Asian Research Journal of Agriculture

6(1): 1-8, 2017; Article no.ARJA.35312
ISSN: 2456-561X

Diagonal Offset Arrangement and Spacing Architecture Effect on Growth and Yield Components of Grain Amaranth in Kenya

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Authors' contributions

This work was carried out in collaboration between all the authors. Author ANR designed the study and wrote the first draft of the manuscript. Authors NKK and JPG reviewed the study design and all drafts of the manuscript. Author NKK performed the statistical analysis. Author ANR managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARJA/2017/35312
Editor(s):
(1) Hatem Boubakri, Laboratory of legumes, Centre of Biotechnology of Borj-Cédria, Tunisia.
Reviewers:
(1) Congyan Wang, Jiangsu University, China.
(2) Willem Jansen van Rensburg, Agriculture Research Council, South Africa.
(3) Salem Aboglila, University of Tripoli, Libya.
Complete Peer review History: http://www.sciencedomain.org/review-history/20628

Original Research Article

Received 6th July 2017
Accepted 10th August 2017
Published 23rd August 2017

ABSTRACT

The grain Amaranth (*Amaranthus cruentus*) is often referred to as the crop of the future because of its advantages both for production and consumption. However, the grain amaranth has an under-exploited potential that can contribute to food security, nutrition, health, income generation and environmental services. However, productivity of the crop in Kenya where it is grown in small plots has not been fully utilized. The current study was conducted to find out how conventional intra row spacing and diagonal offset spacing influence growth and yield of grain amaranth. A field experiment was carried out at Kenyatta University field station. It was laid out in a randomized complete block design (RCBD) with two arrangements (Conventional and Diagonal Offset) and two row spacings (30 cm × 15 cm and 15 cm × 15 cm) that was replicated three times. The longest roots (23.0 cm) were observed in the diagonal offset with 15×15 cm during season one and the widest stem diameter were elicited under the 15×15 cm in the diagonal offset arrangement with 0.62 cm and 1.05 cm recorded during the first and second season, respectively. The root mass under the

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diagonal offset arrangement at 15×15 cm spacing had the highest with 26.3 g and 25.0 g per plant during the first and second season, respectively. The least leaf area per plant was recorded under the narrow spacing (15×15 cm) of the conventional arrangement for both seasons while the greatest was under the narrow spacing of the diagonal offset arrangement recording a mean of 1200 cm^2 and 1230 cm^2 for the first and second seasons, respectively. The diagonal offset arrangement under the narrow spacing showed the highest grain yield per plant with a mean of 48.2 g during the first season and 47.22 g during the second season. There were no significant differences between the treatments on the number of leaves, plant height, number of branches per plant and the 1000-seed mass. The Diagonal offset arrangement led to improved performance of grain amaranth in both seasons and is therefore highly recommended especially in the narrow spacing of 15×15 cm. In conclusion, results of this study revealed that the narrow spacing of 15×15 cm under the diagonal offset arrangement led to the best performance of grain amaranth and is highly recommended.

Keywords: Grain Amaranth; diagonal offset; plant-level plasticity; spacing arrangement.

1. INTRODUCTION

The grain amaranths (*Amaranthus* spp.) are native to the New World. Pre-Columbian civilizations grew thousands of hectares of this pseudo-cereal. Some indigenous populations are said to have used grain amaranth, along with maize and beans, as an integral part of their cropping schemes. The Aztecs relied on amaranth seeds (or “grain”) as an important staple [1]. The genus Amaranthus includes approximately 60 species, most of which are widely dispersed weeds. The weedy amaranths thrive in disturbed soils and tend to be associated with agricultural practices [1]. The tradition of using some species of feral amaranths as forage for livestock, as greens for human consumption and as dye plants continues in many places. The leaves of many cultivated species of Amaranthus are commonly eaten as a “potherb” or leafy vegetable throughout the world [2]. There is no clear dividing line between a “grain” type and a “vegetable” type. The leaves of amaranth plants which are being grown specifically for grain can serve as a food source, if the leaves are consumed when the plants are young. There are three species of the genus amaranthus which produce large seed heads of edible, light-colored seeds *A. cruentus* L., *A. hypochondriacus* L. are native to Mexico and Guatemala and *A. caudatus* L. is native to the Andean regions of Ecuador, Peru and Bolivia [3]. Amaranth grain is considered to have a unique composition of protein, carbohydrate and lipid. It has high protein (12-18%) than other cereals grain. It has higher lysine content and contains high fibre, calcium, iron, magnesium, phosphorus, copper and manganese. The nutrient values of grain amaranth per 100% edible portion (leaves and tender shoots) has moisture content of 86.9 ml, calorie 36, protein 3.5, fat 0.5 g, total carbohydrates 6.5 g, fiber 1.3 g, potassium 411 mg, iron 3.9 mg, vitamin A (beta carotene) 6100 IU, thiamine (B1) 0.08 mg, riboflavin 0.16 mg, niacin 1.4 mg, ascorbic acid (vitamin C) 80 mg, calcium 267 mg, and ash 2.6 g [3].

Grain amaranth is also referred to the crop of the poor. It has been proposed as an inexpensive native crop that could be cultivated by indigenous farmers in the rural areas because it is easily harvested and highly tolerant to harsh conditions and drought. It has also no major disease problems and is among the easiest crops to grow [4]. Despite the huge nutritional benefits of grain amaranth, there is a dearth of information with regards to its requirements for optimum productivity, especially in this part of the world where amaranth is grown mainly for its leaves by resource-poor farmers who have little knowledge on the potential benefits of the grain types.

Grain amaranth is a nutritious vegetable and contains relatively high amounts of minerals and vitamins, which are needed for healthy body growth, sustenance and alleviation of problems of hunger and malnutrition mostly experienced amongst children in developing countries. It has an under-exploited potential to contribute to food security, nutrition, health, income generation and environmental services in Kenya. High population and repeated subdivision of land, coupled with limited resources available to the large proportion of the population living the poverty index, severely constrain grain amaranth production. Kenya’s population continues to increase at an average of 2.6% annually since 2002 and stood at 41.6 million in 2011 [5]. Average farm sizes are shrinking largely due to the traditional land inheritance practice of subdividing land [6]. Decreasing farm sizes coupled with increasing population drives a deficit in which yields decrease because famers can afford fewer and fewer inputs [7]. Part of the solution to this challenge lies in the use of very small scale and low external input farming practices like the Bio-Intensive Agriculture diagonal offset arrangement. However, limited research and documentation has been conducted and reported in the production of grain amaranth in Kenya. This study was therefore conducted to evaluate how plant arrangement and spacing influence growth and yield of grain amaranth.

2. MATERIALS AND METHODS

2.1 Study Site

The field experiment was conducted at The Kenyatta University main campus which is located at Kahawa in Kiambu County. It is approximately 20 kilometers by road, northeast of the central business district of Nairobi. The campus lies along the road between Nairobi and the Central Kenyan town of Thika. The coordinates of Kenyatta University main campus are: latitude; 1°10'59.0"S and longitude 36°55'34.0"E.The County enjoys a warm climate with average temperatures ranging from a low of 12°C and highs of 18.7°C. The rainfall aggregate for the county is 1000 mm each year. June and July rank as the coldest months while January-March and September-October are the hottest months. The rainy season runs from March to July then the dry season is experienced from September to December whereby the first season was the rainy season and the second season was the dry season under the current study.

2.2 Experimental Design and Treatments

The experimental design of the study was a randomized complete block design consisting of two conventional spacing recommended by the Kenya Ministry of Agriculture of 15 × 15 cm and 30 × 15 cm; and two diagonal offset spacing of 15 × 15 cm and 30 × 15 cm. The treatments were then replicated three times. The seeds sourced from Simlaw were planted directly to the experimental plots of size 2 m by 1 m and N fertilizer (CAN) was applied four weeks after planting. Thinning was done just before applying the N fertilizer treatments and two hand weedings followed thereafter. Disease and pest control was done in the case of their respective incidences. Harvesting for the vegetables and grains was done on the four middle rows.

2.3 Data Collection

Data was collected at planting, for every two weeks from four weeks after emergence from 5 tagged plants per plant. The following growth and yield components were measured and recorded: Plant height (cm), root length (cm) on the main root, stem diameter (cm) using a vernier caliper, number of leaves per plant, leaf area (cm^2) per plant, 1000-seed weight (g), and grain weight (g). Dried heads were threshed and the grains obtained were sundried for about three days. The weight of the grains were recorded and used to estimate the grain weight per plot, which was later converted to grain yield per plant by dividing by the stand count.

2.4 Data Analysis

The data collected was summarized using Ms. Excel package and subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) version 9.0 and their individual treatment means compared using Fischer's least significant difference (LSD) at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Root Length and Mass

The root length of amaranth showed significant differences ($P<0.05$) with the diagonal offset arrangement at the narrow spacing of 15 × 15 cm eliciting the highest (23.61 cm) during the first season (Fig. 1). The same trend was observed during the second season with the same treatment exhibiting the longest roots at 21.80 cm which was generally lower that in the first season. Under the conventional arrangement the wider spacing of 30 × 15 cm showed the longest roots for both seasons.

The root weight showed significant differences ($P<0.05$) between the treatments where the diagonal offset arrangement at 15 × 15 cm spacing had the highest with 26.3 g and 25.0 g/plant during the first and the second season, respectively (Fig. 2). The longer roots in the narrow spacing under the diagonal offset arrangement might be due to deep soil preparation that increased porosity and aeration of the soil and stimulated microbial activity, root penetration and enhanced water and nutrient supply potential. The soil tillage obtained by double digging in the diagonal offset allowed plant roots to penetrate downwards rather than spread outwards, enabling high density planting.

This in turn allowed high density planting that led to very high yields on small areas [8].

3.2 Stem Diameter

The stem diameter showed significant differences ($P<0.05$) due to the treatments where the 15 × 15 cm spacing under the diagonal offset had the widest amaranth stems for both seasons (Fig. 3). However, the wider spacing under the diagonal arrangement elicited the least stem diameter for both seasons while the reverse was observed on the conventional spacing.

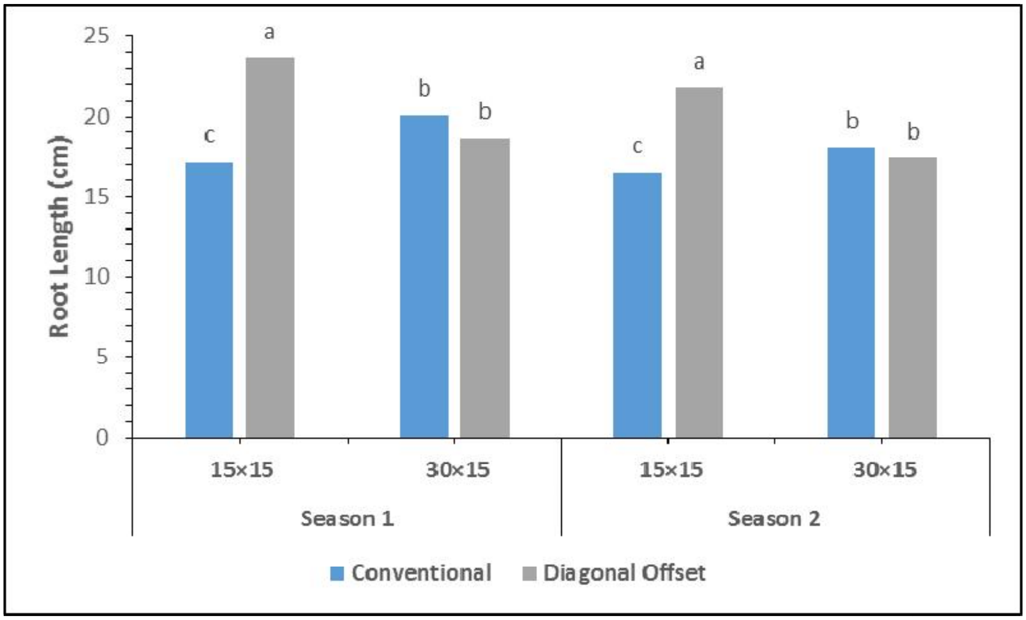

Fig. 1. Root length of grain amaranth as influenced by spacing arrangements during the first and second seasons at Kenyatta University

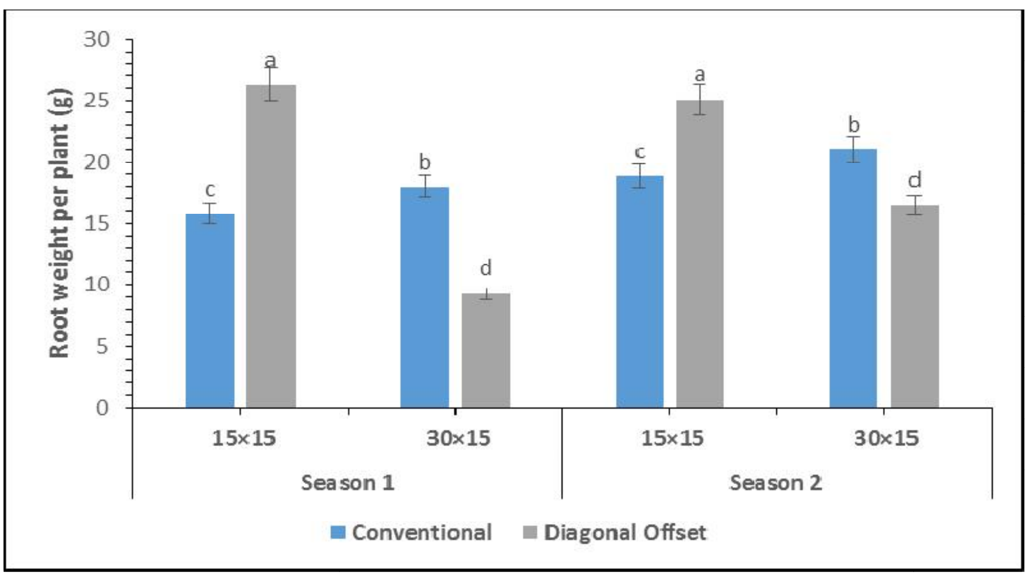

Fig. 2. Root weight of grain amaranth as influenced by spacing arrangements during the first and second seasons at Kenyatta University

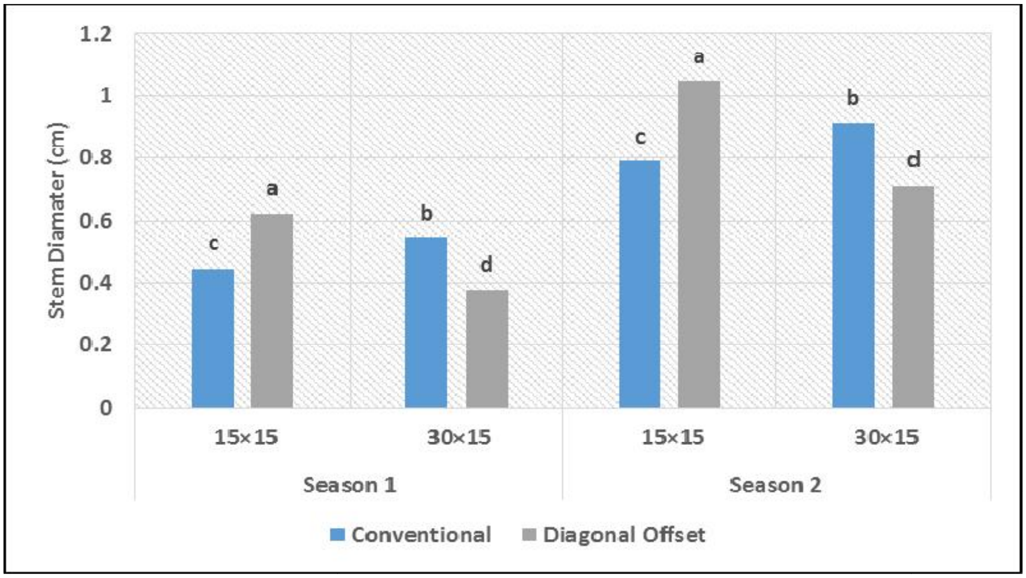

Fig. 3. Influence of diagonal offset and conventional arrangements on the stem diameter for two seasons at Kenyatta University

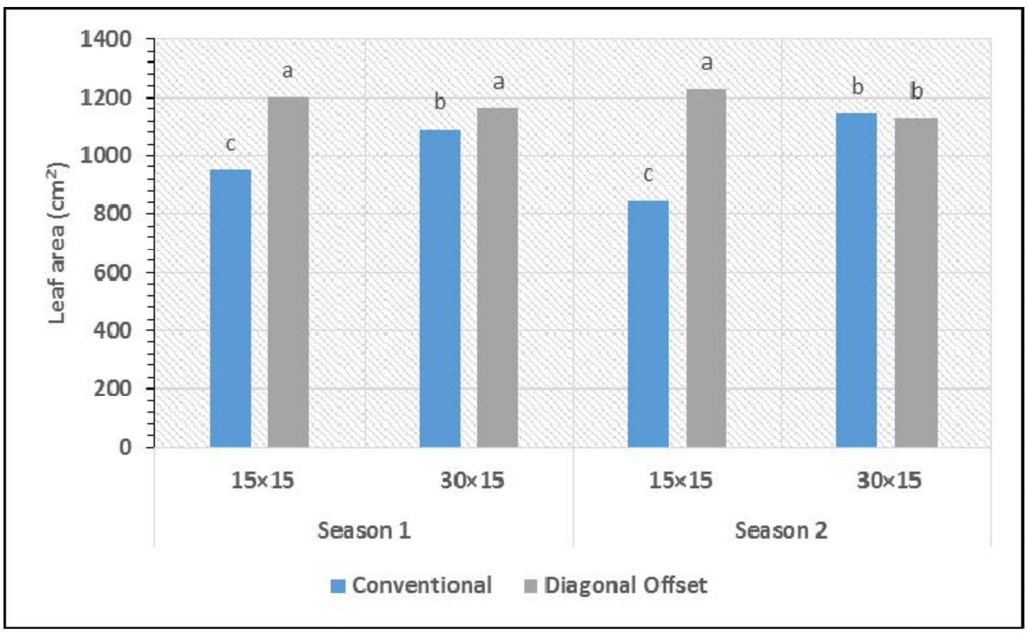

Fig. 4. Influence of diagonal offset and conventional arrangements on the leaf area for the two seasons at Kenyatta University

As observed on the root length and mass, the diagonal offset arrangement enhanced penetration of roots thus metabolic process were enhanced and therefore the stem girth increased in order to take through more nutrients and water to support the plant. The aboveground plant components including leaves and stem, contribute significantly to the economic yield, and is known to be affected by various environmental factors such as spacing and crop arrangement architecture. In accordance with the results of this study, Authors [9] had earlier reported significant variations in the stem diameter due to difference in plant arrangement and spacing revealing that the narrow spacing led to higher stem diameter.

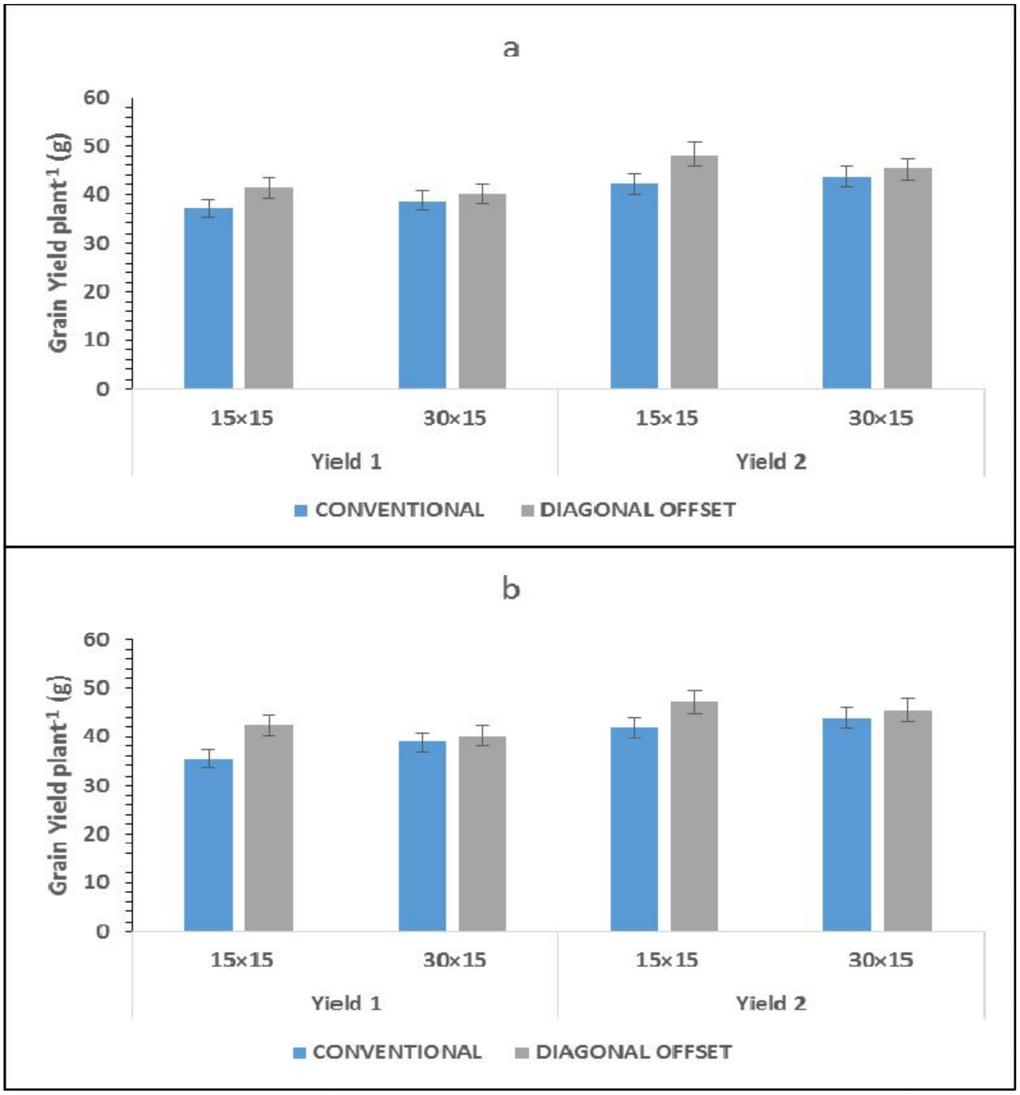

Fig. 5. Grain yield per plant of amaranth as influenced by spacing arrangements during the first (a) and second (b) seasons at Kenyatta University

3.3 Leaf Area

There was no significant differences (*P*<0.05) between the diagonal offset and conventional arrangements at a spacing of 15 × 15 cm and 30 × 15 cm respectively on the leaf area where both had the greatest during the first season (Fig. 4). The lowest leaf area was recorded on the 30 × 15 cm spacing under the conventional arrangement. During the second season, the 15 × 15 cm spacing under the diagonal offset arrangement exhibited the greatest leaf area while the conventional and diagonal offset arrangement in the 30 × 15 cm spacing did not differ significantly (*P*>0.05) as observed during the first season. The narrow spacing under the conventional arrangement had the least leaf area for both seasons. The low leaf area under the narrow conventional spacing during both seasons was probably due to reduced growth by shortened internodes where early vegetative growth was hindered and reduction in the rate of leaf appearance as well as the number of expanding leaves and thus the final leaf area per plant. This indicates that stresses due to high planting density decreased the leaf area by reducing rates of leaf area expansion and growth. Reduction in leaf area might have reduced the light interception and photosynthesis because both are strongly correlated.

3.4 Grain Yield

The crop was harvested twice for both seasons with the diagonal offset arrangement showing significantly (*P*<0.05) the highest grain yield as shown in Fig. 5. The 30 × 15 cm spacing under both arrangements did not differ significantly in both harvests for both seasons. However, the narrow spacing of 15 × 15 cm under the conventional arrangement showed the lowest grain yield for both seasons in each of the harvest. The importance of plant arrangement and spacing in amaranths is attributed to higher yield. It promoted high rates of compost, dense crop spacing, and deep soil loosening and thus leading to greater yield. This also allowed high-density planting that led to higher yielding under lesser land area. These findings revealed that close spacing under the diagonal offset yielded significantly more amaranth grain yield than conventionally spaced plants, conforming with observations by [8] that techniques that combine deep tillage and high density planting can increase crop yield of crops per unit of land 2 to 6 times compared to the conventional average. The result of this study on the diagonal offset was in conformity to the findings of [10] who reported that grain yield increased with an increase in planting density in grain amaranth. These results are at variance with the findings of [11] who suggested that the plasticity of grain amaranth morphology may limit its response to row spacing. Authors [12,13,14] similarly did not observe significant yield responses to row spacing. A Missouri study that compared different row spacing at Thomas Jefferson Agricultural Institute found that the widest row spacing (lowest planting density) produced the highest grain yield which is in tandem with those found on the conventional row spacing. It was in the study that suggested that amaranth plants seem to compete excessively with each other when planted at high planting density (narrower spacing), leading to shorter, less vigorous plants and smaller grain yield.

4. CONCLUSION

The root length, root weight, leaf area and stem diameter of grain amaranth significantly depended upon the plant arrangement and spacing because of the observed differences. The diagonal offset arrangement under narrow spacing (15×15 cm) led to increased growth and higher grain yield than under wider spacing indicating economical land use. On the other hand, the conventional arrangement at wider spacing (30×15 cm) led to greater growth and significantly higher yields compared to the narrow spacing. The grain amaranth showed higher grain yield per plant under the closer spacing of 15 × 15 cm under the diagonal offset arrangement and therefore it is highly recommended.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. National Academy of Sciences (NAS). Amaranth modern prospects for an ancient crop. Nat. Acad. Sci., Washington, DC; 1984.
2. Martin FW, Telek L. Vegetables for the hot, humid tropics, Part 6. Amaranth and Celosia, Amaranthus and Celosia. Agricultural Research (south region) Science and Education Administration, U.S Department of Agriculture, New Orleans, LA; 1979.
3. Kauffman CS, Weber LE. Grain amaranth. In: Advances in new crops, Janick and J.E. Simon (Eds.). Timber Press, Portland, OR. 1990;127-139.
4. Singhal RS, Kulkami PR. Review: Amaranthus-an underutilized resource. Int. J. Food Sci. Tech. 1988;23:125-139.
5. World Bank. Country data: Kenya at a glance [online]. Available:http://data.worldbank.org/country/kenya (2012)
6. Yamano T. The long term impacts of orphan hood on education attainment and land inheritance among adults in rural Kenya. Agric. Econ. 2007;37:141-149.
7. Macharia CN, Njeru CM, Ombakho GA, Shiluli MS. Comparative performance of advanced generations of maize hybrids with a local maize variety: Agronomic and financial implications for smallholder farmers. J. Anim. Plant Sci. 2010;7(2):801-809
8. Jeavons J. How to grow more vegetables than you ever thought possible on less land than you can imagine, Eight Edition, Ten Speeds Press. Berkeley, USA. 2012; 1-6.
9. Olofintoye JAT, Adeniyi HA, Adetula OA. Effects of phosphorus fertilizer and intra-row spacing on the growth and yield of

grain amaranth (*Amaranthus cruentus*). Agric. 2011;6:366-368.
10. Malligawad LH, Patil VC. Effect of planting density and planting geometry on growth and yield of grain amaranth. Karnataka J. Agric. Sci. 2001;14(1):11-17.
11. Henderson TL, Johnson BL, Schneiter AA. Row spacing, plant population and cultivar effects on grain amaranth in the Northern Great Plains. Agron. J. 2000;92:329-335.
12. Aufhammer W, Kaul HP, Herz P, Nalborezyk E, Dalbiak A, Gontarczyk M. Grain yield formation and nitrogen uptake of amaranth. Eur. J. Agron. 1995;4:379-386.
13. Myers RL. Amaranth: New crop opportunity. In: J. Janick (Ed.), Progress in new crops. ASHS Press, Alexandria, VA. 1996;207-220.
14. Gimplinger DM, Dobos G, Schonlenchner R, Kaul HP. Yield and quality of grain amaranth (*Amaranthus* sp.) in Eastern Austria. Plant Soil Environ. 2007;53(3): 105–112.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20628