Available online at www.asric.org

ASRIC Journal on Water, Energy and Environment 1 (2020) 61-67

Assessing the effect of water management regimes on the growth of Tomatoes in Abeokuta, South West Nigeria

Makinde Akeem Adekunle [a,1], Eruola Abayomi Olayiwola [a], Rosanna Akinola [a]

[a] *Department of Water Resources Management and Agrometeorology, Federal University of Agriculture Abeokuta, Ogun State, Nigeria*

Received 18 December 2019; revised 10 October 2020; accepted 10 November 2020

Abstract

The erratic nature of rainfall pattern in parts of the world, had compelled need for consistent works on understanding crops response to different environments to enable identification of the varieties of crops with resistance to drought to ensure food sustainability in drought prone regions. The experiment was conducted in a screen house at Federal University of Agriculture, Abeokuta (FUNAAB) behind College of Environmental Resources Management (COLERM) to study the effect of water management regimes on growth of two tomato varieties. The experimental design was a Complete Randomized Design (CRD) with a 3x2 factorial arrangement in which there were three water management regimes and two varieties of tomatoes. The two tomato varieties used were Roma V. F. and Ibadan Local, under different water management regimes such as alternate wetting and drying (AWD), continuous drying (CD) and continuous flooding (CF). The agronomic parameters were plant height, number of leaves and leaf area which were monitored on a regular basis. The results showed that there was significant difference under the different water regimes; growth was best observed under alternate wetting and drying compared to continuous flooding and continuous drying. The mean plant height under different water regimes were AWD (29.68cm), CF (21.99cm) and CD (21.92cm). The mean leaf area of the crop was AWD (25.54cm^2), CF (16.45cm^2) and CD (19.27cm^2) while the mean number of leaves of the crops were AWD (36). CF (27), and CD (25). Tomatoes in AWD moisture availability yielded highest fruit yield of 17.90 kg/ha followed closely are those under CF with 16.60 kg/ha while the least yield of 14.10 kg/ha was obtained under CD. The research confirmed that alternate wetting and drying (AWD) favours plant height, leaf area and number of leaf more than continuous flooding (CF) and continuous drying (CD). Alternate Wetting and Drying is a very good water management option for the production of Ibadan Local in this environment.

Keywords: Water management regimes**,** Tomatoes, South West, Nigeria

1. Introduction

Water is an important component of life and is required for all the various biochemical and physiological processes involved in plant growth and development. Adequate moisture availability is necessary for optimum leaf development, maintenance of leaf greenness, assimilate production and partitioning as well as total dry matter yield. Water stress has adverse or deleterious effects on crops; the

[1] Corresponding author. *Email addresses*: hakmak4u@yahoo.com (M.A. Adekunle), layosky@yahoo.com (E.A. Olayiwola), roxan0343@gmail.com (R. Akinola)

impact however depends on the severity of the water shortage and the developmental stage of the crop under stress (Chaves *et al.,* 2002; Jaleel *et al.,* 2008). Water stress has been reported to affect the meristematic processes during the initial phase of plant growth and establishment which, consequently, impaired plant growth, as a result of reduction in cell turgidity required for mitotic cell division, elongation and enlargement (Anjum *et al.,* 2003; Bhatt and Srinivasa Rao, 2005; Jaleel *et al.,* 2008). Studies are needed to increase the efficiency in the use of available water through appropriate water management options such as regulated irrigation which is one among many practices that is fast gaining ground, and appears a very promising option to achieving the goal of more crops per drop of water if properly adopted (Oiganji et al., 2010). Variations exist on the effects of water regime on crops which imply that the effects of water regime on a crop vary with location which may be due to climate of the location and in turn dictates the evaporative demand of the crop (Postel, 2000, Oiganji et al., 2010).

Tomato is one of the most important vegetable crops grown all over Nigeria. It is the world's largest vegetable crop after potato and sweet potato but it tops the list of canned vegetables. In Nigeria, tomato is regarded as the most important vegetable after onions and pepper (Fawusi, 1978). It is an important condiment in most diets and a very cheap source of vitamins. It also contains a large quantity of water (%), calcium (%) and Niacin all of which are of great importance in the metabolic activities of man. Tomato is a good source of vitamins A, C and E and minerals that are very good for body and protect the body against diseases (Taylor, 1987).

In view of the growing interest in irrigating with different water regime, a practice to improve water productivity, hence the present study sort to assess the effect of water management regimes on the growth of tomatoes in south west Nigeria.

2. Materials and Methods

Experimental site

The experiment was conducted in a screen house at Federal University of Agriculture, Abeokuta (FUNAAB) behind College of Environmental Resources Management (COLERM), located between Latitude $7^{o}\ 2^{1}\ 23^{11}$ N and Longitude $3^{o}\ 4^{1}\ 03^{11}$ E. The study area is characterized by a tropical climate with distinct wet and dry seasons. The wet season is associated relatively with the prevalence of the moist maritime southerly monsoon from Atlantic Ocean and the dry season by the continental North Easterly harmattan winds from the Sahara Desert. The area is located within a region characterized by bimodal rainfall pattern (April to July being the wettest months, followed by August to October). The annual rainfall ranges between 1400 and 1500mm in Abeokuta ant its environs. Isolated and scanty rains usually start in mid-March and steadily increase to reach the peak values in July followed by a short break in August. The dry season is normally from October to March and often characterized by hot days.

Experimental Procedure

Two Tomato varieties (Roma VF and Ibadan Local) were obtained from National Horticultural Research Institute (NIHORT), Ibadan. Top soil was collected from the FADAMA wetlands of the university, and sieved to fine particle before filled into plastic pots. Eighteen (18) plastic pots were used, they were pierced at the bottom before use to enable free drainage of water. 3kg of sieved soils were measured to into each plastic pot. The plastic pots containing soil was watered and left for a day. After that seeds of two (2) tomato varieties (Roma VF and Ibadan Local) were planted in each plastic pot and they were arranged in a Completely Randomized Design (CRD) with three replicates. Planting of the two tomato varieties was done on 5^{th} July, 2018. The experiment is 3x2 factors consisting of three water management regimes and two varieties of tomatoes. The three water regimes are alternate wetting and drying (AWD) (the plastic pots were alternately flooded and non-flooded for 7 days), continuous flooding (CF), (the plastic pots were kept flooded throughout the crop growth period) and continuous drying (CD), Continuous drying (watering was done once every week throughout the crop growth period) while the two varieties used were Roma V. F. and Ibadan Local. Three weeks after planting the tomato plants were thinned to one per pot and weeded manually. Herbicide was applied in the screen house for the protection of tomato against pests and diseases.

Experimental Pot Layout

Table 1: Experimental layout

REP 1	REP 2	REP 3
V_1 AWD	V_1 CF	V_1 CF
V_1 CD	V_1 CD	V_1 AWD
V_1 CF	V_1 AWD	V_2 CF
V_2 AWD	V_2 CF	V_1 CD
V_2 CD	V_2 CD	V_2 AWD
V_2 CF	V_2 AWD	V_2 CD

Where; V_1: Roma V F;V_2: Ibadan Local; AWD: Alternate wetting and drying (the plastic pots were alternately flooded and non-flooded for 7 days).; CD: Continuous drying (watering was done once every week throughout the crop growth period).; CF: Continuous flooding (the plastic pots were kept flooded throughout the crop growth period).

Data collection and analysis

The data set for number of leaves, plant height, leaf area and fruit yield were subjected to analyses of variance (ANOVA) using SAS software package 9.1 (SAS Institute, 2003). Comparison among the treatments combination were carried out at 0.05% probability level and treatment means were separated using Least Significance Difference (LSD).

3. Results

Plant height

Presented in Table 2 is the effect of Water Regimes on the Plant Height (cm) of Tomatoes in Abeokuta. The Table shows that the plant height was statistically influenced by different water regimes at all sampling occasions except at 9WAP. At 4WAP the valued ranged from 10.00cm for Ibadan-local (V2) under continuous drying (CD), then 10.33 cm for Roma V.F(V1) under continuous flooding (CF) and 12.37 cm for Roma V.F under alternate wetting and drying (AWD) while the highest value of 16.00cm was observed for Ibadan-local under alternate wetting and drying (AWD). Similar trend was observed across other sampling occasions. The table also shows that plant height under alternate wetting and drying ranged from 14.19 cm at 4WAP to 47.18 cm at 10WAP. The value under continuous flooding ranged from 10.50 cm at 4WAP to 30.50 cm at 10WAP while under continuous drying it ranged from 10.33 cm at 4WAP to 31.85 cm at 10WAP. Generally, regardless of the variety, AWD enhanced tomatoes plant height most followed closely by CF while plant height of tomatoes under CD showed least response to water regimes.

Table 2: Effect of Water Management Regime on the Plant Height (cm) of Tomatoes in Abeokuta

Treatment	4WAP	W5AP	6WAP	7WAP	8WAP	9WAP	10WAP
AWDV2	16.00	21.00	31.00	41.33	48.33	54.00	60.00
CFV2	10.67	15.67	25.67	36.00	31.00	31.00	32.32
CDV2	10.00	15.00	26.60	34.00	28.00	34.00	38.33
AWDV1	12.37	14.67	12.67	16.67	24.36	28.67	34.36
CFV1	10.33	13.30	13.00	14.67	20.26	25.33	28.67
CDV1	10.66	12.67	13.57	13.37	21.67	23.66	25.36
LSD(0.05)	**3.66	**7.37	**11.66	**15.23	**26.58	30.08	**34.13
AWD	14.19	17.84	21.84	29.00	36.35	41.34	47.18
CF	10.50	14.49	19.33	25.33	25.63	28.17	30.50
CD	10.33	13.84	20.09	23.69	24.84	28.83	31.85
LSD(0.05)	**3.37	7.43	11.77	13.33	23.66	27.88	31.23

Number of leaves

The difference in number of leaves of two tomato varieties at 4, 5, 6, 7, 8, 9 and 10 weeks after plant (WAP) in response to water regimes is shown in table 3. The number of leaves of both Roma V.F (V1) and Ibadan local (V2) varieties varied significantly at all sample occasions. The number of leaves at 4WAP ranged from 10leaves for Ibadan local (V2) under continuous drying to 16leaves also for Ibadan local under alternate wetting and drying water regime. The number of leaves at 7WAP ranged from 13 leaves for Roma V.F (V1) under continuous drying to 41 leaves for Ibadan local (V2) under alternate wetting and drying water regime. Also the number of leaves at 10WAP ranged from 25 leaves for Roma V.F under continuous drying to 60 leaves for Ibadan local under alternate wetting and drying water regime. The mean Number of leaves under alternate wetting and drying (AWD) ranged from 17 leaves at 4WAP to 53 leaves at 10WAP. The value under continuous flooding (CF) ranged from 13 leaves at 4WAP to 38 leaves at 10WAP while under continuous drying (CD) it ranged from 11 leaves at 4WAP to 36 leaves at 10WAP. This showed that regardless of the tomato variety, alternate wetting and drying (AWD) enhances tomatoes number leaves more than both continuous flooding (CF) and continuous drying (CD) water regimes in Abeokuta.

Table 3: Effect of Water Management Regime on Number of leaves of Tomatoes in Abeokuta

Treatment	**4WAP**	**W5AP**	**6WAP**	**7WAP**	**8WAP**	**9WAP**	**10WAP**
AWDV2	22.00	32.00	42.00	48.00	54.00	65.00	63.00
CFV2	17.00	27.00	39.00	44.00	36.00	40.00	48.00
CDV2	14.00	24.00	37.00	43.00	35.00	39.00	46.00
AWDV1	12.00	14.00	20.00	26.00	32.00	37.00	42.00
CFV1	8.00	10.00	13.00	14.00	22.00	26.00	28.00
CDV1	8.00	12.00	13.00	15.00	20.00	22.00	25.00
LSD(0.05)	**5.05	**11.84	**17.64	**24.22	**31.84	**35.56	42.53
AWD	17.00	23.00	31.00	37.00	43.00	51.00	52.00
CF	12.00	18.00	26.00	29.00	29.00	33.00	38.00
CD	11.00	18.00	25.00	29.00	27.00	30.00	35.00
LSD(0.05)	5.37	11.66	15.67	24.32	30.96	31.42	41.06

Leaf Area

The difference in leaf area of two tomato varieties at 4, 5, 6, 7, 8, 9 and 10 weeks after planting (WAP) in response to water regimes is shown in table 4. The leaf area of Roma V.F (V1) and Ibadan Local (V2) varies significantly at all sample occasions. The leaf area at 4WAP ranged from 4.23cm^2 for Roma V.F(V1) under continuous drying (CD) to 8.99cm^2 also for Ibadan Local (V2) but under alternate wetting and drying (AWD). Similarly, the leaf area at 7WAP ranged from 10.22cm^2 for Roma V.F (V1) under continuous drying (CD) to 40.87cm^2 for Ibadan Local (V2) under alternate wetting and drying (AWD) water regime. Also the leaf area at 10WAP ranged from 10.23 cm^2 for Roma V.F (V1) under continuous flooding water regime (CF) to 44.45cm^2 for Ibadan local (V2) under alternate wetting and drying water regime. The mean Leaf area under alternate wetting and drying (AWD) ranged from 7.33 cm^2 at 4WAP to 33.29 cm^2 at 10WAP. The value under continuous flooding (CF) ranged from 4.55 cm^2 at 4WAP to 22.44 cm^2 at 10WAP while under continuous drying (CD) it ranged from 4.56 cm^2 at 4WAP to 20.97 cm^2 at 10WAP. This showed that tomatoes perform better under alternate wetting and drying (AWD) than both continuous flooding (CF) and continuous drying (CD) water regimes in terms of Leaf Area in Abeokuta. This implies that tomato variety (V2) Ibadan Local performed better in terms of leaf area than tomato variety (V1) Roma V. F.

Table 4: Effect of Water Management Regime on the Leaf Area of Tomatoes in Abeokuta

Treatment	4WAP	W5AP	6WAP	7WAP	8WAP	9WAP	10WAP
AWDV2	8.99	20.88	40.00	40.87	43.33	45.45	44.45
CFV2	4.77	14.05	29.03	30.63	30.63	23.61	20.90
CDV2	4.88	13.84	29.00	30.70	30.70	23.90	24.30
AWDV1	5.67	11.25	16.01	17.01	22.44	21.12	20.03
CFV1	4.33	6.58	8.48	12.48	14.24	14.12	16.42
CDV1	4.23	4.67	6.41	10.22	11.23	12.02	10.23
LSD(0.05)	**4.54	**13.19	**17.08	**16.24	**22.22	**21.94	**20.65
AWD	7.33	16.07	28.01	28.94	32.89	33.29	32.24
CF	4.55	10.32	18.76	21.56	22.44	18.87	18.66
CD	4.56	9.26	17.71	20.46	20.97	17.96	17.27
LSD(0.05)	4.22	13.22	15.33	14.32	22.12	22.32	21.34

Soil Temperature

The influence of water regimes on pattern of soil temperature in pots of the two tomato varieties at 4, 5, 6, 7, 8, 9 and 10 weeks after plant (WAP) is shown in table 5. The soil temperature of pots containing both Roma V.F (V1) and Ibadan local (V2) were not significantly different ($p > 0.05$) at all sample occasions. The soil temperature at 4WAP ranged from 29.47°C for pot containing Ibadan local (V2) under continuous flooding to 31.83°C for pot containing Roma V.F under continuous drying. The soil temperature at 7WAP ranged from 25.53°C observed in soils of Ibadan local(V2) and Roma V.F (V1) under continuous flooding to 26.00°C for soil containing Ibadan local (V2) under alternate wetting and drying water regime. Also soil temperature at 10WAP ranged from 25.53°C for soil containing Roma V.F under continuous flooding to 31.90°C for Ibadan local under continuous drying water regime. The mean soil temperature under alternate wetting and drying (AWD) ranged from 25.87°C at 7WAP to 30.85°C at 4 & 9WAP. The value under continuous flooding (CF) ranged from 25.53°C at 7WAP to 30.04°C at 9WAP while under continuous drying (CD) it ranged from 25.73°C at 7WAP to 31.87°C at 4 & 9WAP.

Table 5: Effect of Water Management Regime on the Soil Temperature of the Tomatoes in Abeokuta

Treatment	4WAP	W5AP	6WAP	7WAP	8WAP	9WAP	10WAP
AWDV2	30.70	30.03	30.70	26.00	30.57	31.00	30.70
CFV2	29.47	29.27	29.77	25.53	29.20	30.30	29.77
CDV2	31.90	29.90	31.90	25.73	30.77	31.83	31.90
AWDV1	31.00	30.57	25.73	25.73	29.93	30.70	25.73
CFV1	30.30	29.20	25.53	25.53	29.30	29.77	25.53
CDV1	31.83	30.77	25.73	25.73	29.90	31.90	25.70
LSD(0.05)	0.90	0.74	0.68	0.46	0.71	0.83	0.67
AWD	30.85	30.30	27.90	25.87	30.25	30.85	28.22
CF	29.89	29.24	27.65	25.53	29.25	30.04	27.65
CD	31.87	30.34	28.82	25.73	30.34	31.87	28.80
LSD(0.05)	0.95	0.67	0.73	0.66	0.71	0.84	0.66

Key: V1: (Roma V. F.); V2: (Ibadan Local); CF: Continuous flooding; AWD: Alternate wetting and drying; CD: Continuous drying.

Fruit yield (kg/ha) and fruit diameter (cm)

The influence of water regimes on fruit yield (kg/ha) and fruit diameter of the two tomato varieties is shown in table 6. In Ibadan local combination, the highest fruit yield of 20.2 kg/ha was obtained under alternate wetting and drying (AWDV2) moisture availability, followed by 19.5 kg/ha under continuous flooding while the least yield of 15.7 kg/ha was obtained under continuous drying moisture availability. In Roma VF combination, the highest yield of 15.5 kg/ha was obtained under alternate wetting and drying followed by 13.6 kg/ha obtained under continuous flooding while the value of 12.5 kg/ha was obtained under continuous drying moisture availability. Generally, tomatoes planted under alternate wetting and drying moisture availability had highest fruit yield of 17.90 kg/ha followed closely by those planted under continuous flooding with 16.60 kg/ha while the least value of 14.10 kg/ha was obtained under continuous drying. Also from the table 6, in Ibadan local combination, the highest fruit diameter of 6.3 cm was obtained under alternate wetting and drying (AWDV2) moisture availability, followed by 5.2 cm under continuous flooding (CFV2) while the least fruit diameter of 4.0cm was obtained under continuous drying (CDV2) moisture availability. In Roma VF combination, the highest fruit diameter of 5.3 cm was obtained under alternate wetting and drying (AWDV1) followed by 5.2 cm obtained under continuous flooding (CFV1) while the value of 3.4 cm was obtained under continuous drying (CDV1) moisture availability. Generally, tomatoes planted under alternate wetting and drying moisture availability had highest fruit diameter of 5.8 cm followed closely by those planted under continuous flooding with 5.2 cm while the least value of 3.4 cm was obtained under continuous drying.

Table 6: Effect of Water Management Regimes on fruit yield and fruit diameter of Tomatoes in Abeokuta

Treatment	**Fruit Yield (kg/ha)**	**Fruit Diameter (cm)**
AWDV2	20.2	6.3
CFV2	19.5	5.2
CDV2	15.7	4.0
AWDV1	15.5	5.3
CFV1	13.6	5.2
CDV1	12.5	3.4
LSD(0.05)	25.4	1.6
AWD	17.9	5.8
CF	16.6	5.2
CD	14.1	3.7
LSD(0.05)	21.3	1.8

4. Discussion

The results of this study showed that alternate wetting and drying water regime appeared more suitable regulated irrigation option for growth and fruit yield of the Ibadan Local and Roma V.F tomatoes used for this study. Across all the growth parameters measured, alternate wetting and drying moisture availability produced the optimum values.

The significant effects of water management regimes on plant height, Number of leaves and Leaf area was explained by the key role played by moisture availability in systems of plants. When moisture level in the plant system is optimum, Adams (1986) reported that much of the energy required for plant metabolism will be made available and released as required. Therefore, important chemical processes involved in growth will be driven steadily. So in this study, the tomato plants grew vigorously, producing higher amounts of fresh and dry matter in the roots, stems, and leaves as more water was made available in the soil and water stress brought about a significant reduction in plant growth and hence a significant reduction in fresh and dry matter production. In the present study, a significant reduction in all growth parameters occurred under both continuous flooding and continuous drying irrigation which reflect the considerable sensitivity of tomato seedlings to water stress conditions. In this research, soil moisture at the flowering and fruit setting stage, early fruit growth stage and fruit development or maturity stage had highly significant effects on tomato yield. This result was in consistent with that of Chen *et al* (2013), who reported that excessive and insufficient soil moisture had negative effects on tomato yield, while increasing soil moisture during the last three stages could significantly promote tomato yield Chen *et al* (2015). Additionally, soil water deficit during flowering and/or yield formation stages sharply reduces the marketable yield of tomato Kuşc *et al* (2014) and Gunter *et al* (2005). Moreover, water deficit could influence the fruit setting and development of the second or third cluster of fruits resulting in reductions in fruit weight and fruit number , which is consistent with the results obtained by Nangare *et al*.(2016).

Furthermore, sufficient water supply at these two stages is crucial to meet the demand of water for high-intensity. Evapotranspiration induced by high temperatures and flourishing leaf area, and vital for enlargement of fruit cells and metabolism of fruit nutritional substances; therefore, single fruit weight increased in treatments with sufficient water supply compared with those exposed under soil moisture deficit.

5. Conclusion

In conclusion, the result showed that water management regimes have major impacts on tomato varieties. The research also confirmed that under different water management regimes, alternate wetting and drying (AWD) favours plant height, number of leaves and leaves area more than continuous flooding (CF) and continuous drying (CD. Regardless of water management option, Ibadan Local (V2) shows more productivity or better performance in terms of plant height, number of leaves and leaf area more than Roma V. F. (V1). Alternate Wetting and Drying is a very good water management option for the production of Ibadan Local in this environment, the savannah-forest transition zone of south west Nigeria

References

Adams, P., 1986. Mineral Nutrition. In: The Tomato Crop, Atherton, J.G. and J. Rudich (Eds.). Chapman and Hall Publishes, New York, pp: 281-324.

Anjum, F., Yaseen, M., Rasul, E., Wahid, A. & Anjum, S. 2003. Water stress in barley (Hordeumvulgare L.). I. Effect on morphological characters. *Pakistan J. Agric. Sci.*, 40: 43-44.

Bhatt, R.M. & Srinivasa, Rao N.K. 2005. Influence of pod load response of okra to water stress. *Indian J. Plant Physiol*, 10: 54-59

Chaves, M.M., Pereira, J.S., Maroco, J., Rodriques, M.L., Ricardo, C.P.P., Osório, M.L., Carvalho, I., Faria, T. & Pinheiro, C. 2002. How plants cope with water stress in the field photosynthesis and growth. *Ann. Bot.,* 89: 907-916

Chen J.L., Kang S.Z., Du T.S., Qiu R.J., Guo P., Chen R.Q., 2013. Quantitative response of greenhouse tomato yield and quality to water deficit at different growth stages. Agric. Water Manag. 129, 152–162.

Chen S, Zhou Z J, Andersen, M N, Hu T T. (2015) Tomato yield and water use efficiency—coupling effects between growth stage specific soil water deficits. Acta Agriculturae Sciendinavica, Section BSoil & Plant Science, 65(5): 460–469

Fawusi M.O.A. 1978. Emergence and seedling growth of Pepper as influenced by soil compaction nutrient status and moisture regime.Soc. Hortic., 9: 329-335.

Gunter C C, Francis D. (2005) Effect of Supplemental Potassium on Yield and Quality of Processing Tomato. Hortscience, 216, 1073.

Jaleel, C.A., R. Gopi, B. Sankar, M. Gomathinayagam and R.Panneerselvam, 2008. Differential responses in water use efficiency in two varieties of *Catharanthus roseus* under drought stress. *Comp.Rend. Biol*., 331: 42–47

Jensen, R., Battilani, A., Plauborg, F., Psarras, G., Chartzoulakis, K., Janowiak, F., Stikic, R., Jovanovic, Z., Li, G., Qi, X., Lui, F., Jacobsen, S., Andersen, M. 2010. Deficit irrigation based on drought tolerance and root signalling in potatoes and tomatoes. *Agricultural Water Management*, v.98, p.403-413.

Kuşc¸u H, Turhan A, Demir A O. (2014) The response of processing tomato to deficit irrigation at various phenological stages in a sub-humid environment. *Agricultural Water Management* 133: 92–103.

Monte, J., de Carvalho, D., Medic, L., da Silva, L., Pimentel, C. 2013. Growth analysis and yield of tomato crop under different irrigation depths. *Engineering Agriculture Ambiental*, v,17 p.926-931

Nangare D D, Singh Y, Kumar P S, Minhas P S. (2016) Growth, fruit yield and quality of tomato (Lycopersicon esculentum Mill.) as affected by deficit irrigation regulated on phenological basis. *Agricultural Water Management* 171: 73–79.

Oiganji, E.; A.A Ramalan; H.E Igbadun . 2010. Yields and Soil Water Balance of Onion Under Mulch and Deficit Irrigation: Unpublished MSC Department of Agricultural Engineering, Ahmadu Bello University Zaria.

Postel, S. 2000. Entering an Era of Water Scarcity: The Challenges Ahead. Ecology. Appl.

SAS Institute.2003. SAS for Windows. V.9.1 SAS Institute. Cary, NC

Taylor J.H 1987. Text of lectures delivered at the national workshop on fruit and vegetable seedlings production held at NIHORT 9-13