EFFECT OF DEFICIT SUB-SURFACE DRIP IRRIGATION ON GROWTH CHARACTERISTICS AND YIELD

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Abstract: -

The challenge of limited water availability for okra crop production due to a decrease in rainfall remains the main problem for many farmers in The Republic of South Sudan, which is exacerbated by effect of climate change. Climate change has a direct effect on the quality and quantity of water for irrigated agriculture. Thus, the reduction of okra crop sufficed for water requirement and water stress to okra crop, which leads to low yield. This study assessed the effect of deficit sub-surface drip irrigation on growth characteristics and yield response of okra crop under various crop water requirements. The controlled irrigation experiment was carried out at Egerton University Tatton Farm under a 20 m x 11 m shade located in sandy-loam soil. The study area was divided into 27 plots, each deficit block measuring 180 cm by 180 cm. Three water applications of deficit irrigation levels 50%, 75% and 100% of the Crop Water Requirements (CWR), were applied to the field. The drip laterals were laid on the soil surface. The spaghetti tubes were buried at 10 cm, 15 cm and 20 cm of depth below the soil surface. The setting of irrigation levels and drip depths were done in three replications. The study used Okra Clemson Spineless (Abelmoschus escullentus) (commonly called Finger Lady), based on agronomic practice. The soil moisture content was monitored at 100% irrigation levels by Tension-meters to determine the crop water requirement. The growth characteristics was affected by different levels of soil moisture content at placement depths. It was observed that, water deficit restricts the crop growth by decreasing the soil-water potential, resulting in reduced number of leaves, the plant height, pod diameter and pod height for some plants. The yield was also affected by different levels of soil moisture content where the least water supply condition (50% ETc) produced the average yield of about (0.03kg) at the top subsurface depth (10cm). And full water supply condition (100 % ETc) produced the lowest yield (0.028 kg) at 20cm placement depth. The result concluded with that the placement depth at 15 cm at 75 % and 10 cm at 50 % and 100 % of deficit irrigation water levels has positive significant effect in regarding of reducing the impact of evaporation losses through soil surface and thus allowing available water of being utilized by the crop at plant root zone.

Index terms: - *Deficit Irrigation, Placement Depth, Growth Characteristics, Yield Productivity*

1. INTRODUCTION

Recently 40% of the world irrigated land is the amount of irrigated crop land listed in India and China and they are among of ten countries accounted worldwide to have two-thirds of the world food produced by irrigated production [1], [2], [3]. Based on the [4], the irrigation systems such as drip irrigation was first introduced in Greenhouse as well as in open field in early 1940s and 1950s in both England and in Israel. The need for irrigation systems such drip irrigation in late 1960s was demonstrated by produced the cheap plastic pipes and fittings irrigation system. Current day's and after more research, the irrigation systems such as drip irrigation system, sprinkler irrigation system and deficit subsurface drip irrigation have showed to be the most effective and efficiently at this time of water scarcity caused by the climate changes.

Limited water availability, increased population, and need for increased food production for food security have led to the need for more efficient irrigation methods- such as drip and sprinkler irrigation. But in some cases, especially when water is applied on the ground surface the applied water is lost due to evaporation because of severe weather conditions that affect agricultural land, thereby affecting the distribution of the amount of water needed at the root zone to meet the plant requirements [5]. Hence, these constraints have resulted in the change from surface irrigation methods to sub-surface drip irrigation to minimise the water losses due to wind, high evaporation losses and surface runoff [6]; [7].

Despite the reduced water losses aimed for under sub-surface drip irrigation, it is further realised that water availability is still not sufficient for meeting the crops' total water requirements in view of other competing water demands. Thus deficit subsurface drip irrigation has been considered as an option to supply less than total water requirement while aiming for optimal crop production. Deficit Sub-surface drip irrigation has been found to be potentially an irrigation method that optimises crop production while conserving the limited available water by reducing water losses due to evaporation, surface runoff; seepage, deep percolation and wind [8].

2.0 MATERIALS AND METHODS

2.1 The Study Area

The study was conducted under shade (rain shelter) within Tatton Farm as shown in Figure 3.1, located at Egerton University at, Latitude 0^{o} 23' S, Longitude 35^{o} 35^{o} E. [9].

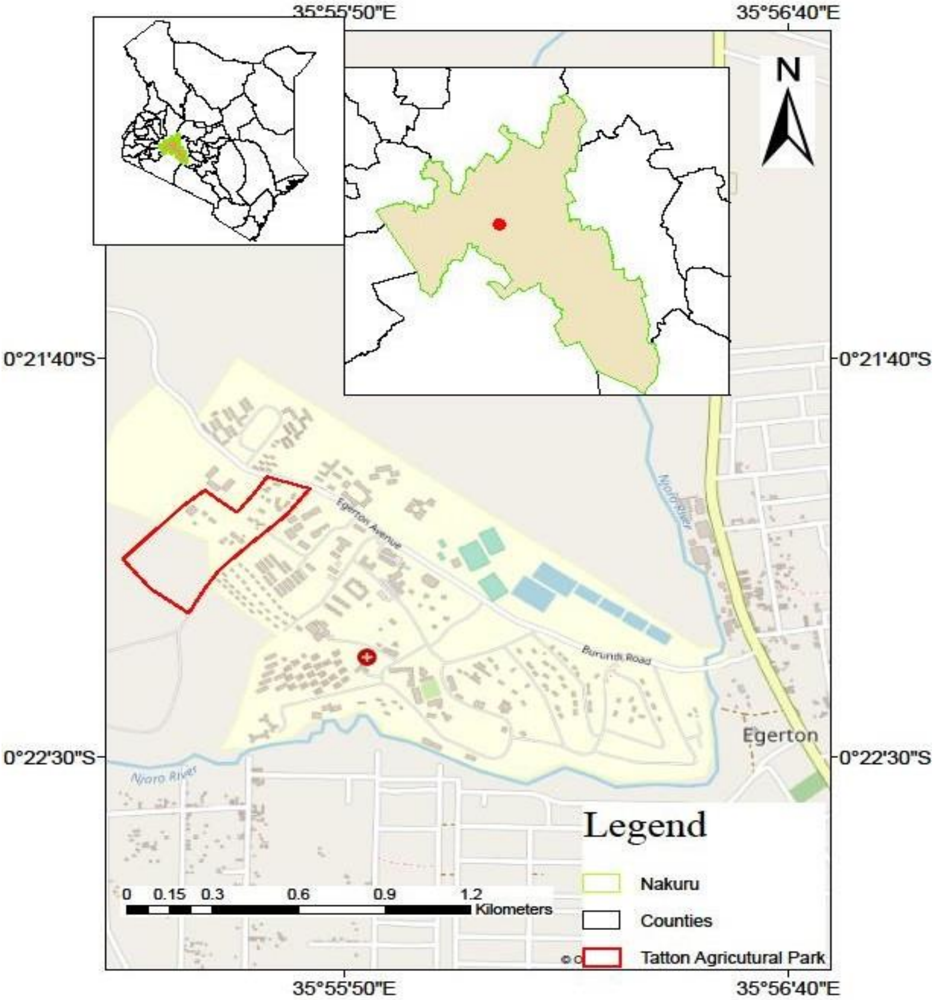


Figure 3.1: Location of Tatton Farm - Egerton University

The experiment was carried out under shade at Tatton Farm, Egerton University. The soil of Egerton is sandy –loam, with good drainage and pH ranging from 6.0 - 6.2. The soil sample for analysis was collected at depths of 0- 10 cm, 10-20 and 20-30 cm to determine moisture content and bulk density. The climate is warm-temperate with an average annual rainfall of about 1020 mm with an annual mean/ average temperature of the area is 21^0 C [10]. The source of water in Egerton is surface runoff from a dam within the Njoro catchment that contributes to the groundwater used as the main water supply to the Egerton community [11].

2.2 Study Parameters

The Deficit Sub-surface Drip irrigation system was constructed with a water source/ reservoir tank (1000 L capacity) at the height of 1.9 m to create pressure head for gravity flow. The reservoir height was 1.9 m. Pressure- compensated drippers/ emitters were used to supply water at a uniform rate so that the different levels of deficit irrigation was achieved by varying the irrigation duration to the individual plots. The deficit irrigation levels of 50% ETc, 75% ETc and 100% ETc were applied at the specified dripper depths 10 cm, 15 cm and 20 cm as per the plot design and irrigation schedules.

2.3 Experimental Design and Layout of Study Plot

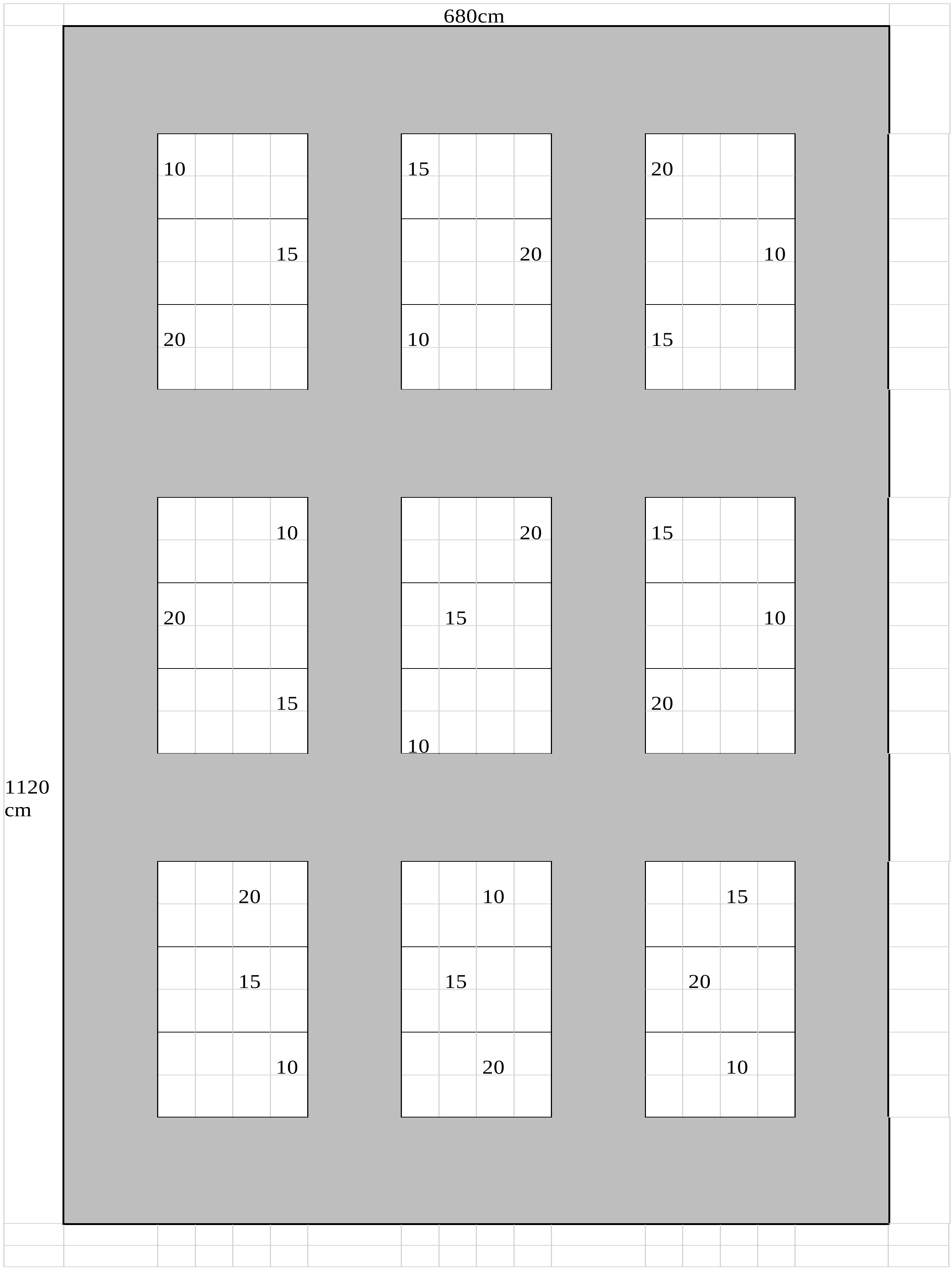
The experiment was carried out between September and January 2021 under rain shade. The research rain shed dimensions were 20 m by 11 m. The irrigation system inlet consisted of filter, control valve, and 25 mm PVC inlet pipe connected to water source. Outlet consisted of a control valve, filter and 25 mm PVC mainlines, sub-mains and laterals. The plots were instrumented with spaghetti tubes (5mm) terminated in flow adjustable emitters (3mm emitters). Each emitter consisted of 8 discharge nozzles. The supply lines were laid over the soil surface along the okra crop rows to deliver the amount of water to the plant root zone through the spaghetti tubes which were attached at the laterals. The Spaghetti tubes were terminated at drippers/emitters which were located at depths of 0 cm (reference/control), and 10 cm, 15 cm and 20 cm respectively below the soil surface. The laterals and emitters were located along the okra crop spacing's with each okra plant having water supply from a single emitter.

Table -3.1: Water deficit and drip depth

Dripper Depth (cm)	Applied water deficit (%ETc)	Replications
10	100	3
	75	3
	50	3
15	100	3
	75	3
	50	3
20	100	3
	75	3
	50	3
Total test plots		27

The plots were blocked for deficit irrigation level such that each block comprised three plots receiving similar irrigation levels treatment. Plots within a block were randomised for emitter depth placement. Emitters were adjusted and calibrated to determine the water application uniformity. Irrigation intervals were applied by varying irrigation time at each crop water evapotranspiration. The treatments were replicated as shown in Table 1. Each study plot was set at dimension of 60 cm by 180 cm with three plots per block. Four (4) plants were planted at each plot at spacings of 60 cm by 45 cm. A buffer area of 100 cm for block separation was provided round the blocks as shown in **Figure 3.2.**

The Okra crop cultivar used for the study was the Clemson Spineless cultivar [12]. It is widely adapted and suited for both fresh market and processed consumption. This is a popular okra variety that grows to about 1.5 m with pods about 7.5 to 12 cm long. It has no spines hence making it manageable for the experiment since intensive handling required called for limited skin irritation. The variety matures in about 55 – 65 days after sowing at a height of 1.2 – 1.5 m at standard growing conditions. It was grown at a spacing of 60 cm by 45 cm.


680cm
1120 cm
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10

		50%	
		75%	
		100%	
	10cm	10	
	15cm	15	
	20cm	20	
		Borders	

Figure -3.2: Study Plots and Treatment layouts

2.4 Study Plots Management

The Okra crop seedbed was ploughed, harrowed, leveled and divided into blocks and plots. The okra crop seeds were soaked in the water and kept the whole night in the water for softened seeds testa. Seeds were planted direct at 5 cm depth, 45 cm between crop and another okra crop space and 60 cm space between rows [13]. Germination and establishment of the seed were facilitated by surface sprinkler irrigation for 3 weeks before the sub-surface drip irrigation schedule is implemented. Once the crop was established subsequent irrigations were applied to the inlet of the plot at three deficit irrigation application levels of 50% ETc, 75% ETc and 100% ETc at the prescribed emitter depths to serve as treatment factors from week three after planting up to harvest time. The application amount of water for irrigation was dependent on the soil moisture conditions, crop growth stages and it was scheduled based on soil moisture deficit levels continuously monitored at the 100% ETc plots by soil moisture sensors (tension-meters).

2.5 Emitters Flow Rate or Emission Uniformity (EU)

The emitters were calibrated to have a uniform emitter discharge of 40ml/min (2.4l/hr). This was confirmed by adjusting the emitters and physically collecting flow discharge using catch-cans. The emitters' emotion uniformity across the blocks and plots were assessed.

Emission Uniformity was estimated based on the Equation of [14].

$$EU = 100\left(1.0 - 1.27\,\frac{C_v}{\sqrt{n_p}}\right)\frac{q_{min}}{q_a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

Where:

EU = Emission Uniformity (%)
Cv = The Manufacturer Coefficient of Variation.
Np = the Number of Emitter per Plant.
$Qmin$ = The Minimum Emitter Discharge on the Lateral (l/h)
Qa = Average Emitter Discharge for Lateral (l/h).

2.6 Crop Water Requirement (CWR)

Crop water requirement (ETc) is the amount of water needed to meet the crops water needs occasioned by the evapotranspiration of the crop. Crop Evapotranspiration (ETc) it is calculated based on the climatic data through direct integration of temporal ETc by multiplying Reference Evapotranspiration (ETo) by crop coefficient Kc [15]. As described by Equation (3.2)

ETc = ETo * Kc ……………………………………………………(3.2) Where;
ETc = Crop Evapotranspiration (mm/d)
ETo = Reference Crop Evapotranspiration (mm/d)
Kc = Crop Coefficient. (Dimensionless)

But crop water requirement in this was calculated based on availability of soil moisture content at plant root zone of the crop through tension meters reading placed at different depths at 100 % ETc levels as reference to determent the daily amount of the water needed by the crop. Soil moisture was recorded for all three blocks at full irrigation levels and deficit irrigation at 75 % and 50 % levels were applied based on the daily moisture reading at 100 % ETc.

2.7 Water Use Efficiency (WUE) and Crop Water Productivity (CWP)

Water Use Efficiency is a measures of the effective use of water for increasing crop yield. Water use efficiency was calculated based on the Equation 3 [16].

$$WUE = \frac{TY}{TWA} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.3)$$

Where:
TY = Total Yield (kg/ha)
TWA = Total Amount of Water Applied (water used in the field (m^3)

Crop Water Productivity (CWP) is the quantitative production of crop produced to the total water applied for crop production. It was assessed based on marketable crop yield depending on the yield components' economic valuation divided by the total water applied to the field.

Crop water productivity (CWP kg/m^3) = $\frac{MY}{TWA}$ ……………………….(3.4)

Where,

MY = Marketable yield (kg/m^2)

TWR = Total Water Applied (m^3)

Water Use Efficiency and crop water productivity were determined and the total yield for the okra crop were recorded during harvest from week one of first harvest to the end of the harvest. Pods were collected after three days of each harvest and the measurement were done using digital weighing balance to determine the yield. Pods yield at different water levels were collected and analysed to estimate the water productivity. At the end of the harvest period, the total yield and the total irrigation water used were evaluated and the total yield (kg/ha) per ha were expressed in (kg). The calculations were determined based on the above equation and the results were described in **Figure 3.7.**

2.8 Assessment of Crop Growth Parameters

The effect of Deficit Sub-Surface Drip Irrigation on crop growth parameters was evaluated by the temporal measurements of the crop growth parameters; including plant height, root development, numbers of leaves per plant, pods diameter, pods length and yield. Growth parameters was determined on a weekly basis for plant height and leaves during growing period starting from the third week of planting. Okra crop yield quantity was measured after three or four days. Root development was measured once after harvest time by cutting soil profile using a ruler and hoe. The plant height measurement was taken from the ground level to the main top of the plant. The plant height, pods diameter, pods height and root development were measured. The productive growth parameters of fruit diameters, fruit length and fruits yield quantity and root development was done at harvest time [17]. The okra fresh market yield or fresh pods were then cuted in the middle using knife for measuring the diamter. The cumlative weight of fruit yield from each plant was determined and total yield of fruit per hectare was calculated. The evaluation was done to determine the variation in okra growth parameters for the different deficit sub-surface drip irrigation levels and different depths.

2.9 Data Analysis

Statistical analysis was performed to evaluate the effect of different irrigation levels and dripper depths on numbers of leaves, plant height, pod diameter, pods height and yield using SAS (MANOVA) at F = 0.05 to show the significant difference between variables to the developmental and production parameters of the okra crop growth. The analysis was carried out by using SAS (MANOVA) based on the study design of a randomized block design for the three dripper depths (10 cm, 15 cm and 20 cm), three water deficit levels of 100% ETc, 75% ETc and 50% ETc, and across the three replication for each combination. Regression of parameter trends was performed to show temporal responses for different treatments.

3.0 RESULTS AND DISCUSSION

3.1 Evaluation of the Effects of Deficit Sub-Surface Drip Irrigation and Placement Depth on Growth Characteristics and Yield of Okra Crop

Assessment of the effect of Deficit Subsurface drip Irrigation of 50 %, 75 %, and 100 % full irrigation had a significant effect on numbers of new leaves, plant height and yield as it is shown in figure3.1, 3.2 and 3.3.

3.2 Evaluation of the Effects of Deficit Sub-surface Drip Irrigation and Placement Depth on Okra Crop Growth Characteristics.

The Okra crop characteristics analysed included the total number of new leaves, plant height, pod diameter and pod height. Figure 3.1 shows the effect of deficit sub-surface drip irrigation and placement depth on Okra crop number of new leaves growth.

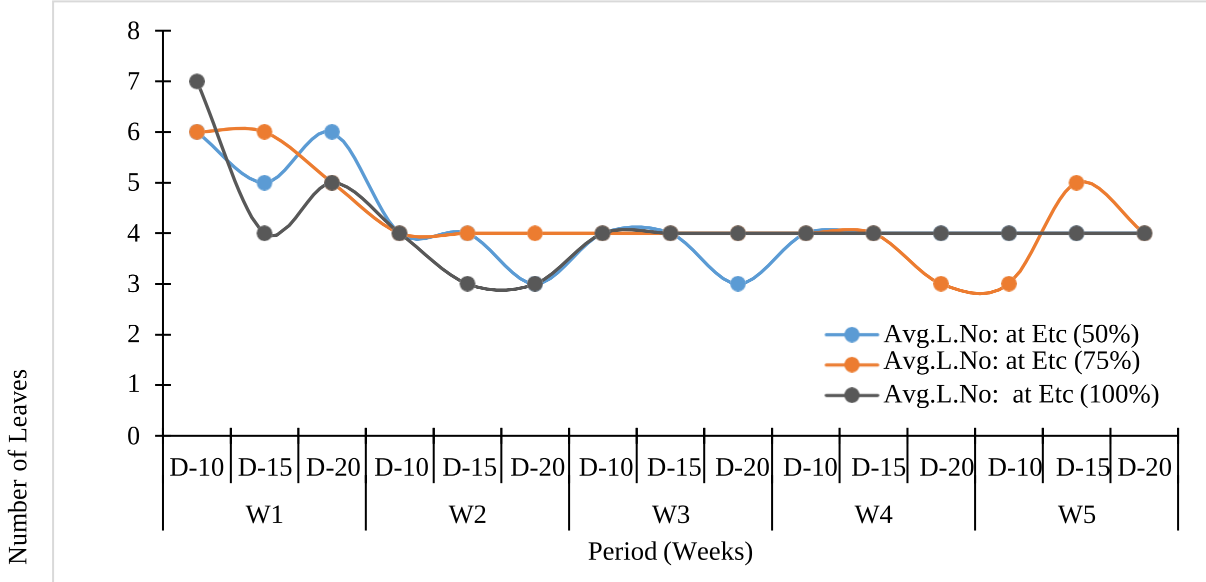
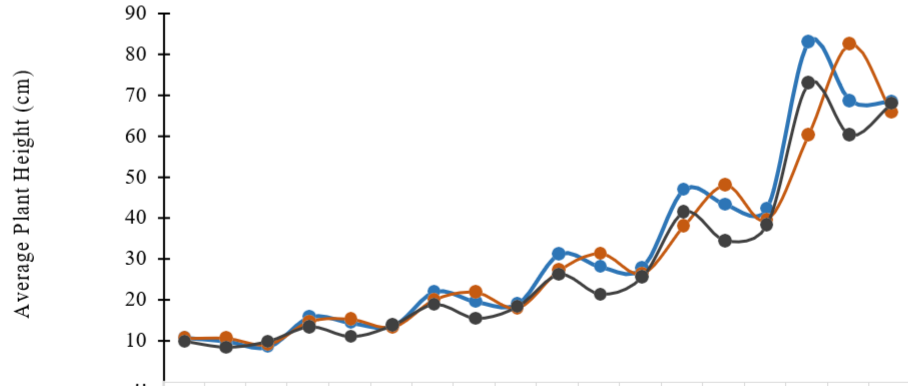


Figure -3.1: Influence of water deficit levels and placement depths on the total number of new leaves growth.

Based on the Figure 3.1, the highest total number of new leaves (23) for placement depth 10 cm were obtained at the 100 % ETc. However, for placement depth 15 cm, the highest total number of new leaves (22) were realised at 75% ETc, while at 20 cm placement depth all the three crop water requirement treatments had same total number of new leaves (20). The variation in the total number of new leaves revealed that the crop growth were influenced by various irrigation levels (ETc at 50, 75, and 100%) and placement depth (10, 15, and 20 cm). The decrease in the total number of new leaves in response to water deficit treatments (at 50 and 75% ETc) was associated with an osmotic adjustment mechanism used by Okra crop to adjust to water-limited environments. Besides, water deficit restricts crop growth by decreasing the soil-water potential, which in turn limits stomatal conductance resulting in reduced photosynthesis and total number of leaves for some plants [18]; [19]; [20] and [21].

It also leads to a reduction in shoot growth and subsequent reduction in fresh and dry biomass. Week one had the highest number of leaves in considering all other subsequent weeks, and there was a progressive decline of the number of leaves for all the placement depths from week one to week five. The temporal decline of leaf numbers was attributed to the fact that Okra shoot and root biomass can decrease significantly under conditions of water deficit but are more pronounced of the water deficit occurs during the first three weeks after planting since plant leaf expansion and taproots development initiate during this period. The findings agreed with other researchers like [22]; [23] and [24].

Figure 3.2 shows the influence of water deficit levels and placement depths on the average of plant height.

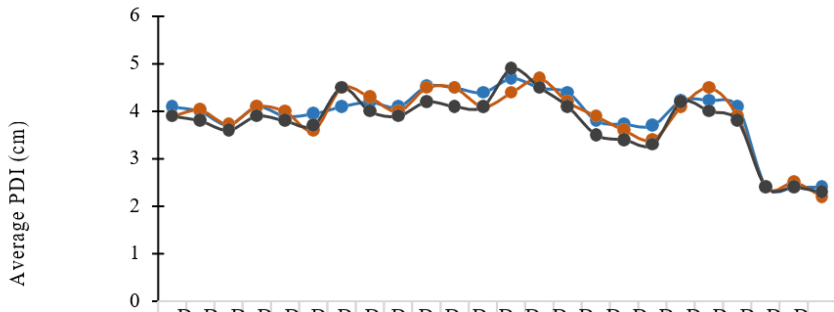


	W1 D-10	W1 D-15	W1 D-20	W2 D-10	W2 D-15	W2 D-20	W3 D-10	W3 D-15	W3 D-20	W4 D-10	W4 D-15	W4 D-20	W5 D-10	W5 D-15	W5 D-20	W6 D-10	W6 D-15	W6 D-20
Avg.H at ETc (50%)	10.8	9.92	8.57	15.9	14.4	13.7	22.1	19.6	19.1	31.3	28.1	27.8	47	43.3	42.3	83.1	68.7	68.5
Avg.H at ETc (75%)	10.6	10.6	9.08	14.8	15.3	13.3	20.1	21.8	18	27.3	31.3	26.4	38.1	48.1	39.5	60.4	82.7	65.9
Avg.Hat ETc (100%)	9.75	8.33	9.79	13.3	10.9	13.8	18.8	15.4	18.3	26.2	21.3	25.6	41.5	34.4	38.3	73.1	60.3	68.1

Period (Week)

Figure 3.2: Influence of water deficit levels and placement depths on the average height

From **figure 3.2** results, averagely at 50%, 75%, and 100 % ETc (treatments), the Okra crop was tallest at placement depth 10cm, 15cm, and 10cm at 50% ETc, 75% ETc and 100% ETc respectively. Okra plant height progressively increased from week one to week 6. The observed Okra crop height variation indicated that shoot development and growth were influenced by different water treatments levels and placement depths, which in turn revealed effects of moisture content variability on Okra crop development. The plant height decrease respond with different water regimes and different placement depths where at limited water supply the reduction in plant height could be attributed to decrease in leaf area, stomatal conductance, and declined net photosynthesis. Moreover, as pointed out in other studies like [25] and [21], water deficit initiates a series of biochemical and physiological processes that result in reduced plant height and growth. Similar finds have also been reported by [26], [27], [23] and [28]. The influence of water deficit levels and placement depth on pods diameter is as presented in **Figure -3.3.**



	W1 D-10	W1 D-15	W1 D-20	W2 D-10	W2 D-15	W2 D-20	W3 D-10	W3 D-15	W3 D-20	W4 D-10	W4 D-15	W4 D-20	W5 D-10	W5 D-15	W5 D-20	W6 D-10	W6 D-15	W6 D-20	W7 D-10	W7 D-15	W7 D-20	W8 D-10	W8 D-15	W8 D-20
Avg.PDDi: at ETc (50%)	4.1	4	3.7	4.1	3.9	4	4.1	4.2	4.1	4.5	4.5	4.4	4.7	4.5	4.4	3.8	3.7	3.7	4.2	4.2	4.1	2.4	2.4	2.4
Avg.PDDi: at ETc (75%)	3.9	4	3.7	4.1	4	3.6	4.5	4.3	4	4.5	4.5	4.1	4.4	4.7	4.2	3.9	3.6	3.4	4.1	4.5	3.9	2.4	2.5	2.2
Avg.PDDi:at ETc (100%)	3.9	3.8	3.6	3.9	3.8	3.7	4.5	4	3.9	4.2	4.1	4.1	4.9	4.5	4.1	3.5	3.4	3.3	4.2	4	3.8	2.4	2.4	2.3

Period (Weeks)

Figure -3.3: Influence of water deficit levels and placement depths on Pods Diameter

Based on figure 3.3 from the first week of harvest results, averagely at 50%, 75%, and 100 % ETc (treatments), the Okra crop pod diameter at placement depth 10 was (2.14 cm), placement depth 15 was (2.14cm) and placement depth 10 cm (2.0 cm) at 50%, 75% and 100% ETc respectively. The pod diameter responded significantly with different soil moisture regimes where at deficit water supply the reduction in pod diameter could be linked to reduced leaf area, stomatal conductance, and decrease in net photosynthesis. The reduction of pods diameter at (W6) to (W7) could be attributed to limited soil moisture regimes at plant roots zone. These observations are consistent with the discussion by [21].

Effect of deficit subsurface drip irrigation and placement depth on pods height

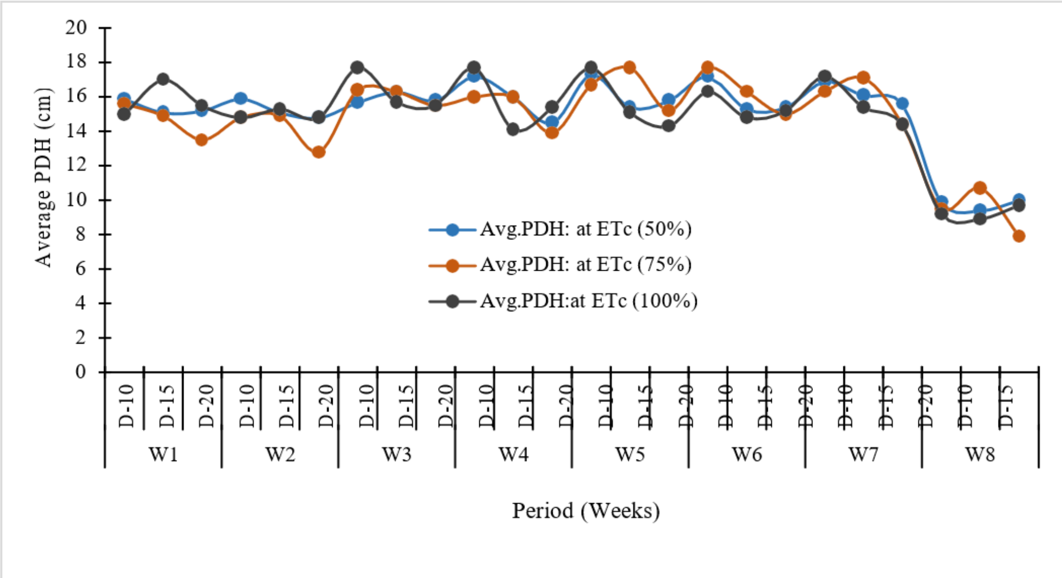


Figure -3.4 Influence of water deficit levels and placement depths on Pods Height

Figure 3.4 results, revealed that on average at 50%, 75%, and 100 % ETc (treatments), the Okra crop pod height was largest at placement depth 10 cm (8.4 cm), 15 cm (8.25 cm) and 10 cm (8.4 cm) respectively. The pod height responded significantly with variations in soil moisture content where at reduced water application the decrease in pod height was associated with reduced leaf area and decline in photosynthetic processes. These results agree with other researchers like [18], [23], [20] and [28].

3.2 Effects of Deficit sub-surface Drip Irrigation and Placement Depth on Okra Crop Yield

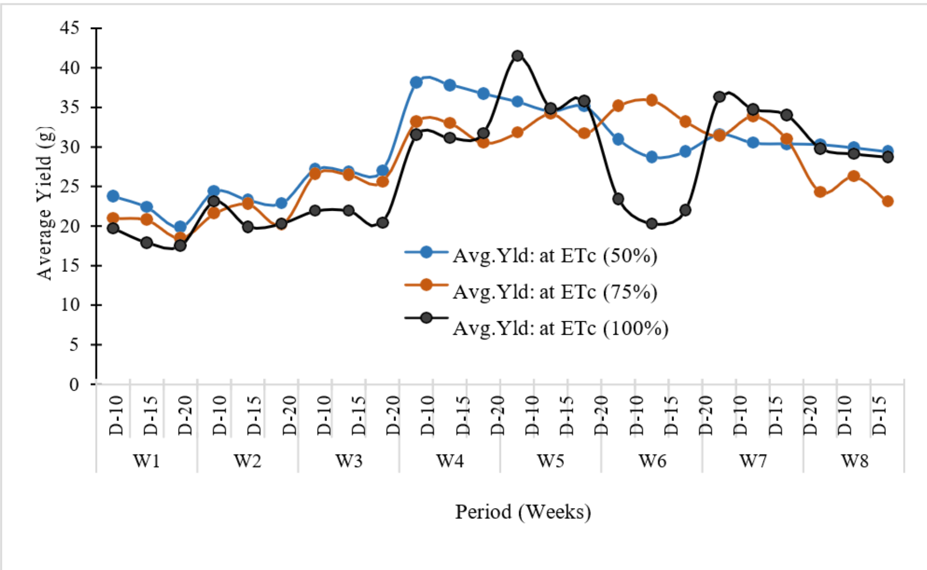
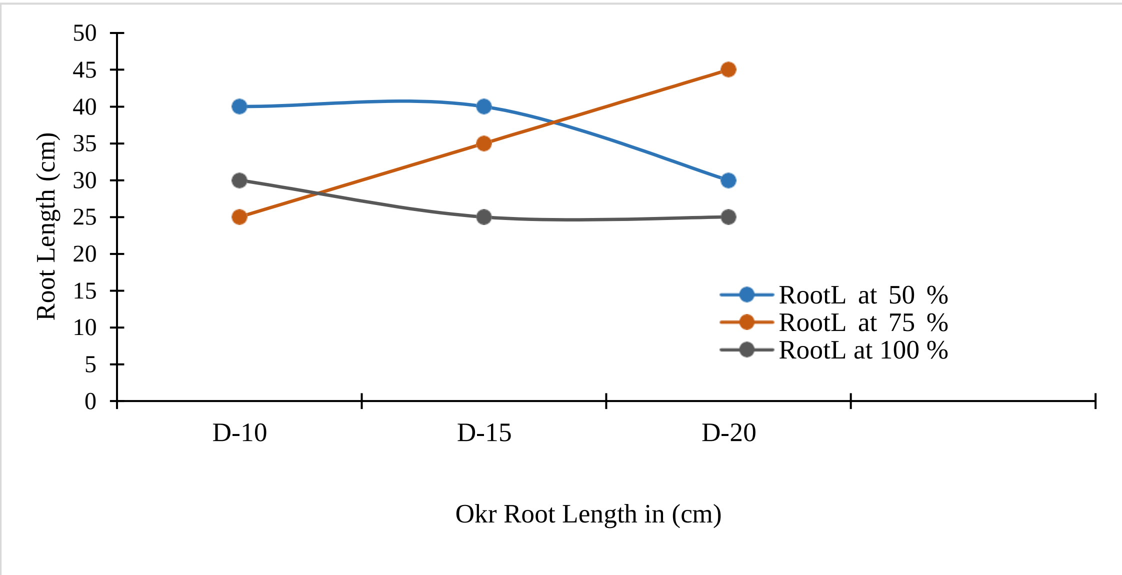


Figure -3.5 Influence of water deficit levels and placement depths on Okra Crop Yield

Deficit irrigation and placement depths had significant effect on crop yield as indicated in Figure 3.5 showing that on averagely at 50% ETc (treatment) the Okra crop yield at placement depth (10cm), (15cm) and (20cm) was (0.03 kg),

(0.029 kg) and (0.028 kg) respectively. Also, at 75% ETc (treatment) yield at placement depth (10cm), (15cm) and (20cm) was (0.028kg), (0.029kg) and (0.026kg) respectively. At 100% ETc (treatment) the yield at placement depth (10cm), (15cm) and (20cm) was (0.028kg), (0.026kg) and (0.026kg) respectively. On average the highest yield was realized at depth 10 at 50 % ETc and the lowest yield at depth (20cm) of 100 % ETc. the okra crop yield responded significantly to the pattern and behaviour exhibited by the growth characteristics (number of leaves, plant height, pod diameter, and pod height). Besides, yield was also affected by different levels of soil moisture content where the least water supply condition (50% ETc) produced a higher yield at the top subsurface depth (10cm). And normal water supply condition (100 % ETc) produced a lowest yield at 20 cm placement depth. Therefore, the findings agreed with [29] in term of application at placement depth 15 cm and disagree with at 50 % of water application levels. Also the finding agree with other researchers such as [30], [31], [28], [32].
Water Use Efficiency (WUE) and Crop Water Productivity (CWP) were assessed based on total crop yield and/ or marketable crop yield depending on the yield components' economic valuation. The fresh marketable yield of about 8884.5 kg was obtained at depth 15 cm at 75 % deficit water levels, 7744.5 kg, depth 10 cm at 50 % of deficit water levels and 7746.5 kg at depth 10 cm of 100 % full irrigation water levels. The lower yield of about 4844.8 kg also was obtained at depth 20 cm at 75 % water deficit levels, at depth 15 cm of 100 % full irrigation water level and depth 15 cm at 50 % water deficit levels respectively. The reduction in fresh pods yield of okra crop was recorded when the allowable moisture content at placement depth 20 cm at 50 %, 75 % was not being well utilized by the plant root zone. This shows that the placement depth at 15 cm at 75 % and 10 cm at 50 % of deficit sub-surface drip irrigation and at depth 10 cm at 100 % of full irrigation water levels has positive significant effect in regarding of reducing the impact of evaporation losses through soil surface and thus allowing available water of being utilized by the crop at plant root zone and to increase the okra crop yield production. it could be due to plant roots concentration at plant root zone that allowed plant to utilized available moisture content at plant root zone compare to the depth 20 cm due to decrease of root concentration at depth 20 cm downward. Therefore, the placement depth of 15 cm at 75 % and 10 cm depth at 50 % of water deficit irrigation were found the best for okra crop optimal yield production for the farmers. The finding agree with/disagree with [30], [33], [34].

3.3 The Effects of Deficit Sub-surface Drip Irrigation and Placement Depth on Okra Crop Root Development (Root Depth and Root Length).



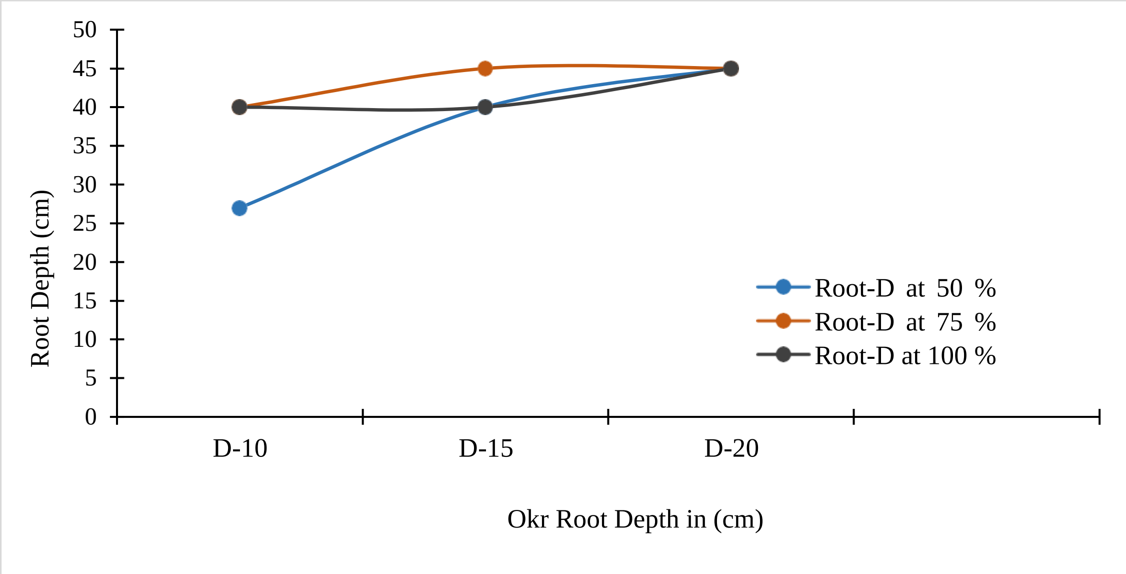


Figure -3.6 Influence of water deficit levels and placement depths on Okra Crop Root Growth (Root Depth and Root Length).

From the figure 3.6 results reveals that okra crop root length and root depth at 50 %, 75 % and 100 % ETc (treatments), the Okra crop root length at placement depth 10 was (40 cm), at placement depth 15 was (40 cm) and at placement depth 10 (30 cm) at 50%, 75% and 100% ETc respectively. The okra crop root depth at placement depth 20 was (45 cm), placement depth 15 was (45 cm) and placement depth 10 was (40 cm) respectively. The okra crop root length and root depth responded significantly with different soil moisture content where at deficit water supply the increase in root length and root depth was linked to the reduction of moisture availability at different placement depths at plant root zone. This increase in root length related to the limit water accessibility at plant root zone. When water was limited at upper part of soil layers it encourage the crop root to reach that limited moisture regimes. These observations were consistent with the discussion by others researchers such as [35], [36], [37], [27], [38], [39].

3.3 Conclusion and Recommendations

The highest total number of new leaves (23) for placement depth (10cm) were obtained at the 100 % ETc, and the lowest total number of leaves (20) was obtained at placement depth (20cm) at all the three crop water requirement treatments, the high average (83.1cm) of plant height was obtained at placement depth 10cm at 50% ETc, (82.7cm) at placement depth 15cm at 75% ETc and the lowest average height of (73.1cm) at placement depth at 100% ETc, likely due to the decrease the soil water potential to crop roots.

The high yield obtained at (75 % ETc) was (8884.5 kg) water supply condition at the top subsurface depth (15cm), and the lowest yield at full irrigation (100 % ETc) was (4844.8 kg) at an irrigation depth of (20cm). The yield was affected by the soil moisture content at placement depths at the plant root zone due to limited water availability to crop roots zone. The study recommended that the placement depth at 10 cm at 50% and at 100 % ETc and 15 cm at 75% of deficit irrigation water levels to be applied in term of reducing the impact of evaporation losses through soil surface, water saving and water conservation for the benefit of the farmers.

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