International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 3, Issue 6 (January 2014) PP: 28-35

Design and Evaluation of Gravity-Fed Perforated Tube Drip Irrigation for Dry Season Irrigation of Citrus Sinensis

Obot E. Essien[1], Michael I. Essien[2]
[1,2]*Department of Agricultural and Food Engineering University of Uyo, Uyo*

ABSTRACT: *Gravity-fed, perforated-tube drip irrigation system was designed and applied to irrigate sweet orange (Citrus sinensis) in the dry season which the fruit tree is highly vulnerable to marked reduction in growth, yield and fruit quality. The aim was to utilize scarce quantity of water for root contact irrigation efficiently. Small surface tank size for supply of water, orifice discharge, number of drip pipes, discharge flow rate and root zone volume of available water were computed; and depletion rate of water was profiled. Plot-scale pilot testing of the drip system gave a very high water use and application efficiency (95%). Soil moisture analysis showed adequacy of moisture content, hence available water distribution. Predictive functions of the height and girth weekly growth rate using test measured data gave very high coefficient of determination (R^2=1.0). Application on field scale.*
Keywords: *Drip irrigator design, Gravity-fed irrigation, Citrus sinensis, Soil moisture application efficiency, Sustainability*

I. Introduction

Sweet Orange (*Citrus sinensis*) is the common name of the most important fruits of the genus citrus, in the Rutaceaefamily which is native to southeastern Asia but has been cultivated for centuries in many parts of the world where climatic and soil conditions are favourable [8]. Several species of orange trees are known, each producing fruits of different sizes, shapes and flavors. [12]. Oranges are an excellent source of vitamin C, vitamin A and several B vitamins.Orange is a sub-tropical fruit crop, and is affected by various environmental factors. Annual rainfall of 700mm is, on the average,adequate forproduction of oranges but annual rainfall of 1250- 1850mm is generally sufficient [1]. In general, under heavy rainfall, fruits become poor in keeping colour and quality and inferior in taste; and are attacked by diseases and pests under heavy rainfall condition [13]. Soil medium for orange growth is pH of 5.5- 6.0. Orange endures extremes of temperatures but not below 0°C and above40°C, although it produces best at 32°C above which the fruit gets heat injury which renders it worthless[6].

Insufficiency of soil available water (i.e. drought) impacts adversely on sweet orange yield [15], causes yield reduction and quality impairment compared to well-watered trees. For instance, un-irrigated trees were reported to produce up to 79% inferior, late-bloom fruits compared to a maximum of 9% of late-bloom fruits in irrigated trees [12]. Increased fruits shedding and reduced rate of fruit growth follow in December.Avoidance of drought is critical for young trees where canopy is essential; the increase in fruit size from June or December to maturity is highly dependent on heat uptake.

In general, when water is insufficient, growth is retarded, leaves curl and drop, young fruits fall and fruits that mature are deficient in juice and inferior in quality. Water stress may also result in smaller, lighter fruits with thicker peel. Soil moisture depletion reaching permanent wilting point is reported to terminate sweet orange tree growth and subsequently affects fruits and leaves, followed by twigs, branches and eventually the whole tree. Prolonged water deficits will not only delay flowering but also leads to over production of flowers which will result in lower yield. Water deficits during flowering period reduce fruit set and water deficits during fruit set reduces size and number of fruits. The overall effect of drought is to reduce total yields and eventual fruit quality. Whether this reduction is due to or in the form of less fruits or smaller fruits depends on when the stress occur.

The climatic environment in Uyo is seasonal in terms of rainfall and diurnal in temperature. The dry season period from November to March produces deficit soil available water (DAW) of up to 61% in January to76% of total available water (TAW) in March [4]; hence produces water deficit which does not support sustained citrus growth and fruit yield , hence causing death of nutritive natural fruit supply.

This impaired environmental condition can be repaired by artificial supply of water to meet optimal water demand of the soil for sustained citrus productivity in a season of soil water scarcity. This requires irrigation for optimum production. The use of drip irrigation is known to provide root- contact supply that reduces evaporative loss of applied irrigation water, since it is sub-surface applied in close contact to roots[11]; [14]. The method allows frequent water application in small flow rates below the soil surface.In this case, maintaining near-optimum water content in the root zone usually involves frequent application of small amounts of water, which small amounts prove the high water use efficiency (WUE), higher yield and quality of orange [7]. The design of gravity–fed, perforated-tube drip irrigator type is easy- to- assemble and use, andaffordable to fairness and issues. Hence the objectives of this research were:

1. To design gravity–fed, perforated- tube drip irrigator for root zone irrigation of orange for sustained growth in the dry season.
2. To assess and evaluate the growth performance of oranges as a response to drip irrigation.
3. To assess environmental factor changes and any water savings in the application.

II. Materials And Methods

2.1 Site Selection

The experiment was carried out at the experimentation farm of the Faculty of Agriculture, University of Uyo, Uyoin five different plots including the control plot. Plots 1 and 2 support in each a young sweet orange tree. Plot 5 served as the control plot. Each plot measured 2x 2m^2. Site analysis provided information essential for the proposed root zone irrigation design. Site factors considered in site selection were the soil type, the overall field area and topography (or changes in elevation), possible water sources (surface or well) and proximity to water sources, as well as quantities available for both seasonal and peak daily requirement.Site study was carried out with particular regard to orange; an orange orchard existed in the University Farm.

2.2 Sample Collection and Characterization

All the soil samples used in the study were collected from the experimentation farm of the faculty of Agriculture, University of Uyo,Uyo. Soil test and analysis were carried in the Soil Science laboratory of the same faculty. Samples were collected at various soil depths, and were placed in different moisture content cans labeled 1 and 2, control1, and control 2 without replication.

Gravimetric method of soil moisture measurement was used to study the variation of soil moisture with depth before and after each experiment. The study period lasted from the third week of November 2011 to the second week of December 2011, in a total of four sampling weeks prior to the experiment. Also, during the experiment, the sampling period lasted from the first week of February, 2012 to the fourth week of April, 2012giving a total of twelve sampling weeks. Soil samples of known weights (100g) were collected at four different depths (50mm, 150mm, 250mm and 350mm) within the experimentation plot (including that of the control experiment) twice every week in an airtight polythene bags with a soil auger. Each sample was weighed and oven dried at 105°C for 24 hours. They were then cooled in desiccators and their moisture content determined as follows [10]:

$$\text{Moisture content, \% by weight} = \frac{W_1 - W_2}{W_1 - W_0} \times \frac{100}{1} \qquad (1)$$

$$\text{Moisture content, \% by volume} = \frac{W_1 - W_2}{W_1 - W_0} \times \frac{100BD}{1} \qquad (2)$$

where, W_0 = weight of empty moisture content can in g
W_1 = weight of empty moisture content can + 100g of wet soil sample
W_2 = weight of empty moisture content can + oven dry soil sample
BD = bulk density of the soil under study in kg/m^3

Some soil samples were collected from the experimentation farm and tested for their textural class using the hydrometer method [3]; [9].

2.3 Dry bulk density determination

The core method was used to determine the dry bulk density (apparent specific gravity) of the collected soil samples [10]. Soil cores samples were used to obtain three pairs of soil samples at three different depths (10cm, 20cm and 30cm) within the experimentation plots. Each sample was weighed and oven dried at 105°C for 24 hours and then reweighed. The height and diameter of the samplers were measured in other to calculate the volume of the soil samples. The dry bulk density was computed as follows:

$$BD = \frac{W_s}{V_s} \qquad (3)$$

where, W_s = weight of oven dried soil
V_s = volume of soil

2.4 Determination of Total Available Moisture Capacity of the Soil

The difference in moisture content of the soil between field capacity and permanent wilting point gave the available moisture content or capacity of the soil:

$$AMC\% = (FC - PWP)\ \% \qquad (4)$$

where,

AMC = available moisture capacity of the soil in %

FC = field capacity of the soil in % obtained as in [10].

PWP = permanent wilting point of the soil in %

The PWP was measured using a pot experiment in which water in a pot planted with the crop was allowed to dry up and the plant dried irretrievably before the soil moisture was tested. Also, the method of silt factor was used for comparison. The permanent wilting point can be approximately estimated in percentage by dividing the field capacity by a factor varying from 2.0 to 2.4 depending upon the amount of silt in the soil [5]. A factor of 2.2 was assumed forUyo. It covered the month of February 2012. The daily rate of evaporation at the meteorological station was assumed to be equal to that of the experimentation site.

2.5 Estimating Evapotranspiration Rate Orange from Evaporation Data

Piche evaporimeter which also gives good indices to maximum rates of consumptive use [5] was used to estimate the evapotranspiration rate.The piche evaporation data used in the determination of consumptive use rate of orange were collected from the meteorological station, government house Uyo. It covered the month of February 2012. The daily rate of evaporation at the meteorological station was assumed to be equal of that of the experimentation site. Values of crop co-efficient (Kc) for orange were obtained from the agricultural farm.

2.6 Root Zone Depth and Root Zone Area Determination

The root zone depth of orange was estimated in the field by digging into the soil and then measuring the depth using a field tape from the top of the soil to the root zone layer of the soil. Three different measurements were made for orange tree and their average values gave the root zone depth of orange. The effective root zone of orange tree was estimated in the field by measuring the diameter of their canopy spread on a sunny day. Measured values were used to estimate their effective root zone area since the root system of a mature tree, for instance, extends two to three times the canopy spread[11].

2.7 The Tube (Root Zone) Irrigator

The rootzone irrigator used in the study was basically an open top and perforated or porous cylindrical pipe completely buried below the soil surface which discharges water from orifices along its entire length to wet the effective root zone area of the irrigated crops. The irrigators (drippers) were spaced round the irrigated crops taking into consideration their effective root zone area. The root zone irrigator was made of a polyvinylchloride (PVC) material with 50mm and 300mm long for orange. Orange drippers had a total of 3 holes drilled 3.0 mm at the 50mm, 150mm and 250mm heights respectively from top to bottom end of the tube.

The farm area had no elevated locality on the experimentation field, therefore the present simpledrip irrigation system used direct linked overhead or ground tank-fed vertical-flow, gravity- driven irrigation. Other researchers used single-manifold subunits for differentiated water supply to smoothen out pressure variation at different zones along the lateral arrangement [16]. For hilly areas, the placement of dug-holes tanks can be made on the uphill for gravity flow downslope [2].

2.8 Method of Soil Moisture Measurement and Depletion

The method involves measuring the depth of water depleted from the drippers over a given time interval using a calibrated float. The crop (orange) were subjected to irrigation every two days and the volume of water at the saturation point of the soil was noted.

During irrigation, the depth of water depletion every 5 seconds was recorded. Soil samples were collected two to three days at the end of every experiment for soil moisture content analysis, having done it prior to the experiment before and after irrigation was also noted and recorded.

2.9 Techniques of Monitoring Orange Growth

Orange growth parameters monitored included: (1) the average plant height above the ground level in mm; (2) the average plant girth at selected heights above the ground in mm.

Using lengths of thread and tape, the crop height and girth were determined weekly. Measurements were done weekly. Leaf colouration on sample crops was also observed.

III. Results And Discussion

3.1 Site Soil Characteristics

The apparent specific gravity of soil of the experimentation field were 1.27 g/cm3 at 10cm depth of sampling, 1.33g/cm^{3}at 20cm depth and 1.67g/cm^3 at 30cm depth. The field capacity was 15.26%at 15cm depth, 15.35% at 35cm depth and 15.37% at 45cm of root zone depth in the experimental field. The permanent wilting

point (PWP) was obtained as 6.97%. Thusroot zone depth (D) moisture distributionshows that, at lower depths, the available water was 11.87cm/m for the soil type at site. Thus, theaverage total available water (TAW)depth inthe root zoneof the soil type was 1.7times the depth of PWP which was notsafe.
Initial root-zone depths(D) for the three sample sites were, on the average, 30.0cm, 29.8cm and 30.2cm, giving average root zone depth (D) of 30.00 for orange trees. Infiltration rate was obtained from the water depletion profile from drippers in sweet orange. The water holding capacity of the site soil was computed withFC= 15.33%, PWP=6.97%, therefore available water content (AWC) for soil under orange trees was 118.7mm/m. For the root zone depth of 30cm, depth of available water moisture content was 35.6mm. The textural, classification of the soil under citrus was 20%silt, 6% silt and 74%, given it a clayey loam soil.

3.2 Crop Characteristics

The canopy of the orange was reassured and gave initial diameter of canopy of 120cm. Infiltration rate was obtained from the water depletion profile from drippers in sweet orange

3.3 Design of Root Zone Drip Irrigator

Effective root zone area was:

$$\mathrm{A}_0 = \text{ diameter of canopy spread}, \emptyset \ \times 3 \qquad (5)$$

Where, $\emptyset$ = diameter spread in both directions. Thus, A_0= 120cm x3 = 360cm^2
Root Zone Water Reservoir Volume, $V_{rootzone}$.
The root zone water storage volume ($V_{rootzone}$) under orange root zone A_Z was:

$$\text{Effective root zone depth x root zone depth x AWC} \qquad (6)$$

$$= 360\text{cm x } 30\text{cm x}3.56\text{cm} = 1281.6\text{cm}^3$$

The number of drip irrigation tubes, N_{drip} was:

$$\mathrm{N}_{drip} = \mathrm{V}_{rootzone} \text{ /volume of drip pipes} \qquad (7)$$

where, $V_{rootzone}$ = 1281.6 cm^3,
Volume of drip pipes = volume of cylinder = $\pi r^2 h$ where h is height of water in pipe = height of root zone depth, and radius (r) of drip pipe for orange tress is 2.5cm.
Thus $\pi r^2 h$ = 3.142 x 2.5^2 x30 =589.1cm^3. This gave N_{drip} as 3 tubes for orange drip irrigators

3.4. Irrigator discharge rate Qr.

The drip pipe irrigator applies the orifice discharge function. Hence,orifice discharge equation was applied as:

$$\mathrm{Q} = 0.61\mathrm{A}(2\mathrm{gh})^{1/2} \qquad (8)$$

where, Q is orifice flow rate ,m^3/s, area is orifice outlet cross sectional area on the tube ,m^2, g is acceleration due to gravity, 10m/s^{2,} h is the depth of water in pipe irrigator tube, m, 0.61 is value of coefficient of discharge (C) through the irrigator tube' d is the orifice diameter on the tube= 3.0mm
Lone trials of orifice discharge from the tube gave the following results;

1) For height (h) of 5 cm, Q was 4.3 x 10^{-4}m^3/s
2) For h of 15cm, Q was 7.47 x 10^{-4} m^3/s
3) For h of 25cm, Q was 9.64 x 10^{-4} m^3/s
4) For h of 35cm, Q was 11.4 x 10^{-4}m^3/s

Therefore, for orange drip irrigation, the total discharge per irrigator pipe, Q was:

$$\mathrm{Q}_T = \sum_{j=1}^{n=5} \mathrm{Q}_j = \mathrm{Q}_5 + \mathrm{Q}_{15} + \mathrm{Q}_{25} = 2.14 \times 10^{-3} m^3/s$$

For the 3 pipes irrigators,

$$\mathrm{Q}_T = 6.43 \times 10^{-3} m^3/s$$

IV. Discussion

4.1 Water use Rate – Its Effect on Orange Growth in Dry Season

From the plots of the average water depleted in the drippers against time (Fig.1), it was evident that the water use rate increased very rapidly within the first 60 seconds of the experiment and then gradually dropped when thedrippers were refilled. Field capacity of the soil (saturation point) was reached after 3 to 4 times refilling of the drippers. At field capacity, the average water use rate depletion in all drippers was approximately equal. Total depletion time I orange drippers was 5 minutes.

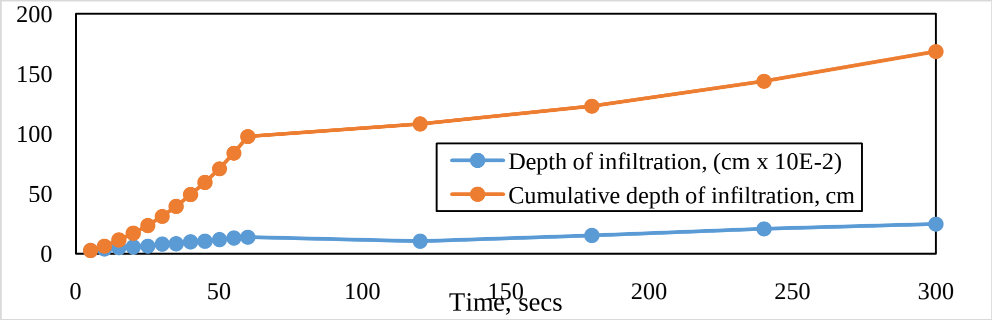

Figure 1: plot of infiltration depth and cumulative infiltration against time

The rapid water use rate manifested itself in the growth habit of orange crops with sustainable growth in the dry season resultant rapid increase in yield. The plot of average crop height against time (Fig. 2) showed orange growth increased with time. Between 6th and 8th week of the experimentation period, it was observed that the crops grew more rapidly than in the previous weeks.

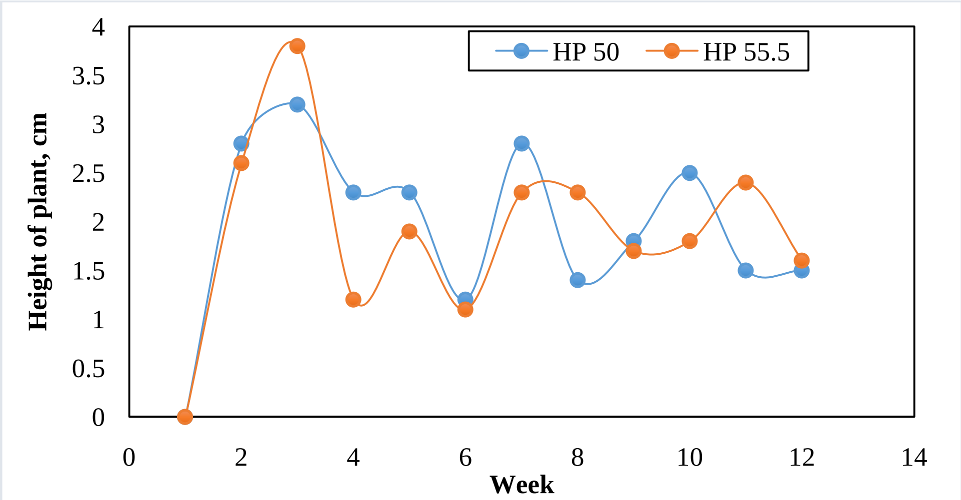

Figure 2: average weekly growth in height of orange tree under gravity-fed pipe drip irrigation for two initial heights of 50cm and 55.5cm.

The plot of girth against time (Fig. 3) showed that there was a gradual increase in the girth with the passage of time.

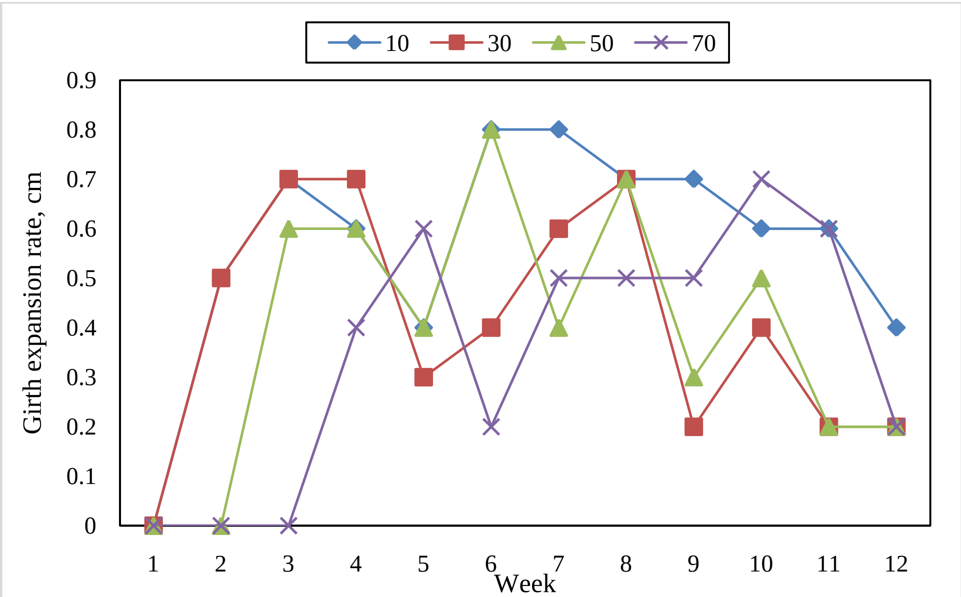

Figure 3: average weekly girth growth rate of sweet orange (*Citrus sinensis*) under gravity-fed pipe drip irrigator

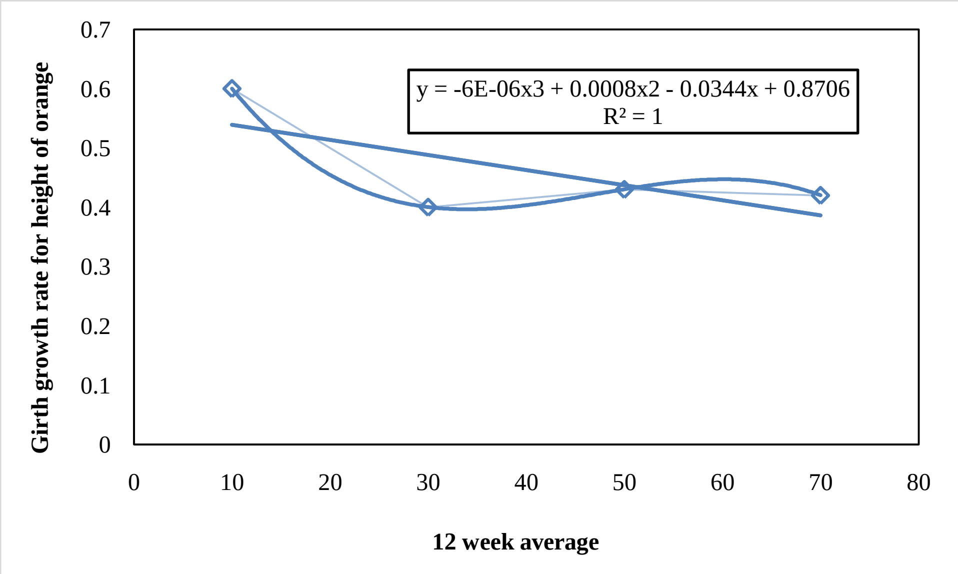

Figure 4: average weekly girth variation with initial height of citrus orange

Fig. 4 shows the average weekly growth rate of girth of sweet orange tree for initial depth of 50cm or 55.5cm. The girth growth rate profile was modelled as third order polynomial, given as:

$$y = -6 \times 10^{-6}x^3 + \times\, 0.0008x^2 - 0.0344x + 0.8706 \qquad (9)$$

R^2 = 1.0, which indicate perfect association.

4.2 Soil Moisture – Its Effect on Orange Growth in dry season

Results of the experiment showed that there has been a considerable increase in soil moisture after irrigation. Reasonable increase in soil moisture at different soil depths during irrigation was observed and compared to that at corresponding soil depth before irrigation. This increase in the root zone soil moisture content resulted in rapid growth of orange crop with observable evidence in the greenish colour leaf development. Comparison of the results shows that micro-irrigation is an absolute necessity in orange cultivation to reduce water stress for unhindered production and availability at all seasons. The graph of soil water levels at two depths in the root zone of sweet orange on weekly interval is shown in Fig. 5.

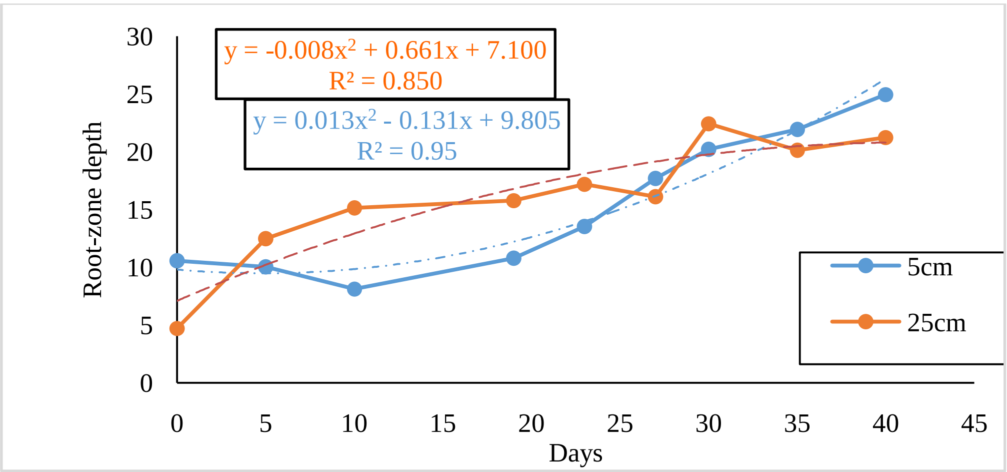

Figure 5: soil moisture content difference between initial and irrigated root-zone measured at 5cm and 25cm

4.3 Efficiency of the Root-zone Irrigation System

The root-zone irrigation experiment was very efficient with application efficiency of more than 95%. The total volume of water used for irrigation was less when compared with other irrigation methods, notably sprinkler irrigation. This was due to decreased evaporation from the soil surface, and elimination of the runoff. As little as one half of the water volume typically needed for traditional overhead sprinkler systems was adequate for irrigation of orange crops in the experimentation farm. Hence it is water saving.

4.4 Soil Moisture – An Absolute Necessity for Sustainable Growth

During the study, comparison of the soil moisture content of that of the trial plots (plots supporting orange crops) with that of the control plot (empty plot) showed that soil moisture content was much higher in the trial plot than in the control plot. High moisture content in the trial plots within the range of 15.55 to 43.08 was as a result of irrigation at the root zone. Soil moisture content in the control plot approached permanent wilting point (PWP) during the dry period of the experiment with no rainfall or irrigation, hence cannot sustain the growth of orange crops.

4.5 RootZone Moisture Distribution

Under the gravity-fed, perforated pipe drip irrigation, distribution of soil moisture favoured sustainability. When such method of irrigation increases water penetration, root growth, and water use by crop, they will have a major impact on sustainability (Tarquel and de Juan, 1999). The perforated drip application of soil moisture to the sweet orange rootzone was very efficient. Firstly the trial plots exhibited homogenous moisture levels at different rootzone profile depths.The mean of the profile moisture content distribution in 40 days between initial date (February 05) and last date (20 April 2010) were slightly different for each profile level as follows (Table1)

Table1,Temporal changes in rootzone moisture content and mean daily rate of variation

Rootzone depth profile	**Temporal change rootzone M. C**	**No. of days**	**40- days mean daily rate of change, mm/day**
05 cm	3.64 mm	40	0.09
15 cm	7.53 mm	40	0.19
25 cm	9.03 mm	40	0.23
35 cm	8.73 mm	40	0.22

The gravity supply of rootzone soil moisture differences at each level of the rootzone did not vary significantly except in the topsoil level. Thus the moisture gradient at any level of the rootzone was about 0.2 mm/day, except the 5cm depth which was 0.09 or 0.1mm/day (Table 1)
Over the time the depths of moisture content were 39.25 mm at 5 cm depth, 35.32 mm at 15cm, 32.25cm at 25mm and 28.21 cm at 35 cm (Table 2).

Table 2 Soil moisture distribution in sweet orange trial and control plotsunder

Days	**Trial plot**				**Control plot**			
	5	**15**	**20**	**25**	**5**	**15**	**20**	**25**
1	39.25	35.32	32.25	30.52	28.21	28.55	27.25	26.01
6	38.59	37.32	35.02	36.89	27.21	26.25	26.05	25.85
11	36.69	36.02	35.25	34.05	30.25	27.85	29.05	27.5
16	37.25	37.52	36.02	35.05	33.25	33.86	32.5	30.87
21	38.6	37.8	36.2	36.1	35.2	36.32	35.02	35.62
26	40.25	40.1	38.62	37.92	38.32	38.65	37.75	35.55
31	41.28	41.02	39.85	38.25	37.85	36.25	35.02	34.24
42	41.56	41.25	40.25	39.25	38.95	37.65	36.56	34.03
48	42.23	40.25	41.25	39.85	39.25	38.56	37.65	36.75
54	42.89	42.85	41.28	40.45	40.25	39.25	38.25	37.85
60	43.15	43.63	40.25	39.25	42.36	41.63	40.25	39.35

The difference between pre-irrigation moisture content and irrigated moisture content in the sweet orange rootzone shows significant difference ($P < 0.05$) indicating that gravity-fed, perforated-pipe drip irrigation caused significant increase inrootzone soil moisture level in dry season hence can sustain crop productivity of the sweet orange in the dry season.

The difference in rootzone soil moisture depth in a 40days irrigation period for February 05 to April 26, 2010 did not show significant differences in their change of moisture content levels at different profile levels (of 5 cm, 15 cm, 25 cm and 35 cm) in the root zone, nor in their 40days means values (Table -). This indicates that the gravity-fed perforated drip pipe irrigation improved the water supply to homogenous distribution of soil moisture depth in th,e rootzone (Table 3).

The homogeneity in rootzone moisture distribution was further observed in the fact that the distributiontemporal moisture distribution gradient at each depth level over the 40-days irrigation period was nearly the same at 0.2 mm/day except at 5 cm depth where it was significantly different at 0.09 (= 0.1) mm/day.

Efficient drip irrigation yields the benefit of convened surface temperature of soil in the drip irrigation also gave this benefit (Surah, 2006). The average temperature of root zone soil surface before irrigation was 34.7^0C at this changed to 30.5 with irrigation, grieving a change of 4.20^0C.

4.6 Prolonged water stress in the soil increases soil temperature

Prolonged water stress I the soil increases soil temperature. Increase in soil temperature was observed. Available soil moisture content in the control plot decreases as temperature increases. High temperature causes yellow leaf colouration in orange as symptoms of excessive temperature.

V. Conclusion And Recommendation

5.1 Conclusion

Results and field observation in plantain and orange plantations have shown that micro-irrigation plays a very vital role in the successful re-invigoration of plantain and orange fruit tree growth from drought blight in the humid areas of Akwa Ibom State. The root zone irrigation system used in the study was found to be very efficient (more than 95%) and water saving when considering the total volume of water used throughout the irrigation period.

Soil moisture content analysis showed reasonable increase in soil moisture content resulting from additional supplemental water from micro-irrigation. The use of root zone irrigator in plantain and orange cultivation reduces the stress due to moisture fluctuation in the root zone resulting in larger and better quality crops and hence satisfying the objectives of sustaining their growth throughout the dry season.

5.2 Recommendation

Results of the root zone irrigation experiment carried out on orange and plantain crops show that micro-irrigation systems use 30 to 50 percent less water and usually cost less to install when compared with other irrigation methods. It is recommended for use on tree crops, shrubs, and flowers, in the high-and moderate-water use areas to maximize efficiency. The result obtained is very encouraging; therefore, it is recommended that irrigation should be continued throughout the dry period till fruiting and harvesting of the crops.

REFERENCES

[1]. Anonymous. Data of Temperature and Rainfall of Panchagarh district. 1997, Deputy Director, Dept. Agric. Ext. Panchagarh, Bangladesh.
[2]. Bhatnagar, P. R.; Srivastava, R.C. Gravity-fed drip irrigation system for hilly terraces of the northwest Himalayas.Irrig Sci, 2003, 21,pp.151-157.DOI 10.1007/s00271-002-0058-y
[3]. Bouyoucos, G. J. Hydrometer method improved for making particle size analyses of soil.1962, Blackwell Science Publishers, Oxford, UK.
[4]. Essien, O.E.; Essien, M. E. Basin-scale temporal distribution of water resources sensitivity of components contributions in Ikpa Catchment of Nigeria.2009,Global Journal of Engr. & Tech.,2009, 2(2), pp.147-153.
[5]. Isrealsen, O. W.; Hansen, V. E. Irrigation Principles and Practices. 1980, John Wiley and Sons, Inc., New York
[6]. Jackson, L. K.; Davies, F. S. Citrus growing in Florida, 4th edn. 1999, University Press of Florida, Gainesville.
[7]. James, A. W. Trickle Irrigation System, 1988, Rain Bird Agric Products Divisions, Glendora, CA
[8]. Janick, J.; Moore, J. N. Advance in Fruit breeding. A Contemporary Approach. 1975, Univ. of Calif. Press, Berkeley, CA.
[9]. Liu, C.; Evett, J.B. Soil properties testing, measurements, and evaluation, 4th edn. 2000, Prentice Hall, Upper Saddle River, New Jersey.
[10]. Michael, A. M. Irrigation Theory and Practice. 1978, Vikas Publishing House PVT Ltd., New Delhi, India.
[11]. Powell, M. A.; Bilderback, T. E. Efficient Irrigation. 1996, North Carolina Co-operative Extension Service, North Carolina.
[12]. Reuther, W.; Calavan E. C. The Citrus Industry. 1978, McGraw Hill Book Co., New York. Vol. 4.
[13]. Samson, J. A. Tropical Fruits.1986, Longman Group Limited, UK.
[14]. Pereira, L.S.; Trout, T. J. Irrigation methods: Land and water engineering.CIGR Handbook of Agricultural Engineering, 1, pp.297-379
[15]. Tugwell, B. L.; Moulds, G. Citrus Growing Manual. 1999, Cambridge Univ. Press, Cambridge, UK
[16]. Wu, P. T.; Zhu, D. L.; Wang, J. Gravity-fed drip irrigation design procedure for a single- manifold subunit. Irrig Sci,2010,28, pp.359-369.,DOI 10.1007/s00271-009-0196-6