Journal of Science and Technology, Vol. 30, No. 2 (2010), pp 128

EFFECT OF DEFICIT IRRIGATION ON GROWTH AND YIELD OF OKRO (*ABELMOSCUS ESCULENTUS)*

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ABSTRACT
The study was conducted to determine the effect of deficit irrigation on the growth and yield of the Dwarf Green Long Pod variety of okro (Abelmoschus esculentus). The location of the study was the School of Agriculture Research and Teaching farm of the University of Cape Coast, Cape Coast. Experimental design adopted for the study was the Randomised Complete Block Design and there were four (4) treatments which were replicated three times. Treatments one, two, three and four were the application of 100%, 80%, 70% and 60% of the amount of water lost through evapotranspiration respectively. A daily irrigation water application was used. The study was conducted throughout the four growth stages of okro. The leaf area, number of pods per plant, pod weight, pod length and pod circumference were all measured at the various growth stages. Soil samples from the various treatment plots were analysed before and after 60 days of planting to determine the amount of nitrogen, phosphorus and potassium (N, P, and K). Similarly, moisture contents were determined before planting, at the developmental and mid stage of growth. It was observed that treatment two which was the 80% application of ETc performed better than the others. It was also observed that the 60% application of ET_C gave the poorest results. It can be concluded that irrigating with 80% of estimated water requirement, is the best application for okro.

Keywords: *Deficit irrigation, okro, water, yield, evapotranspiration*

INTRODUCTION

As food requirements increase and water resources decrease, it becomes more and more important to make the best of both rainfed and irrigated crop production (Ahmed, 1999). Previously, crop irrigation requirements did not consider limitations of the available water supplies. Designing of irrigation schemes also did not address situations in which moisture availability was the major constraint on crop yields. However, in arid and semi-arid regions, increasing domestic and industrial demands for water have necessitated major changes in irrigation management and scheduling in order to increase the efficiency of use of water that is allocated to agriculture. Therefore, innovations are needed to increase the efficiency of use of the water that is available (Allen *et. al.,* 1998).

Water stress is usually the main physical limitation to yield and growth of vegetables (Sasani *et al.,* 2004). It has a considerable effect on forage growth, development and quality. Irrigation technologies and irrigation scheduling must therefore be adapted for more effective and rational uses of limited supplies of water. These technologies must not necessarily be based on full crop water requirement, but ones which will be designed to ensure the optimal use of allocated water. There are several agronomic measures such as varying tillage practices, mulching and anti-transpirants which can reduce the demand for irrigation water (Boland *et al.*, 1993). Deficit irrigation is another way in which water use efficiency can be maximized for higher yields per unit of irrigation water

Stegman (1982) reported that the yield of maize, sprinkler irrigated to induce a 30 - 40 percent depletion of available water between irrigations, was not statistically different from the yield obtained with trickle irrigation maintaining near zero water potential in the rootzone. Ziska and Hall (1983) reported that cowpea had the ability to maintain seed yields when subjected to drought during the vegetative stage provided subsequent irrigation intervals did not exceed eight days. The works of Eck *et al*. (1987) and Speck *et al*. (1989) have shown that soybean is amenable to limited irrigation. Stegman *et al*. (1990) indicated that although short-term water stress in soybean during early flowering may result in flower and pod drop in the lower canopy, increased pod set in the upper nodes compensates for this where there is a resumption of normal irrigation. Cotton shows complex responses to deficit irrigation because of its deep root system, its ability to maintain low leaf water potential and to osmotically regulate leaf-turgor pressure (Grimes and Yamada, 1982).

This study is aimed at determining the effect of different irrigation regimes on the growth and development of okro.

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 Benya udu* 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 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 (Asamoah, 1973)

Experimental Design and Field Layout

The randomized complete block design (RCBD) was used with four treatments (T1, T2, T3 and T4) which were replicated three times (R1, R2 andR3). The site was cleared after which a sprinkler was used to wet the soil over night such that it was at field capacity. It was then left for two days to allow maximum drainage. Lining and pegging were done after which the field was divided into plots with each plot measuring 4m×4m and distances within and between the plots were both 1m. This was to ensure that the 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 set of opposite quadrants were taken out. This was repeated and each time, another opposite quadrants was taken off until a substantial amount was attained. The sample was then dried for four days after which it was grounded and then analyzed for nitrogen, phosphorus and potassium. This was done before planting and after 60 days of planting.

Planting

Planting was done on the 20th of January 2009, three days after irrigating the soil to field capacity. Five seeds were sowed per hole by direct seeding and thinned to one plant when about 7.5cm tall. A planting distance of 90cm×90cm was used and there were 16 crops per plot. The sown seeds were irrigated using a 13 litre watering can. Thinning was done twice within the first 9 days and fertilizer application (N: P: K: 15:15:15) was done at the 2nd week of planting at an application rate of 5kg per the $192m^2$ field. A broad spectrum pesticide was used to control pest in the 3rd and 4th weeks and weeding was done at three week intervals after planting. The pesticide used was Dorsban with the active ingredient being chlorpyrifos and it was applied at a rate of $24ml/192m^2$.

Irrigation Procedure

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, net water requirement of the crop, water holding capacity of the soil and crop-root depth. Irrigation was not effected during the last six days of the project. For general estimating purposes, the crop growth was divided into four growth stages and they were as follows (Allen *et al.*, 1998):

Initial stage ($K_C = 0.2$);
Developmental stage ($K_C = 0.4$);
Mid-stage ($K_C = 1.0$), and
Late-season stage ($K_C = 0.9$)

Calculation of Amount of Water Irrigated at the Different Growth Stages

A daily application of water (irrigation regime) was adopted and the amount of water to apply each morning was derived from the computed reference crop evapotranspiration and the Kc of the crop at different growth stages by the following formula:

$$ETc = ETo \times Kc \quad (1)$$

Where

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

$$ETo = Ep \times Kp \quad (2)$$

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

Evapotranspiration rate and amount of rainfall were obtained from the US class A evaporation pan (Allen *et al*., 1998) and a rain gauge sited 300 m away from the project site.

Rainfall

The rainfall events and the amounts that occurred during the period of the experiment were:

14th February, 2009 - 2.43mm
8th March, 2009 - 2.11mm
12th March, 2009 - 1.94mm

A total rainfall of about 6.48mm was received during the experiment. This amount was so small compared to the amount of irrigation water applied and was thus discounted.

The tables below show the amount of water applied at the different growth stages.

Table 1: Water treatments for the Initial Stage (8days)

Treatments	% of water applied after ETC	Amt. of water req. (mm)/8 days	Vol. per plot/8 days (l)	Ave. vol. per plot/ day (l)
T1	100.00	19.2	307.2	38.4
T2	80.00	15.4	246.4	30.8
T3	70.00	13.4	214.4	26.8
T4	60.00	11.5	184.0	23.0

Table 2: Water treatments at the Developmental Stage (30 days)

Treat-ments	% of water applied after ETC	Amt. of water req. (mm)/ 30 days	Vol. per plot/30 days (l)	Ave. vol. per plot/ day (l)
T1	100.00	144	2304	288
T2	80.00	115.2	1843.2	230.4
T3	70.00	100.8	1612.8	201.6
T4	60.00	86.4	1382.4	172.8

Table 3: Water treatments at mid-season Stage (20 days)

Treat-ments	%of water applied after ETC	Amt. of water req. (mm)/ 20 days	Vol. per plot/20 days(1)	Ave. vol. per plot/ day (l)
T1	100.00	220.4	3526.4	440.8
T2	80.00	179	2864	358
T3	70.00	157	2512	314
T4	60.00	134	2144	268

Table 4: Water treatments at the late season stage (15 days)

Treat-ments	% of water applied after ETC	Amt. of water req. (mm)/ 15 days	Vol. per plot/15 days (l)	Ave. vol. per plot/ day (l)
T1	100.00	151	2416	302
T2	80.00	121	1936	242
T3	70.00	106	1696	212
T4	60.00	91	1456	182

Data Collection

The following data were collected throughout the experiment:

a. Number of fruits per plant: This was obtained by counting.
b. Mean fruit length: the lengths of 30 fruits from each plot were taken by means of a thread and ruler.
c. Mean fruit circumference; the circumferences were also measured by means of a thread and a ruler.
d. Moisture content was obtained using the oven dry method
e. NPK levels were obtained in the laboratory

Statistical analysis

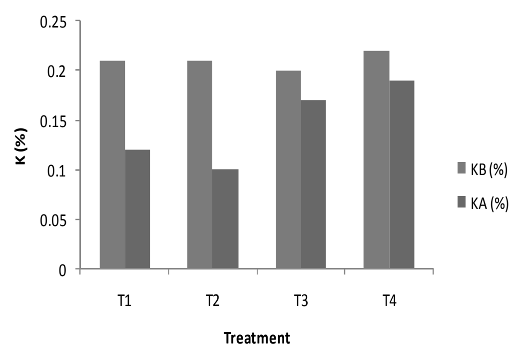
Data collected were subjected to analysis of variance and the means were separated by the Duncan's multiple range test.

RESULTS AND DISCUSSION

NPK levels

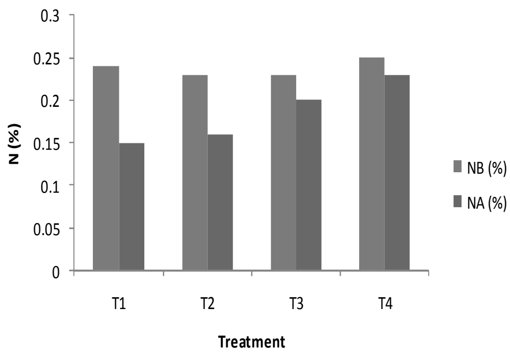
Figure 1 (a), (b), (c) below shows respectively the percentage of potassium, nitrogen and phosphorus contained in soil samples collected from the various treatment plots before the experiment (B) and after 60 days of planting (A).

(a)



It can be seen from Figure 1(a) that the drop in K levels from before planting to 60 days after planting is highest for T2 followed by T1 then T3 and T4.

(b)



(c)

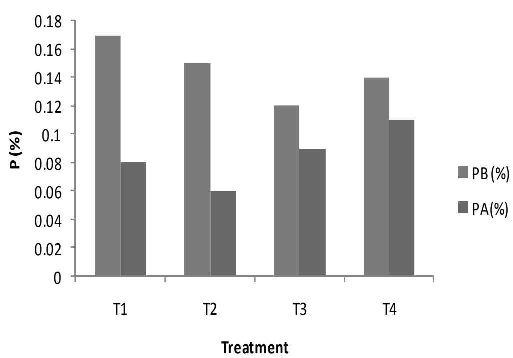


Figure 1: Amounts of Potassium (a), Nitrogen (b) and Phosphorus (c) in the Various Treatment Plots before Planting and 60 Days after Planting

In terms of N (Figure 1(b)) levels however, the drop is greatest for T1 followed by T2, T3 and T4 in that order. In terms of P (Figure 1 (c)), the drop is greatest for T2, followed by T1, T3 and T4 in that order. As the drops indicate utilization, it can be concluded that overall, utilization of nutrients under T2 was greater than for all the other treatments. This could be due to optimum conditions in terms of aeration and moisture availability.

Table 5: Yield Components

Treat-ments	Mean no. of pods/ plant	Mean weight of pod (g)	Mean length of pod (cm)	Mean circ. of pod (cm)
T1	25a	23.10a	7.80ab	2.40
T2	25a	22.30a	8.00a	2.40
T3	22b	19.30ab	7.70ab	2.40
T4	21b	15.00b	6.80b	2.10

Means within a column followed by the same alphabet are not significantly different at 0.05 probability level.

There were significance differences among the treatments for the mean number of pods per plant, the mean weight of pods and the mean pod length. There were however no significant difference among the treatments for the circumference.

The result indicates that T_1 and T_2 produced the highest number of pods per plant of 25 and T_4 gave the lowest number of 21. For the mean number of pods per plant, T1 and T2 were significantly different from T3 and T4.

For the mean weight of pod, T1 had the highest of 23.10g and T4 had the least of 15.00g.
The column for the mean length indicated that T2 had the longest pod of 8.00 cm and T4 had the shortest pod of 6.80 cm.

In terms of the pod circumference, the first three treatments, T1, T2 and T3 measured 2.40 cm with the exception of T4 which was 2.10 cm.

According to Calvache and Reichardt (1999), water deficit during vegetative growth leads to decline in yield. This was evident from the results in Table 3 where T1 and T2 produced 25 pods each while T3 and T4 gave 22 and 21 respectively. T1 which received more water than any other treatment was expected to perform far better than any other treatment yet T2 gave the same number of pods as T1 and it might probably be due to good utilization of nitrogen by the treatment.

The effect of stress on vegetables affects yield quality of which the weight is not an exception (Davenport 1994). However, Behboudian *et al*. (1994) reported that the fruit dry weight in Asian pear was not impaired under water stress. Table 3 above shows that T1 weighed the highest of 23.10g but it was not significantly different from T2 which weighed 22.30g. T3 was 19.30g with T4 weighing 15.00g. T4 was significantly different from the other treatments.

The pod size here comprises both the circumference and length of the pod. According to Boland *et al.* (2000), the leaves of plants will respond to water stress by the closure of their stomata and this will inhibit photosynthesis. West (2004) reported that irrigation increases size and weight of fruit. The low utilization of water deficient crops has poor carbohydrate utilization and therefore fruit decrease in size (Viets, 1999). The results indicate that pod sizes in terms of both length and circumference for the first three treatments were better than for T4.

CONCLUSION

Comparing the various results it was noticed that T_2 and T_1 performed better than the rest of the treatments. However, comparing the outputs to the amount of water used for the two treatments T_2 80% application ETc is considered as the best treatment. The results also showed that T_4 performed poorest among the treatments and that 60% application of the amount of water lost from the soil and the crop through evapotranspiration should be avoided in implementing deficit irrigation. In addition the results confirmed that the vegetative stage of growth of okro suffered the most under deficit irrigation. Conclusively, for higher returns in okro production 80% application of the estimated amount of water lost from the soil and the crop through evapotranspiration should be adopted.

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