International Journal of Plant & Soil Science
12(1): 1-9, 2016; Article no.IJPSS.25963
ISSN: 2320-7035

SCIENCEDOMAIN *international*
www.sciencedomain.org

Productivity of Sweet Potato (*Ipomoea batatas* L.) as Influenced by Water Stress and Variety in Sokoto Sudan Savannah, Nigeria

Mohammed B. Sokoto[1*] and K. A. Sadiq[1]

[1]Department of Crop Science, Faculty of Agriculture, Usmanu Danfodiyo University, P.M.B. 2346, Sokoto, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Authors MBS and KAS designed the study and wrote the protocol. Author KAS wrote the first draft of the manuscript, managed the literature searches and the experimental process. Author MBS analyzed the results. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2016/25963
Editor(s):
(1) Marco Aurelio Cristancho, National Center for Coffee Research, Chinchiná, Caldas, Colombia.
(2) Slawomir Borek, Faculty of Biology, Department of Plant Physiology, Adam Mickiewicz University, Poland.
Reviewers:
(1) Anonymous, University of Ghana, Ghana.
(2) Robert Laurie, Agricultural Research Council –Vegetable and Ornamental Plant, Pretoria, South Africa.
Complete Peer review History: http://sciencedomain.org/review-history/15405

Original Research Article

Received 28th March 2016
Accepted 9th July 2016
Published 16th July 2016

ABSTRACT

Field trial was conducted at the Usmanu Danfodiyo University Sokoto Teaching and Research Fadama Farm, Sokoto, during the 2015 dry season. The objective of the research was to determine the productivity of sweet potato (*Ipomea batatas* L.) as influence by water stress and variety in Sokoto, Treatments consisted of factorial combination of water stress imposed at vegetative growth phase, tuber initiation growth phase, and control (unstressed), three variety of sweet potato Ex-Bakalori, Ex-kano and Ex-Fateka, laid out on a split plot design replicated three times, water stress was allocated to the main plot and variety was assigned to the sub plot. The result indicated that water stress and variety had no significant effect to leaf number, vine length, and leaf area index (LAI) at 3, 6, 9, 12, 15, and 18 Weeks After Planting (WAP). Interactions between water stress and variety also have shown no significant different to number of leaves per plant, vine length, and leaf area index. Similarly vine yield and culled tuber weight indicated no significant effect to water stress and variety. Water stress significantly affected the number of tubers per plants, number of marketable tuber per plants and number of non-marketable tuber per plant, average weight of

**Corresponding author: E-mail: mbsokoto2003@yahoo.com;*

marketable tubers and tuber yield t ha^{-1}. Water stress imposed at vegetative and control (unstress) plots did not differ significantly but differed significantly from plots imposed with water stress at tuber initiation with higher, number of tuber per plant, marketable tuber per plant and tuber yield t ha^{-1}. Water stress at the tuber initiation plots produced smaller tubers and lower tuber yield. Therefore water stress at tuber initiation should be avoided for maximum yield of sweet potato.

Keywords: Sweet potato; water stress, Leaf area index, marketable tuber; non-marketable tuber; culled tuber; vine length.

1. INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is a member of *Convolvulacea* family originated From Central America spreading across the Pacific and transported to warmer region of Asia and Africa by Spanish and Portuguese traders Allemande et al. [1]. Sweet potato is grown in more than 100 countries in tropic, subtropics and temperate climates Alleman et al. [1]. According to [2], it ranks as the world's seventh most important crop with an estimated annual production of 106,569,572 tons. Asia including: China, India, Indonesia and others 88,511,139 tons, Latin America including Brazil and Cuba 1,966,398. North American including - United States has 1,081,720 tons, Oceania including Papua, New Guinea with 742,554 tons and lastly Africa including: - Nigeria, Uganda, Kenya, Tanzania etc with total production figure of 14,213,680 and Nigeria specifically has 2,838,000 tons [3]. In Nigeria it is an important stable food particularly in the Northern part from where the bulk of the production comes and which it is even used in many aspects of nutritional and industrial purposes [4]. An average production figure in Nigeria was estimated at 273,300 metric tons which was equated to the world's average production of 437,000 metric tons [5].

Sweet potato roots are usually boiled and eaten either alone or with bean or groundnut cake, fresh peeled roots may also be sliced and deep fried on groundnut oil. Fresh tubers are also sundried, milled into sweet potato flour which is used to sweeten local food preparations. The leaves and vines are dried as hey for livestock during the dry season Tewe et al. [6]. The vine has high crude protein content 18-30% in dry matter, which is comparable to leguminous forage Farel et al. [7]. It is valuable for ruminant and other livestock species Giang et al. [8]. Thus about 81% of the total production of sweet potato is for home consumption, 9.6% animal feed, 0.6% for planting materials, 0.42% for wages in kind and 1.83% for other uses [9].

Water stress is a world spread problem and a major factor and quality affecting crop production Blum [10]. Cregg [11], define drought as a meteorological term which is commonly defined as a period of withheld significant moisture. Drought is a major abiotic constraint limiting the sweet potato yield Muhammad et al. [12]. Water stress inhibits crop growth and development, and dry matter reduction [13]. Sweet potato is influenced by many factors such as variety, spacing, pest and diseases, land preparation and propagation method Onwueme et al. [14]. The total dry matter of the tuber roots of sweet potato depends on photosynthetic activities of the leaf canopy [15]. The capacity of the plant to translocate assimilates to the tuber roots (sink) and the capacity of the tuber root to accommodate or capture assimilates [16]. Plants are subjected to several environmental stresses that adversely affect growth, metabolism, and yield of plants. Sweet potato is important in the tropic food system FAO, 2012. Ranking seven among food crop of the world Andreas et al. [17]. Storage roots dry matter, total sugar and proteins, vitamins in roots and leaves are some of the quality traits affected by various water stress condition and thus can be improved by appropriate irrigation regimes Ahmad et al. [18]. The objective of the study is: to determine the effect of water stress on growth and yield of sweet potato.

2. MATERIALS AND METHODS

2.1 Experimental Site

Field experiment was conducted at the Usmanu Danfodiyo University Fadama Teaching and Research Farm Kwalkwalawa Sokoto, during the 2015 dry season. Sokoto is located in Northwest Nigeria which lies between latitude 10-13°N and longitude 5-15°E at altitude of 350 m above sea level Mamman et al. [19]. Minimum temperature range from 19°-27°c and maximum temperature range between from 30°-40°C and wind direction generally northwesterly in the dry and southwesterly in the wet season and wind speed range 1.7-4.0 m/s [20]. The experimental site was previously used for cultivation of vegetables and cereals with little or no mineral fertilizer application and inconsistent fallow periods.

Treatment consisted of Factorial combination of water stress imposed at vegetative growth phase, tuber initiation phase, and control (unstressed), three varieties of sweet potato (Ex-Bakolori (Jan kudaku), Ex-Kano (Dan Kano), and Ex-Fateka (Dan Fateka), laid out on a split plot design replicated three times. water stress was assigned to the main plot while variety was allocated to the sub plot.

Prior to planting, soil samples were collected from 0 – 30 cm for physic-chemical analysis [21], [22]. The land was cleared, harrowed and leveled. Water channels constructed and plots of four ridges of 3 m long, spaced 75 cm apart while intra row spacing was 50 cm. Plots were kept weed free by regular manual weeding. The recommended rate of 40 kg/ha N was supplied using (Urea 46%), 45 kg/ha phosphorous was supplied using SSP (18% P_2O_5) and 60 kg/ha potassium was supplied using Muriate of Potash (K_2O 60%). Half of N, all of P and K were applied at land preparation and the second dose of N was applied four weeks after planting. Planting was done manually using hoe at inter and intra row spacing of 75 and 50 cm, respectively. Cuttings of 30 cm were planted. Two cuttings were inserted into the soil at an acute angle to the ground with half to two third of the length buried in the soil with nodes pointing upward. The field was irrigated shortly after planting. The source of water for irrigation was tube well which was lifted using water pump. The soils were irrigated to field capacity at 7 days interval. The irrigation treatment was imposed three weeks after planting. Pests were controlled by spraying Karate® three times at 2 weeks interval while diseased plants were controlled by uprooting whenever noticed. Weeds were controlled manually using hoe as at when due, Harvesting was done manually when the crop reached physiological maturity 126 days after planting as shown by yellowing and falling of leaves and also cracking of the soil. The field was irrigated 3 days prior to harvesting to facilitate easy lifting of the tubers in order to minimize bruising of tubers.

Data was collected in respect of:

2.1.1 Vine length (cm)

This was determined by measuring the vine length of four randomly tagged plants from the base to the tip of the vine at 3, 6, 9, 12, 15 and 18 weeks after planting (WAP) using a meter rule in each net plot and was recorded as vine length.

2.1.2 Number of leaves per plant

The leaves of the four tagged plants were counted at 3, 6, 9, 12, 15 and 18 WAP and the average was calculated and recorded as number of leaves per plant.

2.1.3 Leaf area index (LAI)

The leaf area index was calculated using the following formula as described by [23].

$$A \text{ (Leaf area)} = 0.56 \times P \times 6.20$$

Where: P = length x breath of sweet potato leaves 0.56 and 6.20 are constants which account for the irregularity of sweet potato leaves [23].

$$\text{LAI (Leaf area index)} = \frac{Leaf\ Area}{Land\ Area}$$

2.1.4 Number of tubers per plant

Number of tubers was determined at harvest by counting the number of tubers from the four randomly tagged plants from each net plot and average recorded as number of tubers per plant.

2.1.5 Number of marketable tuber per plant

The number of marketable tubers per plant was determined by counting the harvested tubers of the four randomly tagged plants, of weight ranging from >100 g [24] with no injury and of fresh tubers and average recorded as number of marketable tubers per plant.

2.1.6 Number of non-marketable tuber per plant

This was determined by separating harvested tubers of weight <100 g [24] from the four randomly selected plants. The average of these tubers is then computed and recorded.

2.1.7 Average weight of tuber per plant

This was computed by weighing harvested tubers from the four randomly tagged plants within net plot area. The average is then computed and recorded as tuber weight per tuber.

2.1.8 Average weight of marketable tubers

Marketable tubers are tubers that had no wounds and having weight > 100 g [24]. Tubers from the four randomly tagged plants were weighed and the average computed as average weight of marketable tubers per plant.

2.1.9 Average weight of non-marketable tubers

Tubers that sustain wounds/bruises before or during harvesting and those below marketable weight (less than 100 g) are weighed and recorded as non-marketable tubers.

2.1.10 Culled tuber weight (kg/ha)

These are tubers infected either by insect, pest or injured. They were determined by weighing the number of culled tubers obtained from the four randomly harvested tagged plants. The average is recorded as culled tuber yield in kilogram per hectare.

2.1.11 Total tuber yield (t/ha)

This was determined by weighing the total tuber yield from net plot area and extrapolated as tuber yield per hectare.

2.1.12 Vine weight (t/ha)

This was determined by weighing the total vines of the net plot after harvest and extrapolated to vine weight per hectare.

The data collected was subjected to analysis of variance (ANOVA), Bibinu et al. [25] and [26]. Means were separated using Duncan's Multiple Range Test at 5% level of probability [26].

3. RESULTS AND DISCUSSION

3.1 Physical and Chemical Properties of the Soil

The result of physical and chemical properties of soil is presented in Table 1. The soil of the area is Sandy loam, slightly acidic, low in organic carbon, total nitrogen, exchangeable cations and CEC.

3.2 Number of Leaves per Plant

The result on Number of leaves per plant is presented in Table 2. The result indicated that irrigation interval and variety had no significant influence on number of leaves per plant at 3, 6, 9, 12, 15 and 18 weeks after planting. Interaction effect between variety and irrigation interval was not significant.

3.3 Vine Length (Cm)

Vine length as influenced by variety and irrigation interval is presented in Table 3. The result indicated that irrigation interval and variety had no significant influence on vine length at 3, 6, 9, 12, 15 and 18 weeks after planting. Interaction effect between variety and irrigation interval was not significant.

3.4 Leaf Area Index (LAI)

Influence of Irrigation Interval and Variety on Leaf Area Index is presented in Table 4. Neither irrigation interval nor variety had any significant effect on LAI. The interaction between variety and irrigation interval was as well not significant.

Table 1. Physical and chemical properties of the soil in the experimental site prior to planting

Parameters	
Sand (%)	74
Silt (%)	18.5
Clay (%)	8.3
Textural class	Sandy loam
P^H (H_2O)	6.3
P^H ($CaCl_2$)	5.6
Organic carbon (%)	0.57
Nitrogen (%)	0.07
Exchangeable cations	_
Magnesium (C_{mol} kg^{-1})	0.9
Phosphorous (mg/kg)	0.6
Potassium (C_{mol} kg^{-1})	1.25
Sodium (C_{mol} kg^{-1})	0.73
CEC	2.57

Analysis conducted at the Soil Science Laboratory, Usmanu Danfodiyo University, Sokoto, Nigeria (2015)

3.5 Effect of Water Stress and Variety on Number of Tubers per Plant, Marketable Tuber per Plant and Non-Marketable Tuber per Plant

The effect of water stress and variety on number of tubers per plant, number of marketable tuber per plant and number of non-marketable tuber per plants is presented in Table 5. The result indicated that water stress significantly affected number of tubers per plant, number of marketable tuber per plant and number of non-marketable tuber per plants. The control (unstressed) did not differ significantly from water stress at vegetative but differ significantly from water stress at tuber initiation which have fewer number of tubers per plant, number of marketable tuber per plant and number of non-marketable tuber per plant. This could be as a result of water availability at vegetative stage and control (unstress) at tuber initiation which enhance photosynthesis and assimilate transfer to tuber production, the fewer number of tuber at tuber observed at tuber initiation treatment could be as a result of drought which affect tuber production and development. This research is similar to that of Thakurie et al. [27] who reported that reduction in soil penetration resistivity, due to less number of irrigation, resulted to fewer number of tubers per plant and tuber yield. Singh et al. [28] also reported that water stress at tuber initiation is one of the most influencing factors contributing to substantial yield reduction. Variety has no significant effect to water stress on number of tuber per plant, number of marketable tuber per plant and number of non-marketable tuber per plant. Interaction between water stress and variety was not significant.

Table 2. Influence of water stress and variety on number of leaves per plant of sweet potato during the 2015 dry season at Sokoto Sudan Savannah Nigeria

Treatment	Number of leaves per plant					
	Weeks after planting					
	3	**6**	**9**	**12**	**15**	**18**
Water stress						
Vegetative	19.25	40.12	48.95	60.20	78.62	80.83
Tuber initiation	18.29	39.54	48.45	61.66	76.45	76.08
Control	19.25	40.12	48.95	63.20	78.62	80.83
Significance	NS	NS	NS	NS	NS	NS
SED	3.573	7.10	5.55	4.42	5.21	5.70
Variety						
Ex-Bakolori	23.60	41.8	52.4	60.5	55.4	51.3
Ex-Kano	23.43	42.2	52.0	60.6	54.9	48.8
Ex-Fateka	23.43	42.2	51.0	61.6	53.9	48.8
Significance	NS	NS	NS	NS	NS	NS
SED	1.820	4.31	3.93	2.42	2.98	7.05
Interaction						
W X V	NS	NS	NS	NS	NS	NS

NS = Not significant (P < 0.05) according to Duncan New Multiple Range Test. WXV= Water stress X Variety

Table 3. Influence of water stress and variety on vine length of sweet potato during the 2015 dry season at Sokoto Sudan Savannah Nigeria

Treatment	Vine length (CM)					
	Weeks after planting					
	3	**6**	**9**	**12**	**15**	**18**
Water stress						
Vegetative	30.38	45.0	55.4	58.4	62.8	63.1
Tuber initiation	32.83	48.2	50.4	58.2	59.8	60.7
Control	31.92	40.9	50.5	57.0	58.7	60.2
Significance	NS	NS	NS	NS	NS	NS
SED	2.573	6.10	5.55	3.42	4.21	4.70
Variety						
Ex-Bakolori	33.60	41.8	55.4	60.5	55.4	51.3
Ex-Kano	33.43	42.2	54.0	60.6	54.9	48.8
Ex-Fateka	33.43	42.2	55.0	61.6	53.9	48.8
Significance	NS	NS	NS	NS	NS	NS
SED	1.820	4.31	3.93	2.42	2.98	7.05
Interaction						
W X V	NS	NS	NS	NS	NS	NS

NS = Not significant (P < 0.05) according to Duncan New Multiple Range Test. WXV= Water stress X Variety

Table 4. Influence of water stress and variety on leaf area index of sweet potato during the 2015 dry season at Sokoto Sudan Savannah Nigeria

Treatment	Leaf area index					
	Weeks after planting					
	3	6	9	12	15	18
Water stress						
Vegetative	0.093	0.0463	0.0495	0.0530	0.0530	0.0530
Tuber initiation	0.044	0.0463	0.0510	0.0516	0.0516	0.0516
Control	0.044	0.0470	0.0508	0.0524	0.0439	0.0444
Significance	NS	NS	NS	NS	NS	NS
SED	0.0384	0.0038	0.0044	0.0046	0.0043	0.0041
Variety						
Ex-Bakolori	0.0450	0.0489	0.0531	0.0501	0.0499	0.0523
Ex-Kano	0.091	0.0456	0.0510	0.0516	0.0489	0.0498
Ex-Fateka	0.046	0.0451	0.0470	0.0534	0.0475	0.0479
Significance	NS	NS	NS	NS	NS	NS
SED	0.0384	0.0038	0.0044	0.0534	0.0043	0.0041
Interaction						
WXV	NS					

NS = Not significant ($P < 0.05$) according to Duncan New Multiple Range Test. WXV= WXV= Water stress X Variety

Table 5. Influence of water stress and variety on number of tuber per plant, number of marketable tubers per plant, and number of non-marketable tubers per plant of sweet potato during the 2015 dry season at Sokoto Sudan Savannah Nigeria

Treatment	Number of tubers per plant	Number of marketable tubers per plant	Number of non-marketable tubers per plant
Water stress			
Vegetative	29.33[a]	15.67[a]	13.66[a]
Tuber initiation	15.44[b]	9.22[b]	6.33[b]
Control	29.11[a]	15.70[a]	13.70[a]
Significance	*	*	*
SED	2.352	1.493	1.597
Variety			
Ex-Bakolori	19.0	10.67	8.33
Ex-Kano	21.33	10.33	11.00
Ex-Fateka	19.56	10.11	9,44
Significance	NS	NS	NS
SED	2.353	1.495	1.597
Interaction			
WXV	NS	NS	NS

*Means with the same letter (s) is not significantly different ($P < 0.05$) according to Duncan New Multiple Range Test. * = Significant, NS = Not significant. WXV= Water stress X Variety*

3.6 Effect of Water Stress and Variety on Vine Weight t ha^{-1} and Culled Tuber Yield Kg ha^{-1}

The result in Table 6 indicated the effect of water stress and variety on vine weight t ha^{-1} and culled tuber yield kg ha-^{1}, the result indicated that water stress and variety had no significant effect on vine weight and culled tuber yield, similarly the interaction between water stress and variety showed no significant different.

3.7 Effect of Water Stress and Variety on Average Weight of Marketable Tubers (g), Weight of Non-Marketable Tuber (g) and Tuber Yield (T/ha)

Results in Table 7 indicated the influence of water stress and variety average weight of marketable tubers, average weight of non-marketable tubers, and tuber yield per ha. The result indicated a significant effect of water stress on average weight of marketable tubers and tuber yield per ha, Water stress imposed at Vegetative stage and Control (unstress) did not differ significantly with bigger tubers, while water stress at tuber initiation produced smaller tubers. Water stress had no significant effect on average weight of non-marketable tubers. The results in Table 7 indicated significant effect of water stress on yield t ha^{-1}, Water stress at Vegetative and Control (unstress) did not differ significantly with higher tuber yield, while water stress at tuber initiation produced lower tubers yield. Water stress and variety has no significant effect on vine weight and culled tuber yield, similarly the interaction between water stress and variety shows no significant different. Vegetative and control (unstressed) plots produces bigger tubers as compared to tuber initiation plots that produces tubers with smaller size, this could be as a result of water stress imposed at tuber initiation, which affect photosynthesis, assimilate transfer to tuber initiation and development, this finding is similar to that of Ahmed et al. [18], who observed that water stress at vegetative stage is economically recommended for uniform tuber size and higher yield. This is due to the ability of the plant to recover from water stress imposed at tuber initiation stage of sweet potato growth [29]. Noted that the use of higher and frequent irrigation application have possible increase in productivity and better quality of produce. This also agrees with the work [30]. Who observed significant reduction in root yield for the stress induced during tuber initiation phase.

Table 6. Influence of water stress and variety on vine weight t ha^{-1} and culled tuber yield (kg ha^{-1}) of sweet potato during the 2015 dry season at Sokoto Sudan Savannah Nigeria

Treatment	Vine weight t ha^{-1}	Culled tuber yield kg ha^{-1}
Water stress		
Vegetative	4.24	0.155
Tuber initiation	3.55	0.196
Control	3.62	0.182
Significance	NS	NS
SED	0.371	194.7
Variety		
Ex-Bakolori	3.86	0.283
Ex-Kano	4.05	0.95
Ex-Fateka	3.50	0.154
Significance	NS	NS
SED	0.371	194.7
Interaction		
WXV	NS	NS

NS = Not significant (P < 0.05) according to Duncan New Multiple Range Test WXV= Water stress X Variety

Table 7. Influence of water stress and variety on average weight of marketable tuber, non marketable tubers and tuber yield t ha^{-1} of sweet potato during the 2015 dry season at Sokoto Sudan Savannah Nigeria

Treatment	Average weight of marketable tubers (g)	Average weight of non-marketable tubers (g)	Tuber yield t ha^{-1}
Water stress			
Vegetative	290.89^{a}	87.6	3.88^{a}
Tuber initiation	147.9^{b}	85.8	2.81^{b}
Control	291.0^{a}	86.0	3.93^{a}
Significance	*	NS	*
SED	14.96	4.36	2.30
Variety			
Ex-Bakolori	198.2	86.9	3.43
Ex-Kano	177.3	84.7	3.13
Ex-Fateka	191.7	87.8	3.05
Significance	NS	NS	NS
SED	14.96	4.36	0.30
Interaction			
WXV	NS	NS	NS

*Means with the same letter (s) is not significantly different (P < 0.05) according to Duncan New Multiple Range Test. * = Significant, NS = Not significant. WXV= Water stress X Variety*

4. SUMMARY AND CONCLUSION

The result indicated that water stress at tuber initiation is the most critical growth stage that requires irrigation for higher tuber yield. Therefore water stress at that stage should be avoided for higher sweet potato yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Allemann J, Laurie SM, Thiart S, Voster HJ. Sustainable production of root and tuber crops in Southern Africa. South Afr. J. Bot. 2004;70(1):60-67.
2. FAOSTAT, Février. Statistical Database (online); 2012.
   Available:www.unctad.info/en/infocomm/aacp-products
   (Accessed January 28, 2013)
3. FAO.
   Available:Htt:||www.Fao.org|newsroom|an|news|2012||1000654|index.html
4. Nwokocha HN. Root crop research and technology training course. Training Manual NRCRI. Umudike Nigeria. 1992; 77-84.
5. FAO. Statistical Database; 2014. Available:www.unctad.info/en/infocomm/aacp-products
6. Tewe OO, Ojeniyi FE, Abu OA. Sweet potato production, utilization and marketing in Nigerian. 2003;1-5.
7. Farrell DJ, Jibril H, Perez-Maldonado RA, Mannion PF. A note on a comparison of sweet potato vines and lucerne meal for broiler chickens. Animal Feed Science Technology. 2000;85:145-150.
8. Giang HH, Ly LV, Ogle B. Digestibility of dried and ensiled sweet potato roots and vines and their effect on the performance and economic efficiency of F_1 crossbred fattening Pigs. Livestock Research for Rural Development. 2004;16(7):20-25.
9. CACC. Central Agricultural Census Commission. Ethiopian Agricultural Sample Enumeration, 2001/02 (1994 EC): Report on the Preliminary Result of area. Production and Yield Temporary Crops. (Meher season, Private Peasant Holdings) Part I; 2003.
10. Blum A. Drought resistance, water use efficiency and yield potential- they compatible, dissonant or mutually exclusive? Australian J. Agric Research. 2005;56:1159-1168.
11. Cregg BM. Improving drought tolerance of stress; theoretical and practical considera-tion. Proc. XxviiHc. Nursery crops (Eds) T. Fenandez and Davidson c6, Act Hort 630, ISHS. 2004;147-158.
12. Muhammad W, Asgar A, Tahir MA, Ayub M, Asif T, Ahmad R, Hussain M. Mechanism of drought tolerance in plants and its management through different method. Continental Journal of Agricultural Science. 2011;5:10-25.
13. Ahmad R, Hussain M. Mechanism of drought tolerance in plant and its management through different methods. Continental J. Agric Science. 2011;5(1):10-25.
14. Onwueme MJI, Person CJ, Searl PGE. The ecology of tropical food crops second Ed. Cambridge University Press Cambridge; 1995.
15. Abu M, Jensen CR, Mogensen VO, Esen MN, Hensen IE. Root signaling and osmotic adjustment during intermittent sun drying sustain grain yield of field grown wheat. Field Crop Research. 2003;62:35-52.
16. Hank SK, Hozyo Y. Sweet potato in the physiology of tropical field crops. Eds PR Goldssworthy, NM Fischer. John Wiley and Sons United Kingdom. 1984;551-567.
17. Andreas, Siru JJ. Effect of moisture stress on growth and development of tuberous root in sweet potato. African J. Agric Science. 2009;52-57.
18. Ahmad MDR, Abebie B. Effect of planting methods and vine harvesting on shoot and tuberous root yields of sweet potato African. Journal of Agricultural Research. 2012;7(7):1129-1141.
19. Mamman AB, Oyebanji JO, Peter SW. Nigeria: A people United, a future assured. Survey of State. Gabumo Publishing Company Limited, Calabar, Nigeria. 2000;1(12).
20. NIMET Nigerian Meteorological Agency. Sultan Abubakar iii INTL Airport Sokoto; 2015.
21. Ogunwale JA, Olarinde BD, Aduloju MO. Effects of organic matter removal and adsorbate solution composition on phosphate sorption by selected soils of

Kwara State, Nigeria. Agrosearch. 2006; 8(1):1–12.
22. Sokoto MB, Abubakar IU, Growth analysis of wheat *(Triticum aestivum* L) as influenced by water stress and variety in Sokoto, Sudan Savannah, Nigeria. Agrosearch. 2015;15(1):29-45. Available:http://dx.doi.org/10.4314/agrosh.v15i1.2
23. Asiegbu JE. Response of tomato and egg plant to mulching and nitrogen fertilization under tropical conditions. Science Horticultura. 1991;46:33-41.
24. Ossom EM. Influence of groundnut (AHL) population density on infestation and yield of sweet potato. (IBL). Journal of Food Agriculture and Environmental. 2007; 5(3,4):304-310.
25. Bibinu ATS, Isa A, Bwatanglang NK. Sorghum/millet mixture as affected by crop proportion and sorghum cultivar in a semi-arid environment. Agrosearch. 2010; 10(1&2):89–97.
26. Imoloame EO. The effect(s) of different weed control methods on weed infestation, growth and yield of soybeans (*glycine max* (l) Merril) in the Southern Guinea Savanna of Nigeria. Agrosearch. 2014;14(2):129-143.
27. Thakuria RK, Singh H, Singh T. Effect of irrigation and anti-transpiration on biometric compounds, seed yield and plant water use of spring sun flower (*Helium annus*). Indian Journal of Agronomy. 2004;49(2):121-123.
28. Singh PK, Mihsari AK, Imtiyaz Mohd. Moisture stress and water use efficiency of mustard. Agric Water Manage. 1991;20: 245-253.
29. Bharddway SK. Important of drip irrigation in Indian. Agriculture Kissan World 28; 32-33 Black CA, Evens DD, Clark IE, White JL Method of soil analysis American Society of Agronomy. Madison; 2001.
30. Indira P, Kabeerathumma S. Physiological respond of sweet potato under water stress. Effect of water stress during the different phase of Tuberization. Journal of Root Crop. 1988;14(2):37-40.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/15405