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TARGETING APPROPRIATE GRAIN AMARANTH PRODUCTION TECHNOLOGIES FOR IMPROVED PRODUCTIVITY, HOUSEHOLD NUTRITION & INCOME SECURITY IN SEMI-ARID EASTERN KENYA

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Citation:

Njiru, E.N., Ghelle, F.O. and Mutisya, D.L. (2015). Targeting Appropriate Grain Amaranth Production Technologies for Improved Productivity, Household Nutrition & Income Security in Semi-Arid Eastern Kenya. In: Isutsa, D.K. and Githae, E.W. *Proceedings of the First International Research Conference held from 29th to 31st October, 2014 in Chuka University, Chuka, Kenya.14-20pp.*

ABSTRACT

Grain amaranth (*A. creatus* L. and *A. hypodriacus*) is a nutritious, relatively drought tolerant high value crop, whose production in Kenya outstrips the demand. Due to its tolerance to drought it is an ideal choice for the semi-arid region especially under conditions of climate change. Amaranth production in semi-arid eastern Kenya is however, at its infancy with limited production and utilization know-how. Trials were planted in two locations in Kitui and Makueni Counties of eastern Kenya during long rain and short rain seasons of 2013 with the aim of evaluating appropriate production technologies for validation and dissemination under semi-arid conditions. Objectives of these trials were: to determine ideal amaranth plant spacing for optimal yield performance and suitable and economic fertilizer levels for production under semi-arid conditions of eastern Kenya. Treatments were two inter-row spacing (90cm and 75cm) and four fertility levels (zero, 5 t farmyard manure (FYM)/ha, 10 t FYM/ha and 20 kg P₂O₅ /ha) in a randomized complete block design. There was significant difference (P≤0.05) in yields between locations with yields being higher in Kitui in long rains 2013 than Kiboko in short rains 2013. No significant difference was found between different spacing and fertility levels within locations although highest yields were obtained at spacing of 90 x 30 cm and 20 kg P₂O₅ at Kiboko and 90 x 30 cm with 10 t

FYM at Kitui. More work requires to be done across locations for precise conclusions and recommendations.

Key words: *Production technologies, Household Nutrition, Income security, Semi-Arid Eastern Kenya*

INTRODUCTION

Grain amaranth (*Amaranthus hypochondriacus*) 'manna' is a broad leafed pseudo cereal in Amaranthaceae family (Myers, 1996; O'Brien and Price, 2008) and has multiple uses as a vegetable, nutrient rich grains and livestock feed. Amaranth is grown for its high quality grains that are used to improve nutritive values of other cereals (Tung, 2010; Svirskis, 2003). Once established amaranth is relatively drought tolerant (Mnkeni et al., 2007) and gives reasonable yields under good management making it an ideal crop in semi arid lands (ASALs) especially under the conditions of climate change (Allemann et al. (1996). Amaranth is a relatively new crop in Kenya, and demand outstrips supply with most of the processors importing the grain from Uganda and India. This makes amaranth a high value crop with a kilogram of the grain retailing at between KES 75-100 depending on the buyers. Production of amaranth is picking up in lower eastern Kenya due to awareness created by Kenya Agricultural and Livestock Research Organization (KALRO) Katumani research centre.

Despite the increased interest in amaranth as a crop in the ASALs, there are no appropriate agronomic packages for its production. Only limited information is available on fertility requirements especially from studies conducted in the wetter western part of the country (Nyankanga *et al.*, 2012, Wekesa F.S., 2010). Although reports indicate that amaranth can withstand low soil fertility (Mnkeni et al., 2007) its general performance and ultimate yields will be influenced by existing soil conditions and available soil fertility, just like any other crop. In semi-arid lands of eastern Kenya, little is known about fertilizer requirements for optimum grain amaranth yields. Information on plant spacing in the ASALs is also lacking. Such lack of information and the growing interest in production formed the basis of this study.

MATERIALS AND METHODS

Study site

This study was conducted at Kiboko field station, a sub-centre of KALRO–Katumani in Makueni County and Kitui Agricultural Training Centre (ATC) in Kitui County both in semi-arid eastern Kenya. Kiboko is on Agro-ecological zone V and has a mean annual rainfall of 670 mm and average temperatures of 27°C. Kitui ATC lies in the transitional zone between agro-ecological zones III and IV. It is generally wetter than Kiboko with mean annual rainfall of 1021 mm and average temperature of 21.4°C (27.1°C mean maximum and 15.7°C mean minimum temperatures). Both areas exhibit variable rainfall with a bimodal pattern. These rains occur from March to May and from October to December. March to May rainfall is

referred to as the long rains (LR) and usually has a peak in April. This is followed by an extended dry period which lasts until mid-October before the October to December rainfall season which is also known as the short rains (SR) with a peak in November. Dominant soils are the chromic Luvisols which are low in fertility (0.5–1.0% carbon and 0.07–0.09% nitrogen). The main agricultural production enterprise in the surroundings of the trial locations is mixed crop-livestock production systems with varying degrees of integration.

Experimental design and treatments

Performance of grain amaranth was evaluated in a factorial experiment consisting of two plant spacing (S1 and S2) and four fertility levels (F1, F2, F3 and F4) in a randomized complete block design (RCBD) with three replicates. The trial was planted in two locations during long and short rain seasons of 2013. Grain amaranth was used as the test crop.

Treatments

Treatments consisted of combinations of two inter-row plant spacings of 90 cm (S1) and 75 cm (S2) and application of four fertility levels (0 kg fertilizer (F1), 5 tons farmyard manure (FYM) ha⁻¹ (F2), 10 tons FYM ha⁻¹ (F3) and 20kg P₂O₅ ha⁻¹ (F4) as listed in Table 1. The intra-row spacing was kept constant at a distant of 30 cm. Treatments were randomly applied to plots of 3m x 3m in each of the three replicates.

Land preparation and planting

Land was ploughed and harrowed by tractor drawn plough and harrow before the soil was broken to a fine tilth and leveled using the hand hoe. Shallow furrows were opened using hand hoes at row spacings of 75 or 90 cm according to treatment allocation in the field. Soil samples were collected at the beginning of the first season of the trial before application of treatments at 0-30 cm layer for initial nutrient characterization. Farmyard manure used in the trials was purchased from Katumani research farm due to availability of information on its nutrient composition from earlier studies. Inorganic fertilizer Di-Ammonium Phosphate (DAP) was used as the source of P₂O₅. The fertilizers were applied along the prepared furrows in the specific plots before planting. Amaranth seed was mixed with dry sand at a ratio of 1:10 for easy of sowing and the mixture drilled along the furrows before covering lightly with soil. Planting was done at the onset of the rains at both locations.

Table 1: Treatments used for evaluation of performance of grain amaranth

Treatment	Inter-row spacing	Fertilizer applied (units ha ⁻¹)	Number of plants ha ⁻¹
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	(cm)		1
S1F1	90	0	37,037
S2F1	75	0	44,444
S1F2	90	5 tons FYM	37,037
S2F2	75	5 tons FYM	44,444
S1F3	90	10 tons FYM	37,037
S2F3	75	10 tons FYM	44,444
S1F4	90	20 kg P ₂ O ₅	37,037
S2F4	75	20 kg P ₂ O ₅	44,444

Trial management and data collection

The crop was thinned to an intra-row distance of 30 cm two weeks after emergence. Trials were monitored throughout the growing period and kept free of weeds by hand weeding. Insect pests were controlled by spraying with Lambdacyalothrin 50 g/l (Duduthrim). Grain yields were determined by harvesting crop in the net plots at physiological maturity. A net plot area of 3 rows and 2.4 running metres (6.48 m²) was harvested for the 90 cm plots and 4 rows and 2.4 running metres (7.2 m²) for 75 cm plots by leaving out one row at each end of plot and one plant from each side of the harvested rows. Amaranth heads were harvested and dried before threshing and recording dry weights per plot. The grain was further dried and final dry weights recorded for calculation of yields per hectare.

Statistical analysis

Data was entered and organized in Excel spread sheets before being transferred for analysis of variance (ANOVA) and determination of significant differences ($P \leq 0.05$) in GenStat 14th edition (VSN, 2011).

RESULTS AND DISCUSSIONS

This paper highlights results obtained during March-May (long rains) 2013 season.

Soil and manure characterization

Results of initial soil nutrient characteristics have not been included. Analysis of farmyard manure from the research station indicated the qualities shown in Table 2.

Table 2: Chemical characteristics of farmyard manure on dry matter basis

Nitrogen	Phosphorous	Potash	Calcium (CaO)	Magnesium oxide	Manganese	Zinc	Copper	Iron
1.62%	1.15%	1.62%	0.36%	1.49%	500 ppm	200 ppm	30 ppm	15,000 ppm

Grain yield results

Kiboko location

At Kiboko grain yields were generally low during the season with an overall mean of 112 kg ha⁻¹. No significant differences ($P \leq 0.05$) were found between spacing, fertility levels or interaction between spacing and fertility. The highest grain yields (146 kg ha⁻¹) were however, obtained with application of 20 kg P₂O₅ ha⁻¹ and the least (73 kg ha⁻¹) with no fertilizer application. Addition of farmyard manure or inorganic fertilizer resulted in an increase in grain yields in an almost linear pattern. Thus, application of 5 and 10 tons FYM increased yields from those of the zero fertilizer application plots by 40% and 70%, respectively, whereas 20 kg P₂O₅ ha⁻¹ doubled the yields.

Highest grain yields (153 kg ha⁻¹) came from plots with 20 kg P₂O₅ ha⁻¹ and a spacing of 90 cm (Figure 1). This was followed by 20 kg P₂O₅ ha⁻¹ at 75 cm (139 kg ha⁻¹), 10 t ha⁻¹ at 90 cm (131 kg ha⁻¹), and 10 t ha⁻¹ at 75 cm (121 kg ha⁻¹). The least yields (78 and 68 kg ha⁻¹) came from treatments of 90 cm and 75 cm, respectively, with no fertilizer application. Yield difference between the two spacings was not significant.

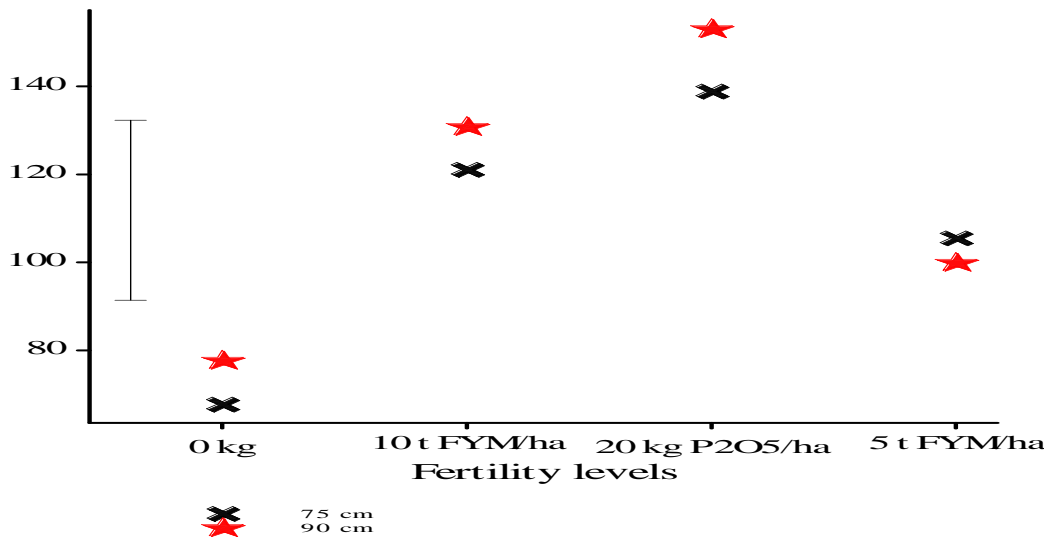


Figure 1: Effect of spacing and different fertility levels on amaranth grain yield at Kiboko

Kitui location

Grain yields at Kitui ATC showed no significant difference ($P \leq 0.05$) in fertility or spacing, or the interaction between spacing and fertility (Figure 2). Higher yields (532 kg ha^{-1}) were obtained from the 90 cm spacing treatment plots compared to 468 kg ha^{-1} from the 75 cm spacing plots (lsd = 104.3). Generally, with the exception of application of 5 t FYM ha^{-1} yields were always higher at 90 cm than 75 m (Figure 2).

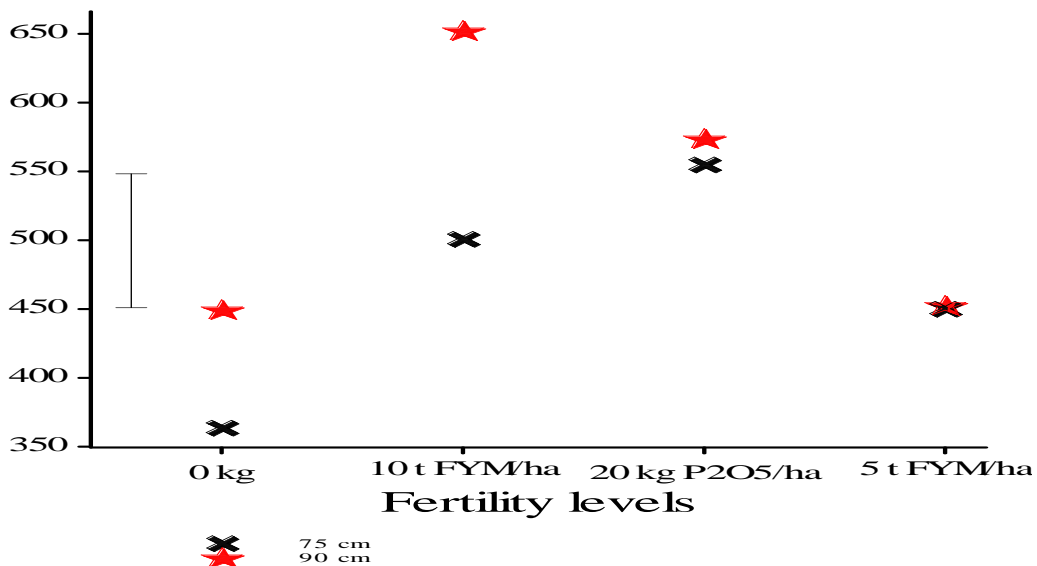


Figure 2: Effect of spacing and different fertility levels on amaranth grain yield at Kitui

Plots with 10 t FYM ha⁻¹ gave the highest yields (577 kg ha⁻¹) followed by those with 20 kg P₂O₅ ha⁻¹ (564 kg), 5 t FYM (451 kg) and zero fertilizer application (406 kg ha⁻¹). A combination of 10 tons FYM and 90 cm spacing gave 652 kg of grain ha⁻¹. These were followed by 574 kg ha⁻¹ from 20 kg P₂O₅ ha⁻¹ at 90 cm and 555 kg ha⁻¹ from 20 kg P₂O₅ ha⁻¹ at 75 cm. Least yield (364 kg/ha) was harvested from 0 kg fertilizer at 75 cm spacing.

Across location analysis

Results of analysis across the two locations are illustrated in Table 3. Significant difference (P < 0.001) was found in the general yield performance across the two locations with highest yields realized from the wetter location (Kitui ATC) compared to Kiboko. No significant difference was found in spacing, interaction between spacing and fertility or spacing, location and fertility interactions.

Table 3: Amaranth grain yield across locations (Kiboko and Kitui ATC) during long rains 2013 season

		0 kg	5 t FYM ha ⁻¹	10 t FYM ha ⁻¹	20 kg P ₂ O ₅ ha ⁻¹
75 cm	Kiboko	68	106	121	139
	Kitui	364	450	501	555
90 cm	Kiboko	78	100	131	153
	Kitui	449	452	652	574
		P values	SED	LSD	% CV
Location		<.001	26.5	54.1	
Spacing		0.188	26.5	54.1	
Fertility		0.009	37.4	76.4	
Location x Spacing		0.289	37.4	76.4	
Location x Fertility		0.359	52.9	108.2	
Spacing x Fertility		0.708	52.9	108.1	
Location x Spacing x Fertility		0.771	74.9	152.9	30.0

However, there was significant difference ($P < 0.009$) in the effect of fertility across the two locations (Figure 3). Grain yields from application of 10 t FYM ha^{-1} (351 kg ha^{-1}) and 20 $\text{kg P}_2\text{O}_5 \text{ ha}^{-1}$ (355 kg ha^{-1}) were significantly different ($\text{LSD} = 108.1$) from zero application of fertilizer (240 kg ha^{-1}).

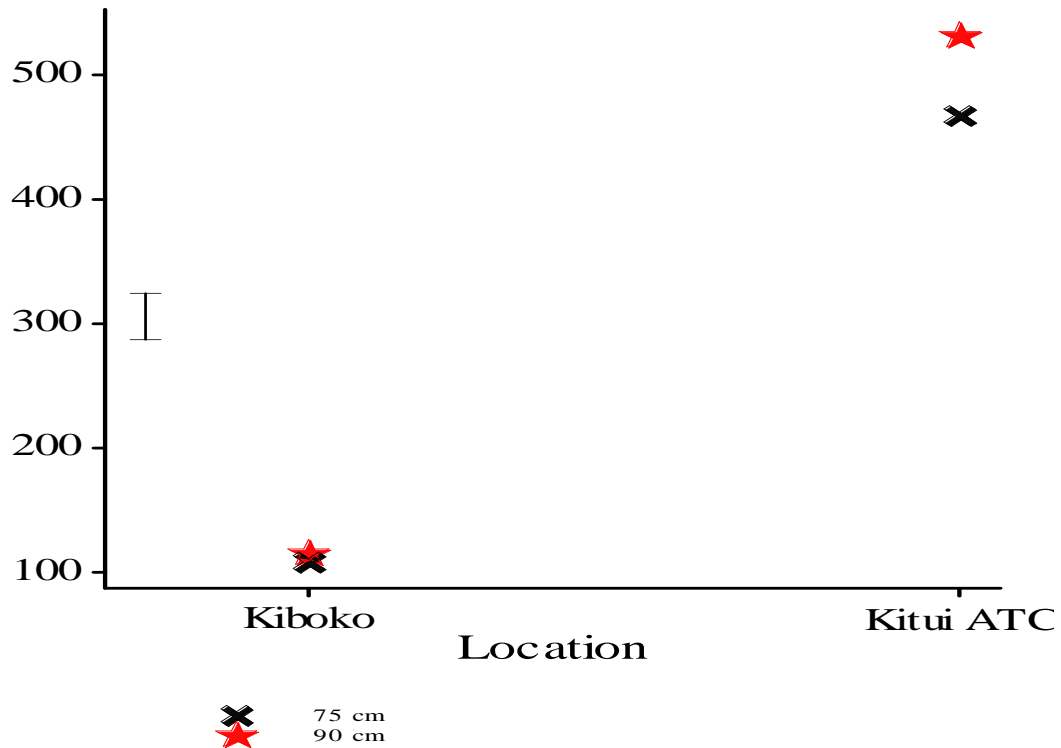


Figure 3. Effect of fertility across the two locations

DISCUSSION

Inter-row spacing of 90 or 75cm did not significantly affect grain amaranth yields at Kiboko or Kitui ATC and only minimal increments were recorded at 90 cm spacing. This partially indicates the need to adopt the wider spacing for ease of operations. Kauffman and Weber (1990) reported that although few growers have grown amaranth successfully in a 25 cm row spacing, weeds can become a serious problem with narrow row spacing if soil surface moisture promotes weed germination. Narrow row spacing provides good early season weed control, but excessive self-competition leads to reduced plant height, earlier flowering and maturity, and reduced yield (Weber, 1987).

Significance of fertilizer application on grain amaranth production in the ASALs was emphasized by the increase in grain yields in plots that received fertilizer either in organic or inorganic form. This is indicative of the poor soil fertility status of the soils, a factor that requires to be confirmed by the

analysis of the soil samples. Addition of fertilizer also resulted in an increase in grain yields in an almost linear pattern. Such a linear relationship between fertilizer amounts and yield was also reported by Guierrez et al. 2002 in a similar study in Bolivia. Similarly, increases in yields with increase in fertilizer application have also been reported in studies of amaranth production in Western Kenya (Nyankanga *et al.*, 2012, Wekesa F.S., 2010). In another study in Arkansas, a two-fold yield increase was reported at the N rate of 100 kg/ha (Endres 1986). No yield advantage was noted at the higher N rate and no response to N was noted in the second year of study.

Grain yield response to fertilizer levels was different at the two locations with highest yields being recorded from plots that received 20 kg P₂O₅ ha⁻¹ at Kiboko and 10 t FYM ha⁻¹ at Kitui ATC. These differences require to be confirmed with further studies and soil analysis. Higher yields from the wetter location may be attributed to availability of more moisture for crop use. This needs to be studied further since earlier studies suggest that grain amaranth is drought tolerant at later stages of growth although some residual soil moisture is needed to assure that emergence occurs (Mnkeni *et al.*, 2007, Weber *et al.* 1988). Studies also indicate that grain amaranth water requirement is 42-47%, 51-62% and 79% that of wheat, maize and cotton respectively (Mwangi, 2003). More work is required in the semi-arid conditions of Kenya to establish these facts.

CONCLUSION

- Generally, application of fertilizer is important for improving yields of grain amaranth in semi-arid Kenya. Emphasis on fertilizer amendment in amaranth production will therefore enhance its productivity in the ASALs.
- There is need to consider using different fertilizer types for the two locations when planting amaranth. Further studies are necessary in order to establish the types and precise amounts to be applied by farmers at the different locations in the ASAL. However, this needs to be accompanied by studies on initial soil nutrient status as a guide on proper application at specific locations.

ACKNOWLEDGMENT

The authors acknowledge the European Union (EU) through the ASAL APRP project for availing funds for the study and Dr. C. W. Kariuki (KALRO-Katumani) for his support. Our special gratitude to Mrs Mary M. Kamau, Messrs. R. Mokuu and C. Magundu who were vital in management of the experiments and data collection. We also sincerely thank Mr. S. Mutali, officer in-charge Kiboko su centre and the Principal Kitui ATC for availing land for the sresearch.

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