p<0.005$) as a result of the various treatment imposed. Results revealed that okra subjected to 100% ETc and 90% ETc performed better with respect to the measured parameters and results obtained for both were not statistically significant from each other. It was also observed that the 70% application of ETc gave the poorest results.
[Ransford Opoku Darko, Shouqi Yuan[1], Junping Liu, Som Shadarack Darko, Haofang Yan. **UTILIZING DEFICIT IRRIGATION TO ENHANCE GROWTH, YIELD AND WATER PRODUCTIVITY PERFORMANCE EFFICIENCY OF OKRA.** *Nat Sci* 2022;20(7):66-76]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature. 08. doi:10.7537/marsnsj200722.08.

Keywords: Deficit irrigation, Water Use Efficiency, Yield, Growth, Okra

Introduction

Okra (*Abelmoschus esculentus L. Moench*) a Malvaceae, is a fast growing common annual vegetable widely consumed in Africa. It is a potential oil and protein fruit vegetable crop which also has an exporting value (Makinde & Ayoola 2012). Okra is widely grown primarily for its soft immature fruits or pods. The pods contain a glutinous, sticky substance that is used to thicken soups and stews (Attigah *et al*., 2013). They are boiled or fried and eaten as a vegetable. They can also be cut into pieces, dried and/or powdered and stored for use in soups during the dry season when fresh Okra fruits are scarce. The young leaves are also boiled and used in soups (Norman, 1992). The leaves are further used for medicinal purposes. Okra responds well to fertilizer application (Babatola, 2006). Soil and water management is an essential element in food security, agriculture sector growth and sustainable land management of sub-Saharan Africa, with Ghana being no exception. Irrigated agriculture has been a key contributor to food security, producing nearly 40% of food and agricultural commodities on 17% of agricultural land (FAO, 2012). Irrigated agriculture uses more than 70 % of the water withdrawn from the earth's rivers in developed countries and over 80 % in developing countries**.** There is therefore the need to meet the growing demand for food and this requires increased crop production from less water. Achieving greater efficiency of water use though a challenge, include the use of techniques and practices that deliver a more accurate supply of water to crops. In this context, deficit irrigation can play an important role in increasing water use efficiency (WUE). Deficit Irrigation (DI) is an optimization strategy in which irrigation is applied during drought- sensitive growth stages of a crop. Water restriction is limited to drought-tolerant and the physiological stages, often the vegetative stages and the late ripening period. DI maximizes irrigation water productivity, which is the main limiting factor (English, 1990). In other words, DI aims at stabilizing yields and at obtaining maximum crop water productivity rather than maximum yields (Zhang & Oweis 1999). Excessive water use across several sectors poses a great challenge in drought seasons. The negative impact of climate change takes an extreme toll within the shores of Africa owing to global warming (Adeosun *et al.*, 2018). The extent of water shortage or scarcity varies around the world; the cost of energy required making water available for agriculture, particularly irrigation purposes are general and could be escalating. Thus for this to be achieved, irrigation water application should take knowledge of the need to secure maximum output for each drop of water in terms of crop yield. In view of this, the general objective of the research was to determine the effect of deficit irrigation on the growth and yield of Okra.

Materials and methods

Experimental Site

The study was conducted at the School of Agriculture Teaching and Research Farm of the University of Cape Coast. The soil is classified as sandy clayey loam of the Benya series, a member of Edina Benyaudu compound association. The site lies within the coastal thicket and shrub vegetation zone of Ghana. The peak rainfalls are usually between May-July and September-November. Temperatures are relatively uniform throughout the year with the mean annual temperature around 25ºC during the night and relative humidity is usually around 90% in the afternoon. The mean annual rainfall for the site is between 900mm to 1000mm (Owusu-Sekyere *et al*. 2012).

Experimental Design and Field Layout

The randomized complete block design (RCBD) was used with four treatments 100% ETc, 90% ETc, 80% ETc and 70% ETc which were replicated three times. The site was cleared and cultivated using a plough and harrow. Lining and pegging were done after which the field was divided into plots with each plot measuring 2 m × 2 m and distances within and between the plots were both 0.6m. This was to ensure that cultural practices could be easily carried out.

Soil Analyses

Soil samples were taken from five different places of the field in a 'Z' pattern and were thoroughly mixed together. The resulting sample was divided into four and one sets of opposite quadrants were taken out. This was repeated and each time, other opposite quadrants were taken off until a substantial amount was attained. The sample was then air dried for four days after which it was grounded and then analyzed for nitrogen, phosphorus, potassium, pH, organic carbon and moisture content.

Soil Moisture Content

The soil moisture content was determined using the gravimetric method. Field or wet core soil sample (undisturbed) was weighed and then oven dried at 105°C until a constant weight was obtained. After drying, soil samples were removed from the oven and placed in a desiccator to cool. After cooling, the dry soil sample was weighed and the weight recorded. The percentage of moisture content was then calculated as follows:

% moisture content=(WSW-ODW)/ODW X 100 (1)

where,

WSW = wet core soil sample (g)

ODW = oven dry core soil sample (g)

Soil pH was measured in a 1:2:5 soil-water ratio using a glass electrode pH meter following the method of Rowell (1994). The total nitrogen in the soil was determined by the modified Micro-Kjeldahl method as described by Rowell (1994).

% Nitrogen (N) = (S-B) ×solution volume)/(100×aliquot×sample weight) (2)

Where:

S = Sample titre value

B= Blank titre value

The available phosphorus in the soil samples was determined using the Bray No. 1 method (Nelson & Sommers, 1982) by using ascorbic acid.

μg P g-1 soil = C × dilution factor (3)

Where

C = concentration obtained from the graph.

Potassium was determined using the flame photometer method. The organic carbon content of the soil was determined using the Walkley-Black method (Nelson & Sommers, 1982).

The organic carbon content of the soil was calculated using the formula:

$$\%\ \text{organic carbon} = \frac{(\text{B}-\text{S})\times \text{Morality of F2}+\times 0.300}{\text{Weight of soil}} \times \frac{100}{77} \times 100 \quad (4)$$

Where,

B = Blank titre value

S = Sample titre value

F^{2+} = Iron two

0.300 = 12/4000 = milli-equivalent weight of carbon

100/77 = the factor converting the carbon actually oxidized to total carbon

100 = the factor to change from decimal to percentage.

$$\%\ \text{Organic Matter (OM)} = \text{OC} \times \frac{100}{58} \quad (5)$$

Planting

Planting was done after the experimental filed was irrigated to field capacity. Planting was done late afternoon to prevent the seeds from scotching, where by a planting density of 2 seeds per hole were adopted however thinning out was done to one plant per hole when the plants were about 10 cm tall. A planting depth of 4cm was used. The planting distance that was used was 0.4m×0.4m between rows and inter rows. There were 18 plants population per bed. A spacing of 0.6m was left between the plots to serve as a buffer zone in order to aid data collection, cultural practices and weed control.

Irrigation

The commencement of irrigation was based on the plant growth stage, the evapotranspiration rate, soil type and quantity of water for the various periods of growth. Irrigation interval was also based on calculated evapotranspiration rate, the net water requirement of the crop, water holding capacity of the soil and crop-root depth. Irrigation treatment was imposed only after 1 week of germination.

Calculation of the Amount of Water to be Applied

A two-day irrigation interval (irrigation regime) was adopted and the amount of water to be applied each morning was derived from the computed reference crop evapotranspiration and the Kc of the crop at different growth stages by the following formula:

$$ET_C = ET_O \times Kc \quad (6)$$

Where ETc is the crop evapotranspiration (mm), ETo is the reference crop evapotranspiration and Kc the crop coefficient, ETo was obtained as:

$$ET_O = E_P \times E_P \quad (7)$$

Where Ep is the depth of water lost from the evaporation pan, and Kp the pan coefficient used was 0.8.

Evapotranspiration rate was obtained from the US class A evaporation pan

Table 1: Growth stages, E pan reading and kc of okra

Growth stage	E pan reading	Duration	kc
Initial stage	111.24	10	0.40
Developmental stage	88.39	31	0.70
Middle stage	122.8	25	1.0
Late stage	101.05	20	0.90

Kc, adopted from FAO

Data Analysis

Results from the study were analyzed using Genstat statistical software. Analysis of variance (ANOVA) was conducted to measure the significant effect of the experimental factors on the various parameters measured at $p<0.05$.

Results and discussions

Chemical Properties of the Experimental Site

The soil at the experimental site had low nitrogen level of 0.05% but high available P level of 21.5ug g^{-1} (Table 2). The low soil N level could be due to low organic matter content at the study site because organic matter facilitates the presence and activities of soil living organisms. When the presence and activities of soil organic matter are enhanced there is the breakdown of organic matter which leads to the release of nutrients in various forms. From Table 2 moisture content of the soil was 4.45% with organic carbon level of 0.4%. The experimental field is characterized by a with a pH of 6.5 which is slightly acidic (Table 2). According to Gunawardena & Silva (2015), the pH of 6.5 is within the preferred pH range (5-7) for vegetable production. The low levels of as N, K, and OC, therefore, calls for the application of organic manure (Usman, 2015).

Table 2: Soil chemical properties of experimental field

Soil parameter	Value
Moisture content (%)	4.45
pH	6.5
Total N (%)	0.05
Available P (ug g^{-1})	21.5
Exchangeable K ($cmol_c$ Kg^{-1})	0.21
Organic carbon (%)	0.4

Effect of Deficit Irrigation on Plant Height

The effect of deficit irrigation on the plant height of okra is presented in Figure 1. Figure 1 shows that okra plants subjected to 100% ETc performed better in terms of plant height than the other plants subjected to 90% ETc, 80% ETc well as 70% ETc at 2 weeks. The remaining data collection period that is 4, 6 and 8 weeks show very similar growth rates between okra plants subjected to 100% ETc and 90% ETc, 80% ETc well as 70% ETc. At the end of the experiment the highest plant height of 23.21 cm was recorded in okra plants subjected to 100% ETc, this was followed by okra plants subjected to 90% ETc (18.57 cm), 80% ETc (18.25 cm) and 70% ETc (17.08 cm). The result from this study is in tandem with the findings of Owusu-Sekyere & Andoh (2010). The experiment demonstrated that reducing the water requirement of crops beyond a percentage would have a significant impact on the height of okra plants. Water is a major component of plant cells and is the medium in which biological process such as photosynthesis occurs, without adequate moisture, photosynthetic rate of a plant is reduced, when photosynthesis is reduced there is a retrogression of plant growth parameters especially plant height. Also, the difference in height could be due to the increase in water use by plants at the mid-season and late growth stage (Allen *et al*, 1998). When water is available to the plant, the plant grows in height, leaf area, vegetative biomass and root because of increase in the rate of transpiration.

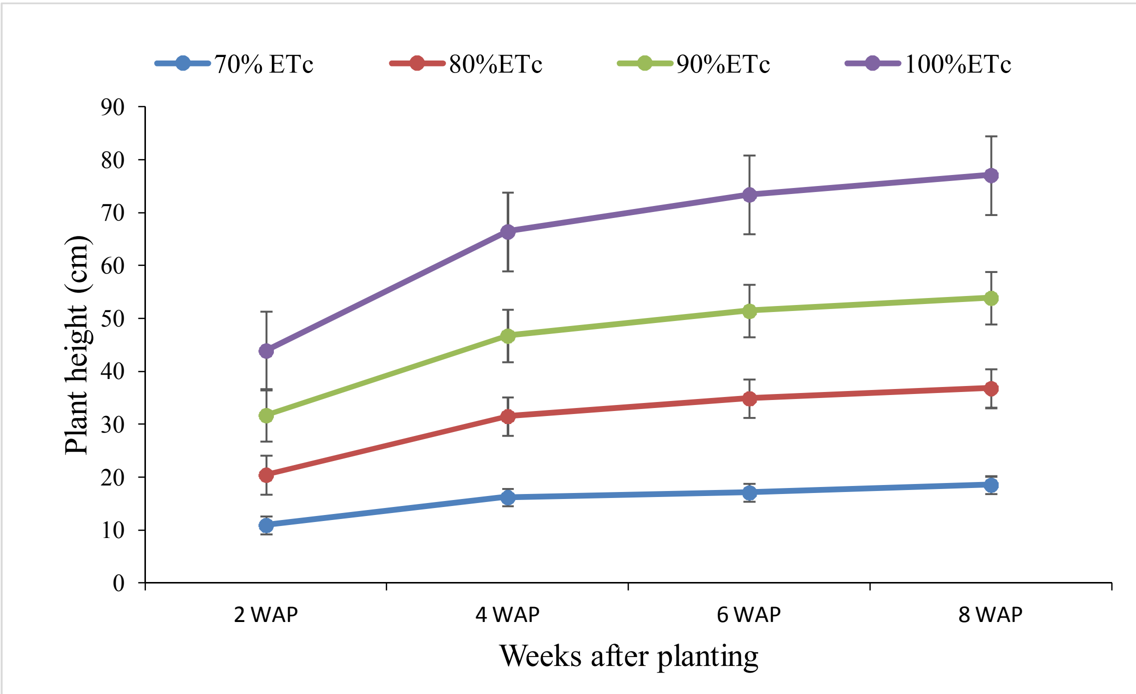

Figure 1: Effect of deficit irrigation on plant height

Effect of Deficit Irrigation on Stem Girth

The response of Okro stem girth to different levels of deficit irrigation is presented in Figure 2. At 2 weeks after planting the highest stem girth was recorded in okro plants exposed to 100% ETc, however, there was a decrease in stem girth observed in okra plants exposed to 90% ETc, 80% ETc and 70% ETc when compared to 100% ETc (Figure 2). A similar trend was recorded at 4 weeks and 6 weeks respectively. At full maturity, the varying levels of deficit irrigation (100% ETc, 90% ETc, 80% ETc and 70% ETc) significantly influenced stem girth of okro. The difference in stem girth could be attributed to the non-availability of water for plant growth due to the reduction of crop water requirement. When available water is less than consumptive water requirement (CWR), the plant reduces or halt its rate of metabolic activities such as photosynthesis (Kramer, 1983), respiration (Wilcox, 1987), transpiration (Craft, 1999) and translocation (Wardlaw, 1968). According to Norman (1995) these important plant metabolic activities, when reduced or haltered hinders the general growth and development of plants. Also, plant under stress would experience difficulty in absorbing essential nutrients because transpiration which is linked with the roles of minerals salt absorbing, cooling and general effect on growth and development is negatively affected (Berie & Berrie 1990).

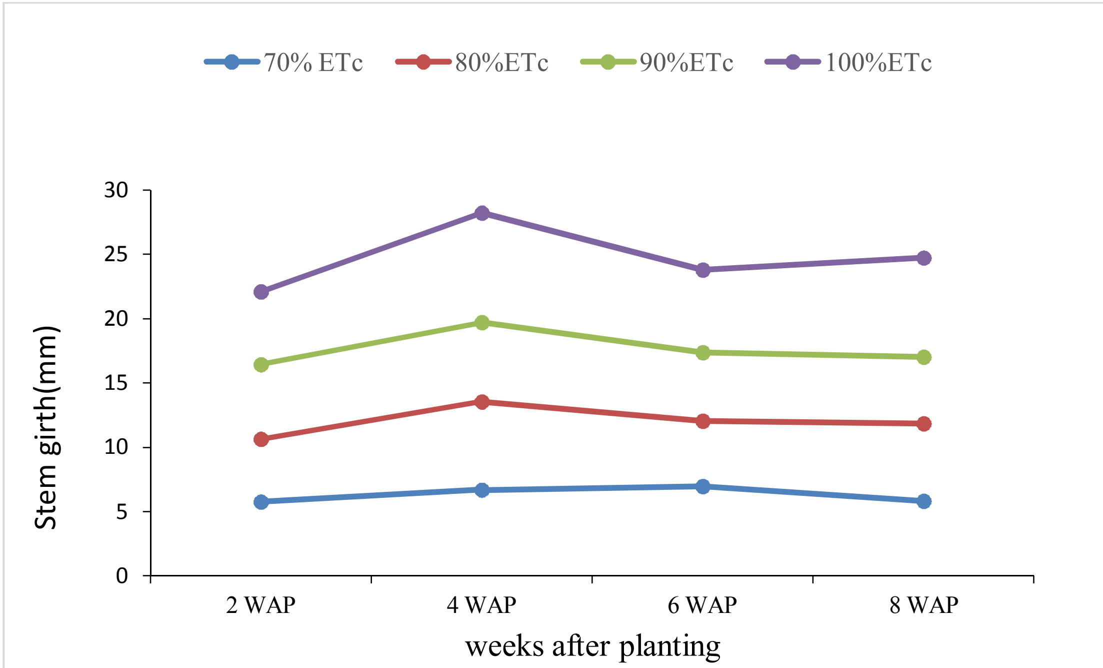

Figure 2: Effect of deficit irrigation on stem girth

Effect of Deficit Irrigation on Number of Leaves

Figure 3 portrays the effect of deficit irrigation on the number of leaves. Data available in Figure 3 demonstrate that okra plant subjected to 100% ETc produced the highest number of leaves compared to other okra plants subjected to 90% ETc, 80% ETc well as 70% ETc. The remaining data collection period that is 4, 6 and 8 weeks exhibited a similar growth rates trend between okra plants subjected to 100% ETc and 90% ETc, 80% ETc well as 70% ETc. At the end of the experiment the highest number of leaves was recorded in okra plants subjected to 100% ETc, this was followed by okra plants subjected to 90% ETc, 80% ETc and 70% ETc. The reduction in the number of leaves as a result of a decrease in the crop evapotranspiration could primarily be due to the amount of water applied during its growth stage. Soil water deficit poses a serious threat to plant production (Abdul Jaleel *et al*., 2007). When plants experience vegetative growth reduction, the absorption of nutrient elements could be decreased (Pascale, 2001). According to Hu & Schmidhalter (1998), water deficit is known to alter a variety of biochemical and physiological processes ranging from photosynthesis to protein synthesis and solute accumulation. Photosynthesis is the process in which plants combine water, carbon dioxide and light to produce carbohydrate for energy, when there is a reduction in critical photosynthetic components such as water there is a negative impact on plant growth. When these happen, leaf growth in terms number will be affected more since they are not able to compensate for moisture stress as compared to other parts of the plants such as the root.

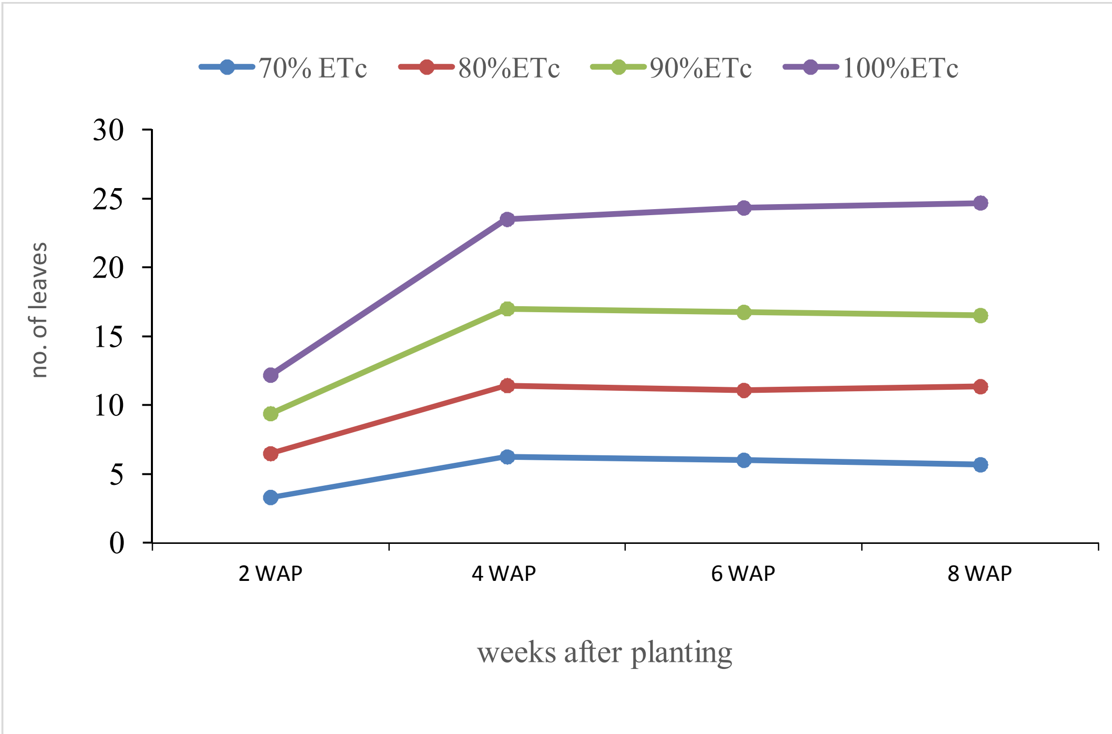

Figure 3: Effect of deficit irrigation on number of leaves

Effect of Deficit Irrigation on Leaf Area

Figure 4 shows the leaf area of okra subjected to different levels of deficit irrigation. This figure illustrates that okra plants subjected to 100 % ETc performed better with respect to leaf area than the okra plants exposed to 90% ETc, 80% ETc and 70% ETc. Analysis of variance was performed on final leaf area measurements to determine the significance difference between averages of leaf area of okra subjected to different levels of deficit irrigation. At 8 weeks, okra plants exposed to 100% ETc exhibited a leaf area of 182.31 cm^2 that was not significantly greater ($p < 0.05$) than leaf area (142.9 cm^2) of okra plants exposed to 90% ETc but significantly greater than leaf area of okra plants exposed to 80% ETc and 70 ETc. However, the leaf area of okra plants subjected to 80% ETc and 70% ETc not significantly different from each other. The results from this study are in agreement with the earlier research of Owusu Sekyere& Annan (2010), where they reported a decrease in leaf area as the crop water requirement was decreased. According to Hsiao & Xu, (2000) leaf growth is very sensitive to water stress and may be inhibited by a slight reduction of water potential in the tissue. Under water deficit conditions, it is assumed that osmotic adjustment in the root occurs before that in the leaf, to enhance turgor pressure for continued root growth and absorption of water and nutrients. Thus, an osmotic adjustment in the root is expected to delay the onset of water deficit in the shoots, which reduces the activity of stomatal conductance and photosynthetic activity (Woodall & Ward 2002). The changes of soil moisture not only significantly affect the spatial distribution of crop roots and the efficiency of nutrition and water adsorption, but also directly affect the biomass of shoots, leaf size inclusive (Benjamin & Nielsen, 2006).

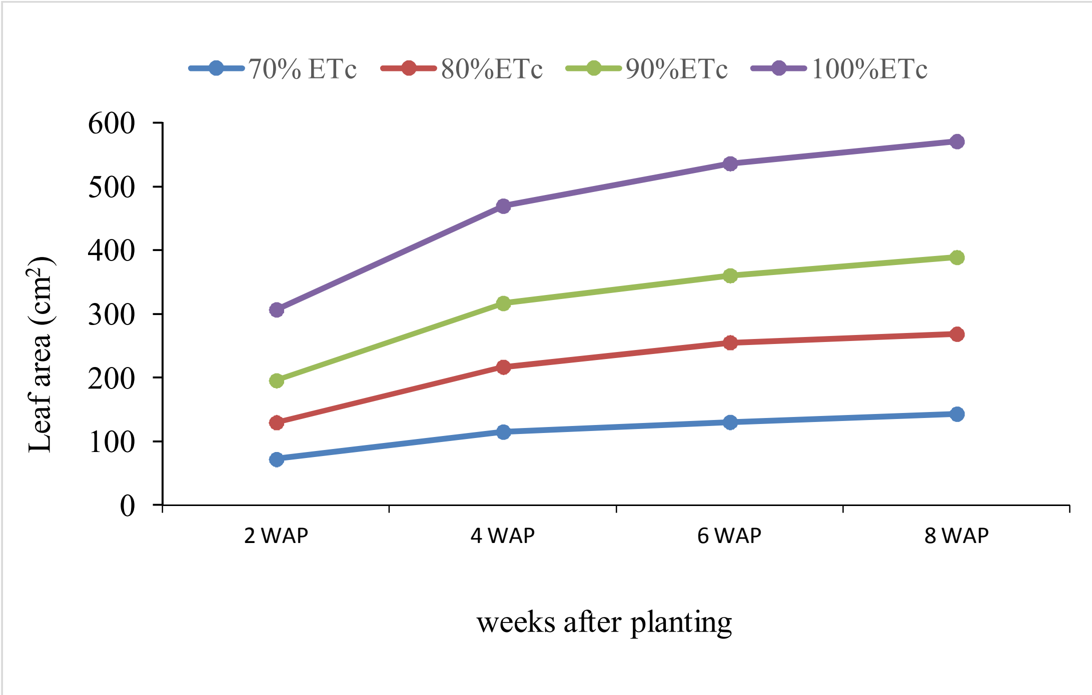

Figure 4: Effect of deficit irrigation on leaf area

Effect of Deficit Irrigation on Number of Fruit/plant

Effect of deficit irrigation on the number of fruits per plant is presented in Figure 5. Okra plants showed an improved number of fruit per plant when exposed to 100% ETc (12.33) followed by okra plants subjected to 90% ETc (8.3) 80% ETc (6.7) and 70% ETc (6.3). Significant ($p < 0.05$) increase in number of fruit per plant was not recorded in okra plant exposed to 100% ETc and 90% ETc (Figure 5). On the contrary, they were both significantly ($p < 0.05$) higher in term of number of fruits per plant compared to okra plants exposed to 80% ETc (6.7) and 70% ETc (6.3). The findings of this research are consistent with the findings of Owusu Sekyere & Annan (2010) and Washington (2015). They reported that the amount of water use to irrigate the okra plant has an effect on the yield parameters of the okra plant. Zodape, *et al.* (2008) reported that the amount of water used to irrigate okro directly affected growth and yield parameters. El-Kader *et al.* (2010) also recorded a similar result. Water stress during these critical periods can affect flowering and fruit sett formation under low moisture conditions. Also, leaf area influences the plant's time of harvesting and quantity of fruit harvested. The amount of intercepted light by a plant has been identified to be influenced by the leaf area index which is affected by the degree or the extent of moisture stress (Ramirez *et al.*,1998), when this happens the yield parameters suffers since a reduction of vegetative growth directly influences yield of okra plants.

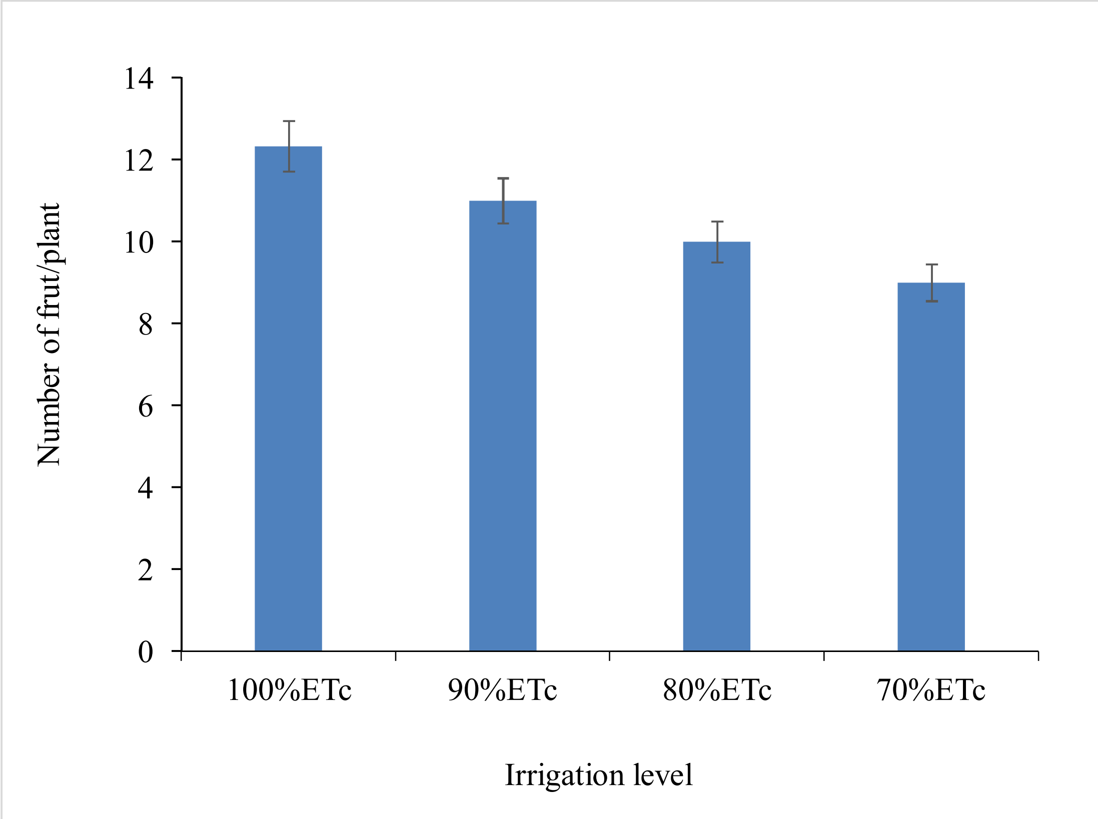

Figure 5: Effect of deficit irrigation on number of fruit/plant

Effect of Deficit Irrigation on Average Weight Per Plant

Figure 6 shows the average fruit weight of the okra plant as influenced by exposure to different deficit irrigation levels. Both okra plant exposed to 100% ETc (32.37 g) and 90% ETc (31.63 g) developed average better fruit weight than the average fruit weight of okra plants exposed to 80% ETc (24.97 g) and 70% ETc (24.50 g). The statistical analysis of data indicates that average fruit weight was significantly affected by different levels of deficit irrigation. There was no significant difference between the average fruit weight of okra exposed to 100% ETc and 90% ETc, yet they were significantly higher than okra plants exposed to 80% ETc and 70% ETc. These results agree with those of Bhatt & Srinivasarao (2005), Singh & Rajput (2007), Bahadur, (2009) and Akande, *et al.* (2010). Water deficit affects growth, development and carbon assimilation and hence reduces the yield of most annual crops (Bradford, 1982). According to Calvache & Reichardt (1999), water deficit during vegetative growth leads to a decline in yield. Sankar *et al.,* (2008) stated that the water stress affects the yield.

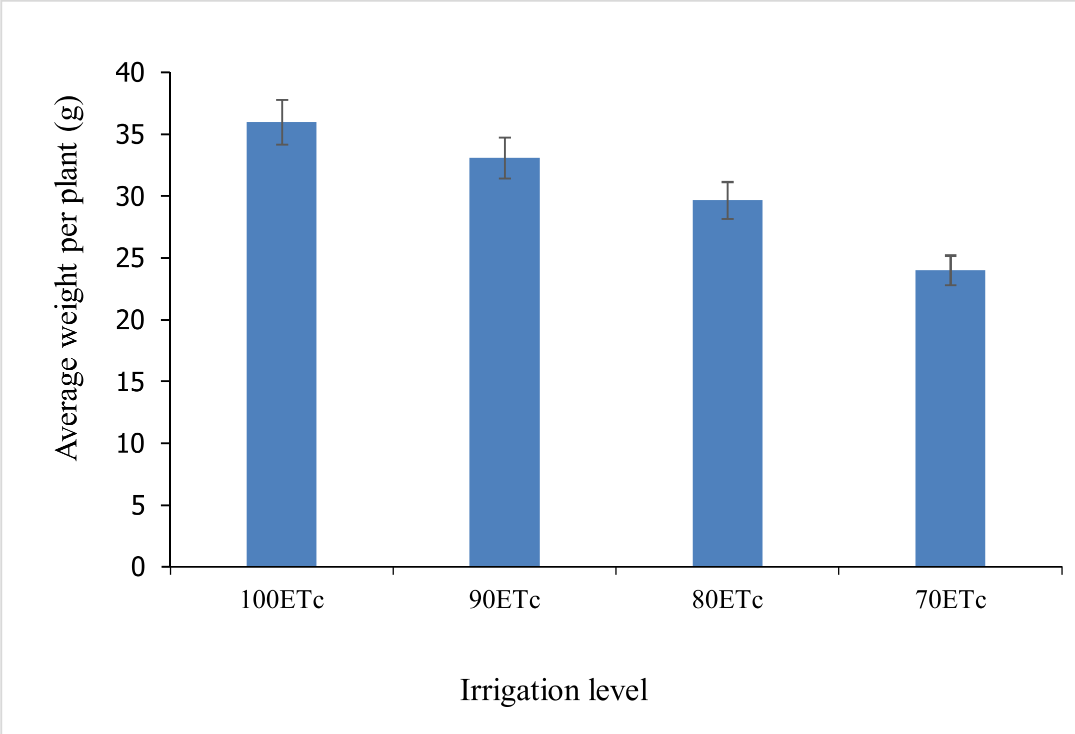

Figure 6: Effect of deficit irrigation on average weight per plant

Effect of Deficit Irrigation on Water use Efficiency

Results of data on water use efficiency (WUE) for all deficit irrigation treatment is in Table 2. It indicates that the highest water use efficiency was exhibited by crops that received 70% ETc (1.724 g/mm) and was significantly higher than the remaining treatments. It can be observed in Table 3 that the lowest water use efficiency (1.502 g/mm) was exhibited by okra crops that received 100% ETc. Likewise, it can also be observed that as the okra plants were exposed to water stress, the water use efficiency of okra plants increased. This result was in agreement with the findings of Wahb-Allah *et al.* (2014). They indicated that WUE decreased with increasing irrigation level. The lowest water level applied (40% ETc) recorded the highest WUE value, whereas the high or medium irrigation level applied (100 or 80% ETc) resulted in the lowest WUE values in that order. A similar tendency was observed by Mahadeen *et al.* (2011) who indicated that the 100% ETc treatment showed the lowest water use efficiency, while 50% ETc showed the maximum WUE.

Table 3: Effect of deficit irrigation on water use efficiency of okra

Deficit irrigation	WUE (g/mm)
100% ETc	1.502 [a]
90% ETc	1.545 [a]
80% ETc	1.594 [a]
70% ETc	1.724 [b]
Lsd (p>0.05)	**0.0744**

CONCLUSION

In this study, the results showed that an amount of water can be saved without significant effect in reducing okra yield. Deficit irrigation that entails reducing crop water requirement (CWR) by more than 20% should be avoided since it has a detrimental effect on growth and yield of the okra plant.

ACKNOWLEDGEMENT

The National key research and development program No.2016YFC0400202, the key teacher training project of Jiangsu University and the Priority Academic Program Development of Jiangsu Higher Education Institutions (PAPD). Also, the University of Cape Coast Teaching and Research Farm, Cape Coast, Ghana is duly acknowledged.

References

[1]. Abdul J, C. A., Manivannan P., Sankar B., Kishorekumar A., Gopi R., Somasundaram R., & Panneerselvam R. (2007). Water deficit stress mitigation by calcium chloride in Catharanthusroseus: effects on oxidative stress, proline metabolism and indole alkaloid accumulation. Colloids and Surfaces B: Biointerfaces, 60 (1), 110–116.

[2]. Adeosun, O. J., Iduwe, W., & Dada, P. O. O. (2018). Water Use Efficiency of Okra Amended with Saw-Dust Under Deficit Irrigation in A Controlled Environment. Irrig. Sci. 11(2), 111-119.

[3]. Akande, M. O., Oluwatoyinbo, F. I., Makinde, E. A., Adepoju, A. S., & Adepoju, I. S. (2010). Response of okra to organic and inorganic fertilization. Nature and Science, 8(11), 261-266.

[4]. Allen, R. G., Pereira L. S., Raes D., & Smith M. (1998). Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements – FAO Irrigation and Drainage Paper 56. Rome, FAO Food and Agriculture Organization of the United Nations, 1–13.

[5]. Attigah, A. S., Asiedu, E. K., Agyarko, K. & Dapaah, H. K. (2013). Growth and Yield of Okra (Abelmoschus esculentus L.) as affected by Organic and Inorganic fertilizer. Nature and Science, 11 (12), 61-67.

[6]. Babatola, L. A (2006). Effect of NPK 15:15:15 on the performance and storage life of okra (Abelmoschus esculentus). Proceedings of the Horticultural Society of Nigeria Conference, pp: 125-128.

[7]. Bahadur, A., Singh, K. P., Rai, A., Verma, A., & Rai, M. (2009). Physiological and yield response of okra (Abelmoschusesculentus) to irrigation scheduling and organic mulching. Indian Journal of Agricultural Sciences, 79(10), 813-15.

[8]. Benjamin J. G & Nielsen D. C. (2006). Water deficit effects on root distribution of soybean, field pea and chickpea. Field Crops Research, 97(2−3), 248−253.

[9]. Berrie, G. K &Berrie, A. (1990) Tropical Plant Science Longman Group. 2nd Ed, UK.

[10]. Bhatt, R. M., & Srinivasarao, R. N. (2005). Influence of pod load on response of okra to water stress. Indian journal of plant physiology, 10(1), 54.

[11]. Bradford, K. J., & Hsiao, T. C (1982). Physiological responses to moderate water stress. In: Physiological plant ecology II. Water relations and carbon assimilation. Encyclopia.

[12]. Calvache, M. & K. Reichardt, (1999). Effects of water stress imposed at different plant growth stages of common bean (Phaseolus vulgaris) on Yield and N_2 Fixation in: Crop Yield Response to Deficit Irrigation, Kirda, C. and D.R Nielson (Eds.)., Kluwer Academic Publishers, Netherlands, p: 121-128.

[13]. Craft A. S. (1999). Solute transport in plants. Plant Science.90: 337-346.

[14]. El-Kader, A., Shaaban, S. M., & El-Fattah, M. (2010). Effect of irrigation levelsand organic compost on okra plants (AbelmoschusesculentusL.) grown in sandy calcareous soil. AgricBiol JN Am, 1(3), 225-231.

[15]. English, M., (1990). Deficit Irrigation. I: Analytical Framework. Journal of Irrigation and Drainage E –ASCE 116, 399-412.

[16]. Food and Agriculture Organization (FAO) (2012). Impact of Globalization on the information needs of farmers in Ghana. Retrieved from http://www.fao.org/3/y4671e/y4671e0c.htm [Accessed on 15th April 2019].

[17]. Gunawardena, M. D. M., & De Silva, C. S. (2015). Impact of induced temperature and water stress on vegetative and reproductive parameters of tomato (Lycopersicum esculentum) variety Rajitha.OUSL Journal, 8, 19–37.

[18]. Hsiao, T. C. & Xu, L. K. (2000). Sensitivity of growth of root versus leaves to water stress; biophysical analysis and relation to water transport. J. Exp. Bot. 51: 1595-1616.

[19]. Hu, Y., & Schmidhalter, U., (1998). Spatial distributions of inorganic ions and carbohydrates contributing to osmotic adjustment in the elongating wheat leaf under saline conditions. Aust. J. Plant hysiol. 25, 591–597.

[20]. Kramer, P. J., Sionit, N., & Tease, I. O., (1983). Effect of Water Stress on Status and Growth. Vol. II. Academic Press (New York). 1968 pp.135.

[21]. Mahadeen A, Mohawesh O, Al-Absi K, & Al-Shareef, W. (2011). Effect of irrigation regimes and frequency on water use efficiency and tomato fruit (Lycopersicon esculentum Mill.) grown under an arid environment. Arch Agron Soil Sci. 57, 105–114.
[22]. Makinde, E.A. & Ayoola, O.T. (2012) Comparative Growth and Yield of Okra with Cow dung and Poultry Manure. American-Eurasian Journal of Sustainable Agriculture, 6(1), 18-23.
[23]. Nelson, D. W., & Sommers, L. W. (1982). Total carbon, organic carbon and organic matter. In: Page AL, Ed. Methods of soil analysis, part 2. Chemical and microbiological properties, 2nd Edition, America Society of Agronomy Inc., Soil Science Society of America Inc., Madison, USA, p. 539-577.
[24]. Norman, J. C., (1992). Tropical Vegetable Crops. Stockwell LTD. Illfracombe. United Kingdom.
[25]. Owusu-Sekyere, J. D., Sam-Amoah, L. K., Teye, E., & Osei, B. P. (2012) Crop Coefficient (Kc), Water requirement and the effect of deficit irrigation on tomato in the coastal savannah zone of Ghana. International Journal of Science and Nature 3(1), 83-87.
[26]. Pascale, S. D., Paradiso, R & Barbieri, G. (2001). Recovery of physiological parameters in Gladiolus under water stress. ColtureProtette. 30 (7),65-69.
[27]. Ramirez, B. V. H. & Harmsen, W. E. (1998). Water vapor flux in agroecosystems: methods and models review. In: Labedski, L. (ed.), Evapotranspiration. INTECH Open Access Publisher, 3-48.
[28]. Rowell, D. L. (1994). Soil Science: Methods and applications. UK: Longman Scientific and Technical.
[29]. Sankar, B., Jaleel, C.A., P. Manivannan, A. Kishorekumar, R. Somasundaram, & Panneerselvam, R. (2008). Relative efficacy of water use in five varieties of Abelmoschus esculentus (L.) Moench. under water-limited conditions. Colloids Surf. B: Biointerfaces, 62: 125–129.
[30]. Singh, D. K., & Rajput, T. B. S. (2007). Response of lateral placement depths of subsurface drip irrigation on okra (Abelmoschusesculentus). International Journal of Plant Production, 1 (1), 73-84.
[31]. Usman, M. (2015). Cow dung, goat and poultry manure and their effects on the average yields and growth parameters of tomato crop. Journal of Biology, Agriculture and Healthcare,5(5), 7–11.
[32]. Wahb-Allah, M., Abdel-Razzak, H., Alsadon, A., & Ibrahim, A. (2014). Growth, yield, fruit quality and water use efficiency of tomato under arbuscular mycorrhizal inoculation and irrigation level treatments. Life Science Journal, 11(2), 109–117.
[33]. Wardlaw, F. (1968). The control and pattern of movement of carbohydrates in plants. Bot. Rev. 34, 79-105.
[34]. Washington, K. T. W. (2015). The Effects of Deficit Irrigation, Deficit Irrigation Chicken Manure and Deficit Irrigation-NPK 15:15:15 Interactions On The Growth And Yield Of Okra (Abelmoschus Esculentus) In Pot And Field Experiments. Unpublished thesis. UNIVERSITY OF CAPE COAST
[35]. Wilcox, J. R. (1987). Soybean Improvement, Production and Uses. 2nd Ed. American Society of Agronomy Madison. Wisconsin, USA. 16, 559-605.
[36]. Woodall, G. S & Ward, B. H. (2002). Soil water relations, crop production and root pruning of a belt of trees. Agricultural Water Management, 53(1−3), 153−169.
[37]. Zhang, H., & Oweis, T. (1999). Water-yield relations and optimal irrigation scheduling of wheat in the Mediterranean region. Agric. Water Manage 38, 195-211.
[38]. Zodape, S. T., Kawarkhe, V. J., Patolia, J. S., & Warade, A. D. (2008). Effect of liquid seaweed fertilizer on yield and quality of okra (Abelmoschusesculentus L.). Bot. Rev. 37, 99-110.

3/2/2022