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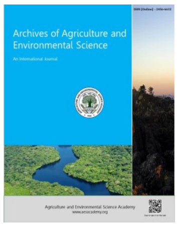

ORIGINAL RESEARCH ARTICLE

Growth and yield of amaranths (*Amaranthus spp.*) as influenced by seed rate and variety in Sokoto, Nigeria

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ABSTRACT

This experiment was conducted at the Teaching and Research Vegetable Garden of the Department of Crop Science, Usmanu Danfodiyo University, Sokoto during the rainy season of the year 2016. The objective of the research was to determine the effect of seed rate and variety on the growth and yield of Amaranths (*Amaranthus spp.*) in Sokoto. The treatment consists of factorial combination of four (4) seed rates (2.0 kg ha^{-1}, 2.5 kg ha^{-1}, 3.0 kg ha^{-1} and 3.5 kg ha^{-1}) and two (2) varieties Ex-Egypt (''*DAN EGYPT*) and Ex-Kano *'DAN KANO*''. The result indicated that seed rate had no significant effect on plant height of amaranths at 2 Weeks after Planting (WAP). However, at 4, 6 and 8 WAP, seed rate significantly (p<0.05) affected plant height. Seed rate at 3.0 kg ha^{-1} resulted to significantly taller plants which did not differ significantly from 3.5 kg ha^{-1} and 2.5 kg ha^{-1}. The shortest plant was from 2.0 kg ha^{-1}. The effect of seed rate and variety on number of leaves is not significant (P>0.05) at 2, 4, 6, and 8 WAP. The result also showed that seed rate had significant (P<0.05) effect on fresh and dry weight of amaranths at harvest; seed rate of 3.5 kg ha^{-1}did not differed significantly from seed rate at 3.0 kg ha^{-1} and 2.5 kg ha^{-1}, while seed rate at 2.0 kg ha^{-1} recording the lowest fresh and dry weight of amaranths. Seed rate at 2.5 kg ha^{-1} and any of the two varieties, Ex-Egypt (*DAN EGYPT*) or Ex-Kano*'DAN KANO*'' would be beneficial for the farmers in Sokoto State and areas with similar environmental conditions.

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INTRODUCTION

Amaranth belongs to the family *Amaranthaceae,* the genus *Amaranthus* includes 50-60 species, cultivated for green leaf and grains and a few wild species (Rai and Yadav, 2005). Amaranth is one of the oldest food crops in the world; evidence of its cultivation dates back to as far as 6700 BC (RSA, 2010). Amaranth is considered one of the most commonly produced and consumed indigenous vegetables on the African continent (Grubben and Denton, 2004). According to Olorode (1984), *Amaranthus cruentus* L. is a leafy vegetable commonly cultivated in Nigeria and other West African countries. Aphane *et al.* (2003) reported that foods of animal origin which are known to be the major source of vitamins and proteins are very expensive for poor households. Wehmeyer and Rose (1983) observed that fruits and vegetables could alternatively play a major role in alleviating problems associated with malnutrition due to their ability to supply proteins, vitamins, calories and othernutrients needed in a balanced diet. Laker (2007) observed that of more than 100 different indigenous leafy vegetable species in Africa, Amaranth is the most widely consumed. According to Olorode (1984), *Amaranthus cruentus* L. is a leafy vegetable commonly cultivated in Nigeria and other West African countries. Amaranth, a C4 plant, is one of a few dicots in which the first product of photosynthesis is a four carbon compound. Kaul *et al.* (1996) observed that increased efficiency of amaranth to use CO_2 under a wide range of both temperature and moisture stress environments could be as a result of its anatomical features and C4 metabolism and this contributes to the plant's wide geographic adaptability to diverse environmental conditions. African indigenous vegetables play significant role in the food security of the under-privileged in both urban and rural settings (Schippers, 1997). Many communities use vegetables as source of energy and micro nutrients in their diets (Gravetti and Ogle, 2000). Vegetables are usually picked fresh, used as greens in salads or blanched, steamed, boiled, fried in oil, and mixed with meat, fish, cucurbit seeds, groundnut or palm oil. Cooked greens can be used as a side dish, in soups or as an ingredient in sauce and baby food etc. (Grubben, 2004a, b). Amaranth grain if rolled or popped can be used in muesli and in granola bars. Grain can also be use for beer production. In Africa Amaranth species have been used for medicinal purposes. In East and West Africa *A. graecizans* is used to manufacture a local salt, where by the plants are dried and burned to ashes and used as a substitute for common salt. In Uganda the leaves are chewed and the liquid swallowed to treat tonsillitis. In Senegal, the leaves are used as an anthelmintic (Maundu and Grubben, 2004a, b). According to Lehman (1988), the carbohydrates in Amaranth grain consist primarily of starch made up of both glutinous and non-glutinous fractions. The unique aspect of Amaranth grain starch is that the size of the starch granules are much smaller than found in other cereal grains. The unique size and composition of Amaranth starch suggested that the starch may possess unique gelatinization and freeze / thaw characteristics which could be of benefit to the food industry. Several considerations for the use of Amaranth starch in food preparation of custards, pastes, and salad dressing have been reported by Singhal and Kulkarni (1990 a, b, c). The folic acid in amaranth reduces the risk of neural defects in pregnant women and their newborns (AVRDC, 2011). Amaranth seed is rich in the two essential amino acids (lysine and methionine) that are not frequently found in other grains, Lysine plays a vital role in the treatment and prevention of a disease known as *osteoporosis* that makes bones prone to fracture (Pisarikova *et al.,* 2005). In Nigeria *A. blitum* is used as medicine against lung disorder (Grubben, 2004a). Grubben (2004b) stated that, *A. cruentus* is use as medicine in different parts of Africa; in Senegal the roots are boiled with honey as a laxative for infants; in Ghana the water of macerated plants is used as a wash to treat pains in the limbs; in Ethiopia it is used as a tapeworm-expeller; the ash from the stems is used as a wound dressing in Sudan and in Gabon heated leaves were used on tumours.

Patel *et al.* (2011) reported significant interaction amongst the genotype, row spacing and seed rate on growth and yield of amaranth fodder. According to Rai and Yadav (2005) the seed rate per hectare is between 2 kg to 3 kg. However for cultivation of Amaranth for grain purpose, 1.5 kg seed will be sufficient for a hectare area, because it is sown at wider spacing. Planting Amaranth on narrow row spacing of 18 cm or less may aid in weed control, by the shading effect of the amaranth plants (Stallknecht *et al.,* 1990). Esechie (1992) observed that the difference in response of plant height to seed rate might be attributed to the levels of seed rates and condition under which the crop is grown. Since higher densities contain more plants per unit area, dry matter yield per unit area increased with increasing plant density). Gasim (2001) reported that plant height increased with increase in seed rate, and number of leaves per plant was significantly affected by seed rate.

Amaranth is considered as underutilized crop and has, until recently, received little research attention (NRC, 1984). Low crop productivity is a general problem facing most farming systems in Sub-Saharan Africa (SSA). Mabulu and Chalamila (2005) reported that the average leaf yields of amaranths in Sub-Saharan Africa are less than 1.2 t h^{-1}, against the potential yield of 32-40 t h^{-1} (Oluoch *et al*., 2009). Most of existing cultivars of amaranth in Africa are generally much smaller, up to 50 cm, strongly branched and prostrate with many flowers and small leaves which creates difficulties during harvest e.g. *A. blitum, A. graecizans* (Maundu and Grubben, 2004). These characteristics contribute to the problem of low yield which farmers experience in production.

Amaranthus an indigenous vegetable can also become popular with commercial growers if suitable high yielding variety and appropriate seed rate is applied to promote the yield and nutritive value of *amaranths*. *Amaranthus,* one of the cultivated indigenous vegetables has short production cycle, high yielding with good nutritional value and low cost of production. The crop can therefore support farmer's income, In Sub-Saharan Africa; about 20-25% of the population is under-nourished due to poor energy and protein intake. In addition 40% of women in childbearing age are anemic; while a similar proportion of children under-five lack enough nutrients for normal physical development (IFPRI). Research indicates that the vast majority of yield growth in African agriculture to date has been due to improved seed varieties and appropriate seed rate, as opposed to technological improvements in cultivation practices or other inputs (Evenson, 2004). Improved vegetable productivity and resources use efficiency could only be achieved, when appropriate planting technologies and seed density are available. Vegetables can be grown all year round and can be produced even on marginal soils. Amaranth requires 40-50% less moisture than maize and survives better than most crops under dry and hot conditions because of its extensive root system and use of C_4 photosynthesis mechanism (Stallknecht *et al*., 1993). Research indicates that the vast majority of yield growth in African agriculture to date has been due to improved seed varieties and appropriate seed rate, as opposed to technological improvements in cultivation practices or other inputs (Evenson, 2004). Most of the important indigenous vegetables including *Amaranthus* have been identified as having potential for commercial exploitation and production for human consumption (Taylor and Moss, 1982). Most indigenous plants are adapted to the prevailing conditions and require few agricultural inputs and perform well in areas unsuitable for introduced vegetables (Aphane *et al.,* 2003). The objectives of the study are to determine the variety for optimum yield under Sokoto condition and also determine the appropriate seed rate for optimum yield of Amaranth.

MATERIALS AND METHODS

Experimental site: Field experiment was conducted during the year 2016 in the raining season at the Teaching and Research Vegetable garden of the Department of Crop Science, Faculty of Agriculture, Usmanu Danfodiyo University. Sokoto is located on latitude 13°1'North and longitude 5°15'East and altitude of about 350m above the sea level in Sudan Savannah Agroecological Zone of Nigeria. The climate of the area is semi-arid with mean annual rainfall of 645mm and the temperature ranges from 15°-40°c, Sokoto Energy Research Centre (SERC, 2016). Prior to planting, a composite sample of soil was collected from 10 randomly selected points within the experimental site at a depth of 0-30cm using auger. The sample was bulked, air-dried and sieved by using 2mm sieve. The bulked sample was used for physico-chemical analysis of the soil. Treatment consisted of factorial combination four seed rate (2.0Kg ha^{-1}, 2.5Kg ha^{-1}, 3.0Kg ha^{-1}, and 3.5Kg ha $^{-1}$) and two varieties (Ex-Egypt (*DAN EGYPT*) and Ex-Kano *DAN KANO*") laid out in a randomized complete block design replicated three times. Gross plot measuring 2m x 2m ($4m^2$), while the net plot was $1.2m^2$.

Characteristics of the varieties

Ex-Egypt (*DAN EGYPT*): Colour of seed is cream; Native of Egypt; Leaf is alternate and broad, ready for harvest between 21-28 days after planting.

Ex-Kano *(DAN KANO)*: Colour of seed is black; Native of Kano state; Nigeria, Leaf is alternate and narrow; ready for harvest between 28-35 days after planting.

Cultivation practices: The experimental site was ploughed, harrowed and gross plot measuring 2m x 2m ($4m^2$) prepared. The seeds of two varieties *viz.,* Ex-Egypt (''*DAN EGYPT*) and Ex-Kano *DAN KANO*''of amaranth were obtained from Sokoto Vegetable market [Kasuwa Dan Kure]. The seeds of the different seed rates were planted by drilling method which was spaced at 40cm between each row and lightly covered with the soil. Recommended fertilizer rate of 70 kg N ha^{-1}, 34 kg P ha^{-1} and 26 kg Kha^{-1} was applied in two applications, basal and top dressing at three weeks after planting. Weeding was done using hoe. First weeding was carried out at two weeks after sowing and second weeding at 4 weeks after sowing. Harvesting was done by uprooting the whole plant at 8 weeks after planting (WAP).

Data collection: Data was collected on growth and yield parameters as per Omary (2013); Abubakar (2015).

Plant Height (cm): A meter rule was used to take the height of four (4) tagged plants in each experimental unit at 2, 4, 6 and 8 weeks after planting, and the mean was calculated and recorded. The height was measured from the ground level to the tip of the plant following (Omary, 2013; Abubakar, 2015).

Number of leaves: Leaves of four (4) tagged plants were counted in each experimental unit at 2, 4, 6 and 8 weeks after planting, and the mean determined. Only fully opened leaves were counted.

Leaf area: The length and width multiplied by a constant (6.6) of the four (4) tagged plants in each experimental unit was used to obtain this parameter, the mean was calculated and recorded.

L x W x 6.6 = LA (Muhammed, 2012)

Fresh weight of the plant (kg ha^{-1}): The whole plant in the net plots after been uprooted and root washed was weighed, and then extrapolated to per hectare.

Dry weight of the plant (kg ha^{-1}): The separated parts of the leaves and the stems were then sun dried for a week (7 days) and weighed to determine the dry matter of the net plot and then extrapolated to per hectare.

Data analysis: The data collected was subjected to analysis of variance (ANOVA) (Muhammed, 2012; Omary, 2013; Abubakar, 2015), where treatments are significant Duncan's New Multiple Range Test (DNMRT) was used for mean separation.

RESULTS AND DISCUSSION

Physical and chemical properties of soil: The result recorded on soil physical and chemical characters are presented in Table 1. Based on the results of the analysis, the soil is sandy loam in texture, low in exchangeable cations, nitrogen and organic carbon.

Effect of seed rate on plant height: The effect of seed rate on plant height of Amaranths is presented in Table 2. The result indicated that seed rate had no significant effect in plant height of amaranths at 2 WAP. However, at 4, 6 and 8 WAP, seed rate significantly affected plant height. Seed rate of 3.0kg ha^{-1} resulted to significantly taller plants which did not differ significantly from 3.5kg ha^{-1} and 2.5kg ha^{-1}. The shortest plant was from 2.0kg ha^{-1}. This could be as results of competition for light at higher seeds rates. Seed rate of 2 kg ha^{-1} recorded the shortest plant height which could be as a result of reduced canopy spread which could affect light interception increasing rate of evapotranspiration and also competition between individual plants for space and resources in Seed rate of 3.5 kg/ha at a higher seed rate which results to higher plant population per unit area. Stallknecht and Schulz-Schaeffer (1993), reported that individual cultivars can vary in height, dependent upon plant density and available soil moisture. This result is consistent with findings of Gasim (2001), who reported that the effect of seed rate on plant height per plant increased with increase in seed rate of Teff grass.

Effect of variety on plant height: The effect of variety on plant height of amaranths is presented in Table 2. The result revealed that variety had no significant (p>0.05) effect on plant height at 2, 4, 6 and 8 WAP.

Effect of seed rate and variety on number of leaves: The effect of seed rate and variety on number of leaves is shown in Table 3. The main effect of seed rate, variety and their interaction had no significant effect on number of leaves of amaranths at 2, 4, 6, and 8 WAP.

Effect of seed rate and variety on leaf area at harvest: Leaf area of Amaranths as affected by seed rates, variety and their interaction during the 2016 rainy season is presented in Table 4. The result showed that seed rate, variety and their interaction had no significant effect on leaf area at harvest.

Fresh weight at harvest: Fresh weight of Amaranths as affected by seed rates, variety and their interaction during the 2016 rainy season is presented in Tables 4 and 5.

Effect of seed rate and variety on fresh weight of amaranths: The result showed that seed rate has significant effect on fresh weight of amaranths at harvest. Seed rate of 2.5kg ha^{-1}3.0kg ha^{-1} and 3.5kg ha^{-1} did not differ significantly with the highest fresh yield, while seed rate of 2.0kg ha^{-1} recording the lowest yield. This may be due to low seed rate resulted in lower fresh yield as a results of fewer number of stands/plants as compared to the higher seed rate which produce more/higher number of plants.

This may be attributed to fact that low seed rate produced low number of plants per unit area. The result is in agreement with the results of Mwai *et al*. (2009) that Amaranths total leaf fresh and dry mass increased with an increase in plant densities. The result also showed that there was no significant difference `as regard to the effect of variety on fresh weight at harvest.

The result shows that the interaction between seed rate and variety has significant effect on fresh weight of amaranths at harvest. Seed rate of 2.5kg ha^{-1} 3.0kg ha^{-1} and 3.5kg ha^{-1} did not differ significantly with the highest fresh yield, while seed rate of 2.0kg ha^{-1} recording the lowest yield across each of the variety. The result is in conformity with the results Patel *et al.* (2011) who reported interaction amongst the genotype, method of planting and seed rate on growth and yield of amaranths.

Dry weight: Dry weight of Amaranths as affected by seed rates, variety and their interaction during the 2016 rainy season is presented in Table 4.

Effect of seed rate and variety: The result showed that seed rate has significant effect on fresh weight of amaranths at harvest. Seed rate of 2.5kg ha^{-1} 3.0kg ha^{-1} and 3.5kg ha^{-1} did not differ significantly with the highest fresh yield, while seed rate of 2.0kg ha^{-1} recording the lowest yield. The result indicated that a higher yield was produced with high seed rate. This may be due to low seed rate resulted in lower fresh and dry yield compared to the higher seed rate. This may be attributed to fact that low seed rate produced low number of plants per unit area. Although this was not true for seed of 3.5kg ha^{-1} which did not produce a high yield with high seed rate which may be due to high competition between plants for soil and aerial resources. The main effect of seed rate, variety and their interaction had no significant effect on dry weight of amaranths at 2, 4, 6, and 8 WAP.

Table 1. Physical and chemical characteristics of the soil.

Particle distribution (g/kg)	Value
Sand (%)	45.63
Clay (%)	9.53
Silt (%)	44.83
Texture	Sandy loam
Chemical properties	
Soil Ph	5.50
Organic Carbon (%)	0.41
Total Nitrogen (%)	0.73
Available Phosphorus (mg/kg)	0.51
Cation Exchange Capacity (CEC)	2.20
Exchangeable Bases (Cmol/kg)	
Calcium (Ca^{2+})	0.41
Potassium (K^{+})	0.23
Magnesium (Mg^{2+})	0.15
Sodium (Na^{+})	0.52

Table 2. Effect of seed rate, variety and their interaction on plant height of Amaranths at Sokoto during the 2016 rainy season.

Treatment	Plant height (cm) Weeks after planting			
Seed rate (Kg ha^{-1})	2	4	6	8
2.0	13.04	32.84^{b}	49.73^{b}	93.42^{b}
2.5	11.51	36.96^{a}	56.98^{a}	91.77^{b}
3.0	14.87	37.01^{a}	57.86^{a}	98.02^{a}
3.5	11.32	35.83^{a}	53.69^{a}	97.86^{a}
SE±	0.957	2.579	3.554	3.639
Significance	NS	*	*	*
Variety				
Ex-Egypt	13.85	38.32	57.75	97.41
Ex- Kano	11.52	32.99	50.88	90.63
SE±	0.231	0.312	0.331	0.363
Interaction				
SR × V	NS	NS	NS	NS

Mean with the same superscript letter in a column are not significantly different (p<0.05) according to Duncan's New Multiples Range Test; Ns = not significant, * = significant at 5%.

Table 3. Effect of seed rate, variety and their interaction on number of leaves of Amaranths at Sokoto during the rainy season of the year 2016.

Treatments	Number of leaves Weeks after planting			
Seed Rate (Kg ha^{-1})	2	4	6	8
2.0	8.06	12.46	20.42	33.04
2.5	8.03	12.00	18.88	29.63
3.0	8.09	11.38	19.42	32.44
3.5	8.08	13.50	19.71	28.89
SE±	0.310	0.360	0.676	1.405
Significance	NS	NS	NS	NS

Mean with the same superscript letter in a column are not significantly different (p<0.05) according to Duncan's New Multiples Range Test; Ns = not significant, * = significant at 5%.

Table 4. Effect of seed rate, variety and their interaction on leaf at harvest, Fresh weight at harvest (kg ha^{-1}) and Dry weight (kg ha^{-1}) of Amaranths in Sokoto during the rainy season of the year 2016.

Treatments	Leaf area at harvest	Fresh weight at harvest (kg ha^{-1})	Dry weight (kg ha^{-1})
Seed Rate (Kg ha^{-1})			
2.0	0.08	14166.67^{b}	3194.50^{b}
2.5	0.07	20555.50^{a}	4722.33^{a}
3.0	0.08	20566.83^{a}	4305.50^{a}
3.5	0.14	20545.67^{a}	4305.50^{a}
SE±	0.543	0.500	0.476
Significance	NS	*	*
Variety			
Ex-Egypt	0.08	21041.75	4652.83
Ex-Kano	0.19	21005.58	4651.08
SE±	0.432	0.072	0.139
Significance	NS	NS	NS
Interaction			
SR × V	NS	NS	NS

Mean with the same superscript letter in a column are not significantly different (p<0.05) according to Duncan's new multiples range test; Ns = not significant, * = significant at 5%.

Table 5. Effect of interaction between seed rate and variety on fresh weight of Amaranths at harvest at Sokoto during the rainy season of the year 2016.

	Variety	
Seed rate (Kg ha-1)	Dan Egypt	Dan Kano
2.0	15277.67^{b}	13055.67^{b}
2.5	23611.0^{a}	17500.00^{a}
3.0	21667.00^{a}	16666.67^{a}
3.5	23611.33^{a}	20000.00^{a}
SE±	1.404	1.400
Significance	*	*

Mean with the same superscript letter in a column are not significantly different (p<0.05) according to Duncan's new multiples range test; Ns = not significant, * = significant at 5%.

Conclusions

The research indicated that seed rate at 2.5 kg ha^{-1}and any of the two varieties, Ex-Egypt (*DAN EGYPT*) or Ex-Kano (*DAN KANO*) can result in higher growth and yield of amaranths and would be beneficial for the farmers in Sokoto State and areas with similar environmental conditions. Farmers in this part of the world considered amaranths as a minor crop, most of the time the farmers do not consider seed rate while planting and this result in sub optimum plant population, the finding will help farmers in selection of optimum seed rate for optimum plant population and also varietals selection.

REFERENCES

Abubakar, M.J.D. (2015). Effect of different soil amendment rates (chicken manure and NPK fertilizer 15-15-15) on the growth and yield of vegetable amaranth (*Amaranthus hybridus*) University for development studies, tamale. Dissertation submitted to the Department of Horticulture, Faculty of Agriculture, University for development studies, in partial fulfillment of the requirements for the award of masters of philosophy degree in horticulture. pp: 139.

Aphane, J., Chadha M.L. and Oluoch M.O. (2003). *Increasing the consumption of micronutrient-rich foods through production of indigenous foods.* In: FAO / AVRDC International Workshop Proceedings, 5 - 8 March 2002, Arusha, Tanzania. AVRDC - The World Vegetable Centre Shanua, Taiwan: AVRDC Publication No. 03 - 561: pp: 1-77.

AVRDC (2011). New variety releases expand market options for Tanzania's farmers. Fresh news from AVRDC-The World vegetable center pp: 1-3.

Esechie, H.A. (1992). Effect of planting density on growth and yield of irrigated maize in the Batina Costa Region of Oman. *Journal of Agricultural Science,* 119: 165-169.

Evenson, R.E. (2004). Making science and technology work for the poor. In: Baidu-Forson, J.J (Ed) Green and Gene Revolution in Africa. Annual Lectures 2003 sponsored by UNU-INRA and UN ECA, October 2003, pp: 203.

Gasim, S.A. (2001). Effect of nitrogen, phosphorus and seed rate on growth, yield and quality of forage maize (*Zea mays*). MSc Thesis, Faculty of Agriculture, University of Khartoum.

Gravetti, L.E. and Ogle, M.B. (2000).Value of traditional foods in meeting macro and micronutrient needs*:* The While Plant Connection. *Nutrition Research Reviews,* 13 (1): 31-46.

Grubben, G.J.H. (2004a). *Amaranthus blitum* L. In: Grubben, G.J.H. and Denton, O.A. (Eds.), PROTA 2. Vegetables/ L`egumes [CD-Rom].PROTA, Wageningen, Netherlands, pp: 74-83.

Grubben, G.J.H. (2004b). *Amaranthus cruentus* L. In: Grubben, G.J.H. and Denton, O.A. (Eds.), PROTA 2. Vegetables/ L`egumes [CD-Rom]. PROTA, Wageningen, Netherlands, pp: 205-213.

Grubben, G.J.H. and Denton, O.A., (Eds.) (2004). Plant Genetic Resources of Tropical Africa 2: Vegetable. Wageningen, Netherlands: PROTA Foundation.

Kaul, H.P., Aufhammer, W., Laible B., Nalborczyk, E., Pirog, S. and Wasiak, K. (1996). The suitability of amaranth genotypes for grain and fodder use in Central Europe. *Die Bodenkultur,* 47 (3): 173-181.

Lehman, J. (1988). *Carbohydrates of amaranth.* Legacy 1: 4-8 (America Amaranth Institute Bricelyn, MN).

Laker, M.C. (2007). Introduction to the special edition of Water SA on indigenous crops, water and human nutrition. Water SA, 33 (3): 311-315.

Olorode, O. (1984). Taxonomy of West African Flowing Plants. Longman Group Ltd., London, UK, pp: 158.

NRC (1984). Amaranth: modern prospects for an ancient crop.National Research Council. National Academy Press, Washington, D.C.

Mabulu, R.B. and Chalamila, B.N. (2005). Organic vegetable production an alternative income generating activity to the disease effected coconut farming system in Mkuranga District in Tanzania. African crop science conference proceedings, Vol. 7. pp: 1539-1544.

Maundu, P.M. and Grubben, G.J.H. (2004). *Amaranthus graecizans* L. In: Grubben, G.J.H. and Denton, O.A. (Eds). PROTA2.Vegetables/Legumes [CD-Rom]. PROTA, Wageningen, Netherlands.

Muhammed, J. (2012). Productivity of amaranths (*Amaranthus spp*) as influenced by water stress and pot size in Sokoto Sudan Savannah Nigeria. A BSc project, Crop Science Department, Usmanu Danfodiyo University, Sokoto, pp: 14.

Mwai, G.N., Onyango, M.O.A., Onyango, J.C., Chadha, M.L. and Oluoch, M.O. (2009). Effect of plant density on yield component of nightshade. *Acta Horticulture,* 806: 733-739.

Olorode O. (1984). *Taxonomy of West African Flowing Plants.* Longman Group Ltd., London, UK, pp. 158.

Oluoch, M.O., Pichop G.N., Silue D., Abukutsa-Onyango M,O., Diouf, M.and Shackleton, C.M. (2009). Production and ha vesting systems for african indigenous vegetable. In: Lich fouse, E., Hamelin, M., Nararrete, M. and Debaeke, P. (Eds.): *Sustainable Agriculture volume* 2. London. EDP Sciences. Ch. V.

Omary, I.M. (2013). Morphological characteristics, growth and yield of elite grain and leaf amaranth in northern Tanzania. Master of Science (research methods). A dissertation submitted in partial fulfillment of the requirements for the degree of Master of Science in research methods in the Jomo Kenyatta University of Agriculture and Technology Jomo Kenyata University of Agriculture and Technology. pp: 84.

Patel, P.A., Smitha, S.C., Alagundagi, C.P., Mansur, V.S., Kubsad, S.V., Hosamani and Megeri, S.N. (2011). Effect of row spacing and seed rate on growth, fodder productivity and economics of amaranth genotypes. *Karnataka Journal of Agricultural Science,* 24 (5): 651-653.

Pisarikova, B., Zraly, Z., Kracmar, S., Trckova, M. and Herzig, I. (2005). Nutritive value of amaranth grain (*Amaranthus*L.) in the diets for broiler chickens. *Czech Journal of Animal Science*, 50: 568-573.

Rai, N. and Yadav, D.S. (2005). Advances in Vegetable Production. Published by Research co Book Center 25-B/2, New Rohtak Road Karol Bagh, New Delhi-110005 India, pp: 550 -558.

RSA. Republic of South Africa (2010). Amaranthus: Production guideline. Department of Agriculture, Forestry and Fisheries. Pretoria

Schippers, R. (1997). Domestication of indigenous vegetables for Sub-Saharan Africa: A strategy paper. African indigenous vegetables, Workshop Proceedings, January 13-18, 1997, Limbe, Cameroon, pp: 125-135.

Singhal R.S. and Kulkarni P.R. (1990a). Some properties of *Amaranthus paniculatas* (Rajgeera) starch pastes. Starch/ Starke, 42: 5-7.

Singhal R.S. and Kulkarni P.R. (1990b). Utilization of *Amaranthus paniculatas* (Rajgeera) starch in salad dressing. Starch / Starke 42: 52-53.

Singhal R.S. and Kulkarni P.R. (1990c). Studies on applicability of *Amaranthus paniculatas* (Rajgeeraa) starch for custard preparation. Starch / Starke 42: 102- 03.

SERC, Sokoto Enegy Research Center (2016). Meteorological data: Usmanu Danfodiyo University, Sokoto, Nigeria.

Stallknecht G.F., Duffus J.E. and Schaeffer J. (1990). Curly top virus in grain amaranth. Post Paper. Fourth U.S. Amaranth Conference, Minneapolis, MN Aug 23 - 25.

Stallknecht, G.F. and Schulz-Schaeffer, J.R. (1993). Amaranth rediscovered. pp: 211-218. In: J. Janick and J.E. Simon (eds.). New crops.Wiley, New York.

Taylor, F.K. and Moss, H. (1982).The potential for commercial utilization of veld products in Botswana.Veld Products Institute, Gaborone.

Wehmeyer, A.S. and Rose, E.F. (1983). Important indigenous plants in the Transkei as food supplements. *Bothalia*, 14: 613 - 615.