

# Water Use Efficiency of *Manihot Esculenta* Crantz Under Drip Irrigation System in South Western Nigeria

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## Abstract

Field experiments was conducted at Teaching and Research Farm, Federal University of Technology, Akure between November 2006 and November 2007 to find out the water use efficiency under drip irrigation system and effect on the growth and yield of Cassava (*Manihot esculenta* Crantz). A popular hybrid of cassava TMS 30572 was tried as a test crop. The soil of the experimental site was moderately drained, loamy sand. The experiments were laid out in a 4 X 4 X 2 randomised complete block design (RCBD) consisting of 4 treatments, 4 replicates and 2 varieties using a spacing of (1m x 0.8m) for mechanical harvesting. The results indicated that the highest moisture content was recorded at depth of 40cm during the late stage of tuber development and the highest biomass yield was recorded under full irrigation treatment than in other treatments. The yield of cassava ranged from 21.87 to 14.13 t ha<sup>-1</sup> in all the treatments except for the control that has 8.45 t ha<sup>-1</sup> while the water use efficiency ranged from 19.18 to 23.63 kg ha<sup>-1</sup>mm. Irrigation through full treatment registered the highest mean tuber yield of 21.87 t ha<sup>-1</sup> while the least tuber yield was associated with the control treatment. The height and stem diameter of cassava also responded higher under full treatment of available water. This study demonstrated that medium irrigation (60% AW) could be best option in terms of water efficiency.

**Keywords:** *Manihot Esculenta Crantz*, Water Use Efficiency, Irrigation, Yield

## 1. Introduction

Cassava (*Manihot esculenta Crantz*) is a very important crop in Nigeria deriving from the extensive use of the various products and by-products as staples to most Nigerians. The consumption of cassava cuts across all parts of the country. Its adaptability to climatic and soil conditions even in marginal soils has endeared cassava to most people that have to do continuous cultivation on limited available land. The yields of cassava according to (IITA, 1990) are mostly above 22.0 tons per hectare even on poor soils, which gives it superior advantage over other tuber crops like yams, cocoyams and potato. The general acceptance of cassava and its products to all classes of Nigerians on its own draws close attention to the producers of cassava.

The development of cassava could be an effective means to promote social and economic development, especially in developing countries. The strategy to promote cassava development is supported by the following arguments. Firstly, the cassava market is perceived to be attractive. A study by (Fuglie, 2002) related to cassava use in Asia, shows that cassava is a competitive crop, especially for the production of starch and animal feed. The use of cassava from 1993-2020 is predicted to increase by around 1.74 per cent per annum in the region. This implies that there is room to expand production.

Secondly, the productivity of cassava, especially in Asia, can be increased significantly since the potential yield and value of cassava have not yet been fully achieved. By using better planting material and improving input management, the productivity of cassava could be doubled. Moreover, improvements in quality, processing, and product marketing could increase the value of cassava products by about 20 per cent (Harshey *et al.*, 2000). Thirdly, cassava is well known as an enduring crop, especially toward climate and soil conditions. It can grow in places where cereals and other crops do not grow well. It can tolerate drought and can grow in low-nutrient soil (IFAD and FAO, 2000). Cassava is an important crop of water deficit areas, where in it is generally grown with limited amount of irrigation water. The crop is mostly grown under conventional surface method of irrigation in which major portion of irrigation water is lost by evaporation and deep percolation resulting in lower efficiencies.

Water is the most important compound in an active plant and constitutes more than 80% of the growing tissue. Because it is essential for most plant functions, the amount of water applied during irrigation, the time and method of water application, the quality of the irrigation water, and prevailing micro-meteorological conditions are important in plant health and yield. The inability of a plant root system to supply such demands is one of the principal constraints of plant productivity (Baker *et al.*, 1992). There is indisputable evidence that irrigating land leads to increased productivity. In Asia, yields from most crops have increased 100-400% after irrigation (FAO, 1996). Irrigation allows farmers to apply water at the most beneficial times for the crop, instead of being subject to the erratic timing of rainfall. Water for irrigation is becoming both scarce and expensive and necessitates to be utilized in a scientific manner. Drip irrigation has proved to be a success in terms of water and increased yield in a wide range of crops (Bhardwaj, S.K., 2001). Its ability of small and frequent irrigation applications have created interest because of decreased water requirements, possible increased production and better quality produce.

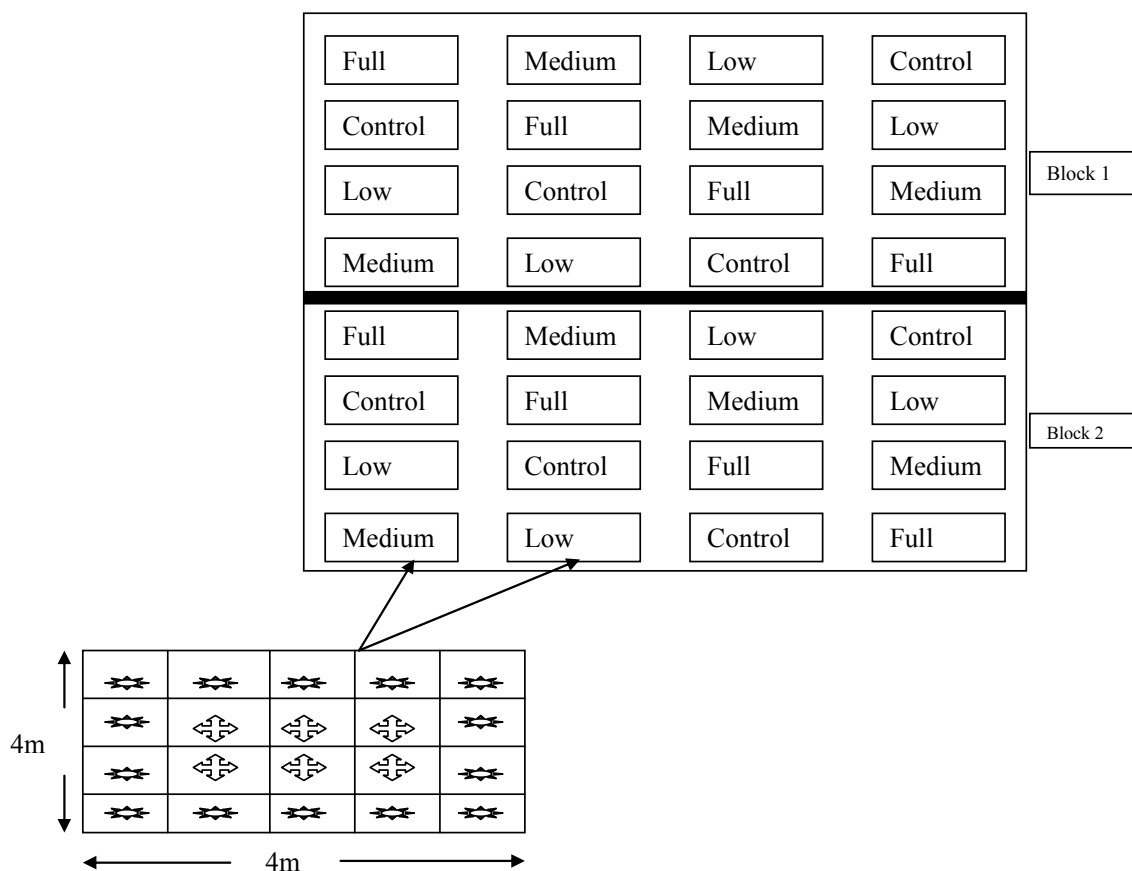
Hence, This study will lead to a better understanding of the effect of drip irrigation on the growth, development and yield of cassava, this is essential because of the peculiar demand for cassava both locally and internationally and it will also compliment the various efforts of research in improving the production of cassava in Nigeria with the aim of optimizing the irrigation requirement of cassava thorough drip system of irrigation and to find out the effect on the yields, growth and development of

cassava. Secondly, it will also generate reliable data like soil analysis, agronomic growth, water efficiency and moisture content for further study.

## 2. Material and Methods

Field experiments were conducted at Teaching and Research Farm, Federal University of Technology, Akure. The University Campus is situated in Akure South Local Government Area of Ondo State, Nigeria. It lies on latitude  $7^{\circ} 17'$  north of the equator and longitude  $15^{\circ} 18'$  east of the Greenwich meridian. This location places it in the tropical humid climate. The experiment was conducted between November 2006 and November 2007 to find out the water use efficiency under drip irrigation system and effect on the growth and yield cassava. A popular hybrid of cassava TMS 30573 was tried as test crop. The soil of the experimental site was moderately drained, loamy sand. The experiments were laid out in a  $4 \times 4 \times 2$  randomised complete block design (RCBD) consisting of 4 treatments, 4 replicates and 2 varieties using a spacing of (1m x 0.8m) to allow for mechanical harvesting as recommended by (IITA, 1990). Each plot size is 4m X 4m separated by 1m wide spacing for demarcation between plots making sixteen (16) plots including the control treatment. Also 20 cassava plants was planted per each plot which include the border plants. The border plants are provided to line the plots to take care of sub lateral flow in each plot (Fig 1) .

**Figure 1:** Layout of the Experimental Field



Treatments at these sites was based on water regimes and cultivars. Four differential water regimes, three of which was based on fractions of Available Water (AW) was applied:

- (I) Low water regime: 30%AW;
- (II) Medium water regime 60%AW;
- (III) Full regime 100%AW and

(IV) Control which will be rain fed as practiced by local farmers in the vicinity.

Climatic data was evaluated using 20 - 30 years data in order to determine the variability, sequence of wet and dry season and also to estimate the potential and reference crop evapotranspiration (using the modified FAO Penman- Monteith ET model), Initial soil physico-chemical properties including soil nutrients of the sites and irrigation water quality was determined for the location. Disease free sets of cassava were planted at a spacing of 1 x 0.8m. A fertilizer dose of 60:60: 150 NPK Kg ha<sup>-1</sup> was uniformly applied to all the plots. Three hand weeding on 30<sup>th</sup>, 60<sup>th</sup> and 90<sup>th</sup> day after planting was given commonly for all the plots.

For drip irrigation, drip lateral was laid out at 80 cm spacing between rows. Drippers were placed at 1m apart along the lateral line with a discharge capacity of 4 liters per hour each. The quantity of water in drip irrigation treatments was worked out based on daily pan evaporation value (for e.g. Drip irrigation at 100 per cent of surface = 1.0 x 0.6 x pan evaporation in mm). Growth parameters and tuber yield of cassava were recorded at harvest. The number of storage tubers of five plants was counted and the mean was expressed in number per plant. The length of storage tubers of five plants was measured and the mean was expressed in cm. The Maximum girth of cassava tubers was measured for ten tubers at random and expressed in cm. Total water used and water use efficiency was computed for each irrigation treatments. The water use efficiency (WUE) of the cassava plant was calculated as yield (kg ha<sup>-1</sup>) divided by seasonal evapotranspiration (mm). Regression technique was used to evaluate water use-yield relationships using seasonal evapotranspiration and yield data obtained from the experiment. Analysis of variance (ANOVA) was conducted to evaluate the effects of the treatments on the yield, LAI and DM components. Duncan's multiple range tests was used to compare and rank the treatment means. The differences were declared significant at P < 0.05 or 0.01.

### 3. Results and Discussions

#### 3.1 Yield Attributes of Cassava

The result shows that the tuber yield was significantly influenced by the irrigation treatment. Analysis indicates that cassava yield under full irrigation recording the highest tuber yield of 21.87 t ha<sup>-1</sup> followed by medium, low and control as shown in Table 1. Similarly tuber length and tuber girth showed positive response to drip irrigation treatments recording highest values in full irrigation compared with other treatments. However in tuber per plant ratio, the low irrigation treatment and control shows no significant difference. This is justifiable because the roots system of cassava can still expand under conditions of water storage (Mohamed *et al*, 2006). Comparing all the yield attributes, It is quite obvious that continuous application of water at optimum levels would result in improvement in yield attributes under drip system. Manickasundaram *et al*. (2002) also reported similar results of improvement in yield attributes of cassava due to irrigation through drip at 75 % of surface irrigation. Selvaraj *et al*,(1997a) reported that the fresh rhizome yield of turmeric under drip irrigation scheduled at 80 per cent of surface irrigation was superior over surface irrigation scheduled at 0.90 IW/CPE ratio. (Bhardwaj, 2001) reported 100 per cent yield increase in banana, 40 to 50 per cent in sugarcane, pomegranate and 25 per cent in grapes and cotton under drip method of irrigation. Selvaraj *et al*. (1997b) also reported 32 per cent yield increase in sugarcane under drip irrigation system over surface method.

**Table 1:** Yield Attributes of cassava under the three treatments

Treatments	Tuber per Plant	Tuber girth (cm)	Tuber length (cm)	Biomass Yield (kg/ha)	Biomass Yield (t/ha)
Full	6.64	17.7	27.3	21,872	21.87
Medium	6.32	17.5	27.0	20,230	20.23
Low	6.01	16.3	26.4	14,139	14.14
Control	6.01	15.9	20.2	8,453	8.45

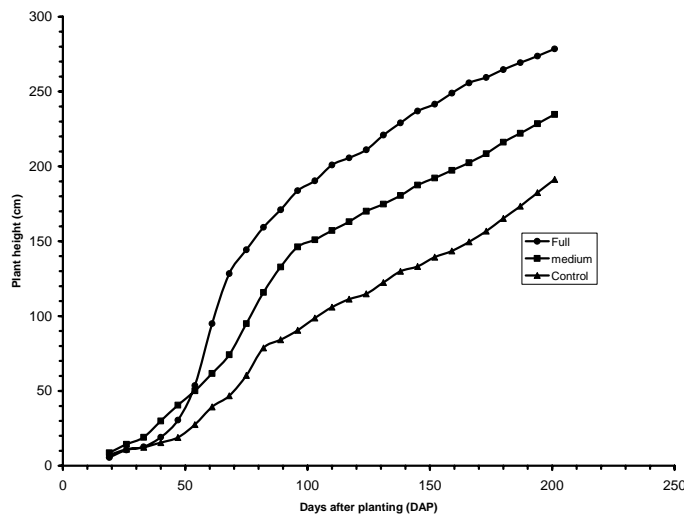
### 3.2 Phenological Development Of Cassava

#### (a) Height of plants versus days after planting (DAP) under full, medium and control irrigation

Figure 1 shows the changes in heights of cassava plant with time that is, Days After Planting (DAP). The initial average height of cassava cutting was 5cm which was subjected to full, medium and full irrigation. From 20 to 40 DAP, the heights of cassava plants under full irrigation was lower than that under medium irrigation. This indicates that full irrigation at early stage of growth of the crop does not lead to increase in height. Between 50 and 100 DAP, there were sudden increases in the plants heights under the three treatments of full, medium and control irrigation unlike during the early and the late stages of growth and development when the increase in heights were minima.

At 90 DAP; the measured heights were 84.2, 132.8 and 171cm for control, medium and full irrigations respectively.

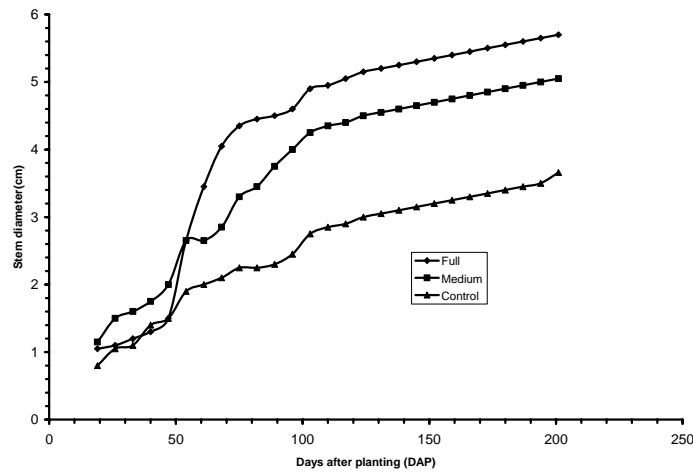
**Figure 1:** Changes in height of cassava with time (DAP) under full, medium and control irrigation



#### (b) Stem diameter versus days after planting (DAP)

Figure 2 shows the changes in stem diameter with time (DAP). The average length of the cassava cutting used at initial stage of planting was 0.5cm. Under full, medium and control irrigation, the stem diameters at 20 DAP were 0.8, 1.05 and 1.15cm respectively. During the mid season that is, 60 to 120 DAP, all the irrigation treatments experienced sudden increase in stem diameters as it occurred in heights in Fig.1. The increase in stem diameter was smaller towards the late season compared with the mid season. This shows that the water intake by cassava during the late season was not used for stem development but for tuber formation. In the three treatments however, the stem diameter of cassava under full irrigation was higher than the medium and control irrigation.

**Figure 2:** Changes in stem diameter of cassava under full, medium and control irrigation treatment with time (DAP)



**Changes in Plants Physiological Features in the Three Treatments**

**Full Irrigation**

Figure 3a. shows the relationship between number of leaves and the plant leaves with the height under full irrigation treatment. The coefficient of determination  $R^2$  was 0.9818. This shows that there is good correlation between the number of leaves and their corresponding heights with time. Fig 4b shows the similar graph comparing the relationship between the number of leaves and plant height but under medium irrigation. The coefficient  $R^2$  was 0.9684. Figure 4c shows the graph of number of leaves against the plant height under the control irrigation. The coefficient  $R^2$  was 0.9688.

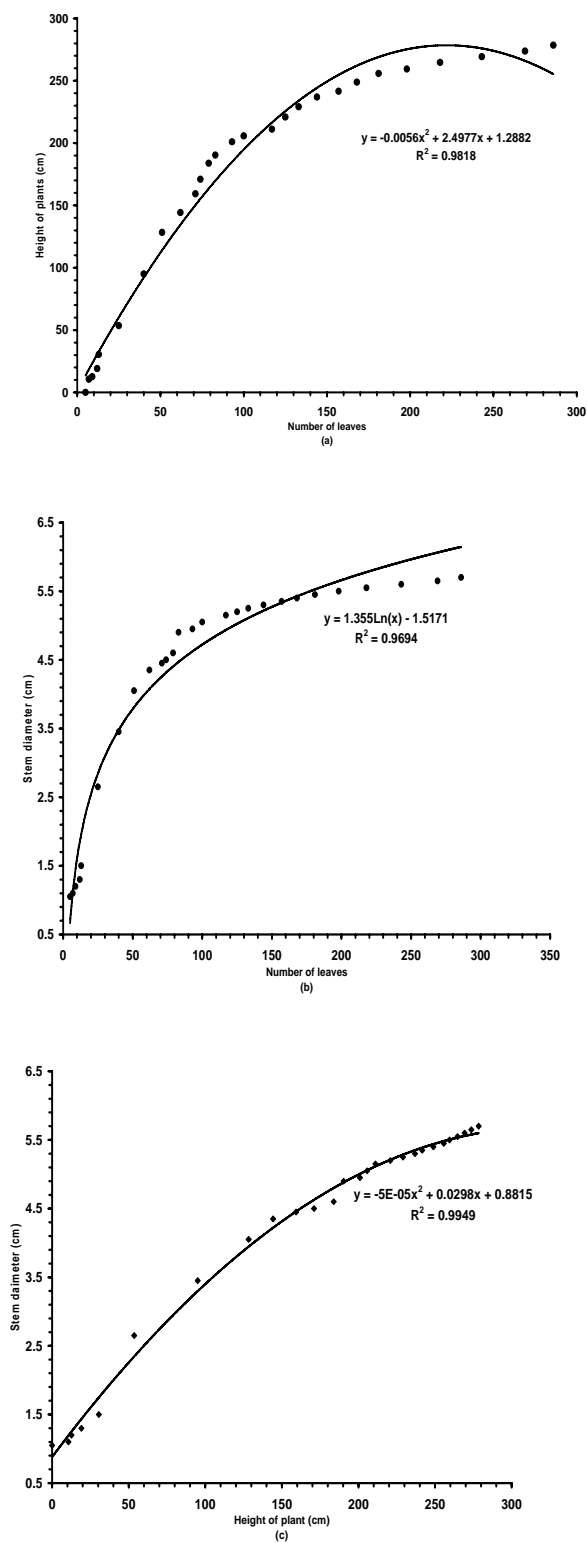
**Medium Irrigation**

Figure 4a. shows the relationship between number of leaves and the stem diameter under control irrigation treatment. The coefficient of determination  $R^2$  was 0.9694. Fig 5b shows the similar graph comparing the relationship between the number of leaves and stem diameter under medium irrigation treatment. The coefficient  $R^2$  was 0.9447. Figure 5c shows the graph of number of leaves against the stem diameter under the control irrigation. The coefficient  $R^2$  was 0.9604. The highest  $R^2$  was obtained under the full irrigation system.

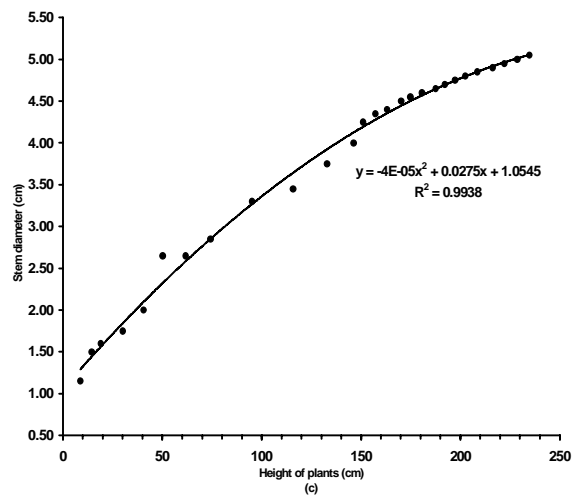
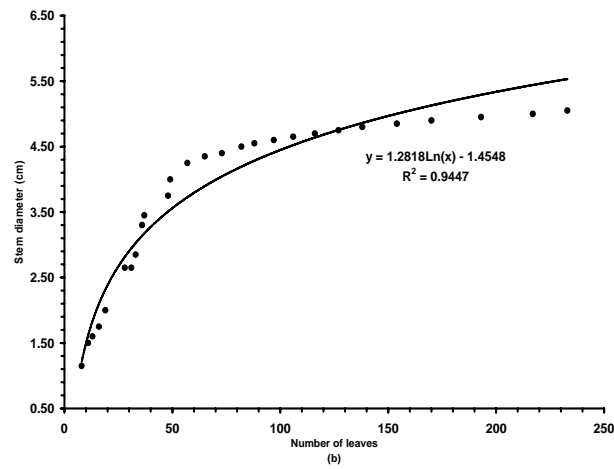
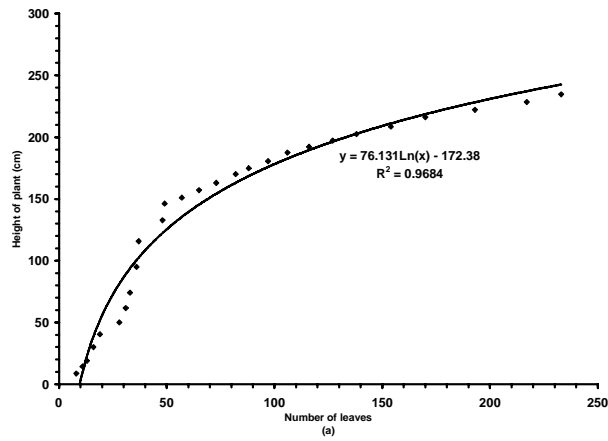
**Control Irrigation**

Figure 5a. shows the relationship between plant heights and stem diameter under full irrigation treatment. The coefficient of determination  $R^2$  was 0.9949. Figure 6b shows the similar graph comparing the relationship between the plant height and stem diameter under medium irrigation treatment. The coefficient  $R^2$  was 0.9447. Figure 6c shows the graph of number of leaves against the stem diameter under the control irrigation. The coefficient  $R^2$  was 0.9939. The highest  $R^2$  was obtained under the full irrigation system. This shows that the cassava plant utilized the irrigation water to the maximum.

**Figure 3:** Changes in height of plants with number of leaves (a) Stem diameter with plant height (b) and stem diameter with height (c) under medium irrigation treatment

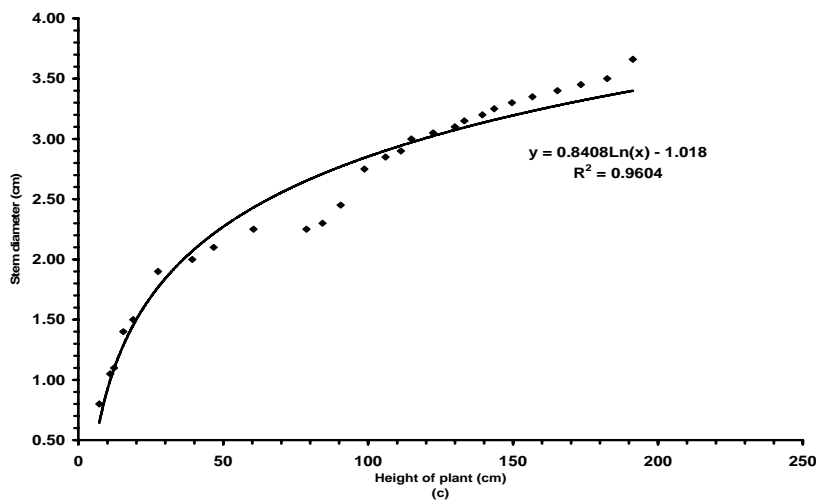
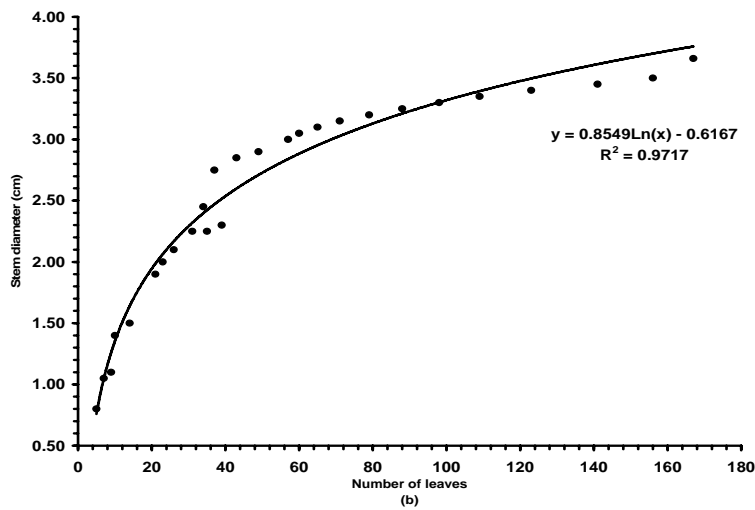
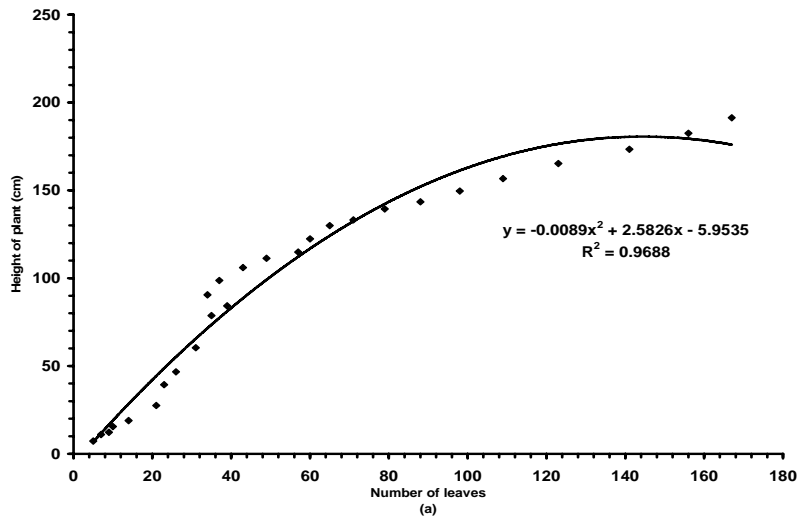


**Figure 4:** Changes in height of plants with number of leaves (a) Stem diameter with plant height (b) and stem diameter with height (c) under medium irrigation treatment





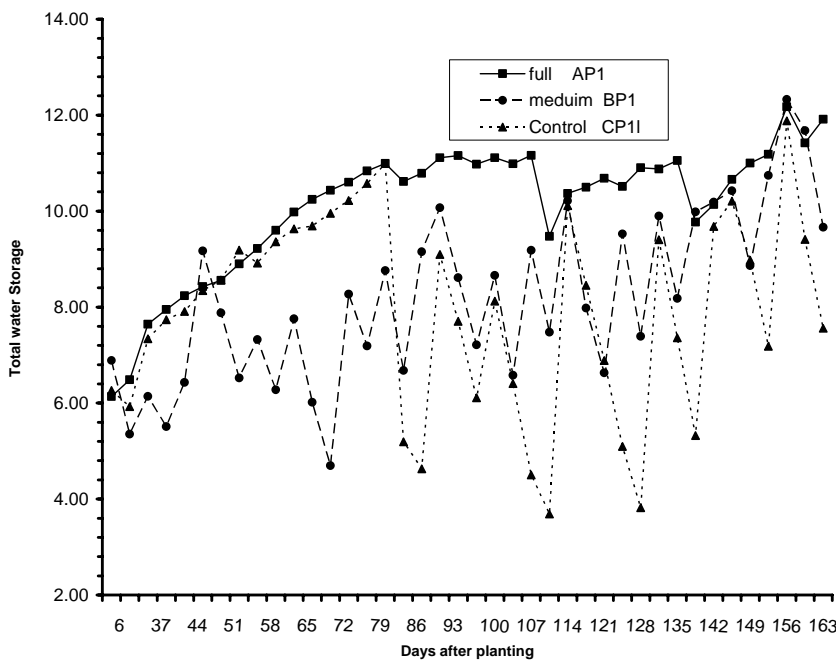
**Figure 5:** Changes in height of plants with number of leaves (a) Stem diameter with plant height (b) and stem diameter with height (c) under control irrigation treatment



### 3.3 Water Storage In Root Zone

Figure 6. shows the changes in total water storage with time (DAP). The total water storage in the root zone at 60 DAP under the full, medium and control irrigations were 9.50, 7.30 and 9.30 cm respectively. Under full irrigation, the total water storage increased to 10.99 cm 83 DAP while under the medium and control treatment, the water storage were 8.76 and 10.99cm respectively. Towards the late season that is, 160 DAP, the total water storage for full, medium and control irrigations were 12.17, 12.33 and 11.88cm respectively. At the early stage of growth, maximum water was stored in the root zone under the medium irrigation. Both full and control irrigation treatments experienced the same total water storage during the mid-season unlike at the late season when the highest “total water storage” was observed under full irrigation.

**Figure 6:** Shows the changes in total water storage with time (DAP).



### 3.4 Water use efficiency

The annual irrigation water amounts were 213.75 mm, 426.12 mm and 710.24 mm while the Total water use values during the period of planting were 430.00 mm, 643.75 mm, 856.12 mm and 1140.24 mm in control, low, medium and full Irrigation (Table 2). The water use efficiency of all the treatment ranges from 19.18 to 23.63 while the medium treatment has the highest water use efficiency of 23.63. It can also be deduced from the results of the percentage difference in water use efficiency compared to control that the medium treatment is the only one that has a positive difference. Also comparing the productive, an increase in irrigation water volume from 30% to 60% of Available (AW) record an increase in yield from 14,139 to 20,230 with a tuber productivity of 43% increase while an increase in irrigation water from 60AW to 100AW only resulted to an increase of 8%. It is quite obvious looking at all this differences that 60% of available water is the most efficient in production of cassava in southwestern Nigeria and any further increase in water application can lead to a waste while a lesser application of water will results to a low yield. This is in conformation with the report by Bhardwaj 2007 and Manickasundaram et al 2002. Future studies on cassava water use efficiency based on plant dry matter accumulation should require the monitoring of leaf area index, leaf emergence and leaf

senescence rates for a better screening of WUE data. The global WUE calculated over the growth period seems more appropriate for the cassava crop.

**Table 2:** Water use efficiency for cassava in 2006-2007 growing season using three treatments

Particulars	Treatment	Irrigation Applied (mm)	Effective Rainfall (mm)	Water saving	Total Water use (mm)	Tuber Yield (kg ha <sup>-1</sup> )	Relative Yield	WUE (kg ha <sup>-1</sup> mm)	% difference in WUE to Control
Full(100% AW)	Full	710.24	430	0	1140.24	21,872	100.00	19.18	13.59
Medium(60%AW)	Meduim	426.12	430	40	856.12	20,230	92.49	23.63	6.44
Low(30% AW)	Low	213.75	430	70	643.75	14,139	64.64	21.96	-1.07
Control	Control	0.00	430		430.00	8,453	38.65	19.66	0.00

#### 4. Conclusion

Irrigation management is a key to obtaining profitable growth in the absence of wasting water. Irrigation led to higher soil water content favouring crop evapotranspiration and dry matter accumulation. Actual evapotranspiration (AET) followed the trend in soil water content while the maximum evapotranspiration (MET) was mainly dependent upon the evaporative demand. Growers should pay close attention to irrigation scheduling and apply the adequate amount of water necessary to keep the plant at optimum production. It is quite obvious that continuous application of water at optimum levels would result in improvement in yield attributes including yield, tuber length and tuber girths. It also shows that the irrigation water supply affects the productivity parameters more in term of water volume per crop, than water-use efficiency. This is dependent on the available water in the soil and the climatic condition in that locality. Water use efficiency is a better water conservation method of conserving water most especially in a water scared environment. The application of effective use of water will go a long way in addressing the global water crisis in future, thereby reducing wastage. Agronomist should make has a point of duty to set their priority aright in other to ensure more crop per drop of water. In that wise, It can be concluded that in moderate water scarcity areas, drip irrigation of 60 % of Available water could be recommended for getting higher yield in cassava. In areas where water is very scarce, drip irrigation at 100%AW can be recommended for more yields. Lastly, the major difficulty in estimating cassava WUE is the heterogeneity in plant growth leading to sampling problems and highly variable water use efficiency.

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