International Research Journal of Agricultural Science and Soil Science (ISSN: 2251-0044) Vol. 3(3) pp. 81-87, March 2013
Available online http://www.interesjournals.org/IRJAS

Full Length Research Paper

Fertilizer effects on biological efficiency of maize-leaf amaranth intercropping systems

Ayodele, O.J and Shittu, OS*

Department of Crop, Soil and Environmental Sciences, Ekiti State University, Ado-Ekiti, Nigeria

Abstract

Marketable yield of leaf amaranth obtained by uprooting and repeated cutting were not affected by intercropping with maize but increased significantly with fertilizer application. The application of 400 kg NPK+100 kg urea.ha^{-1} gave the best yield of uprooted amaranth, especially under intercropping, while 400 kg NPK.ha^{-1} was required for optimum yield by repeated cutting in sole and intercropping. Sole amaranth gave significantly higher seed yield. Application of 400 kg NPK and 400 kg NPK+100 kg urea.ha^{-1} gave best yields in intercropping and sole cropping, respectively. Cropping system and fertilizer did not significantly affect maize grain yield. Land equivalent ratio (LER) values exceed 1.0 indicating maize-amaranth intercropping advantages over sole crops. Fertilizer application increased LER and confirms the recommendation of 400 kg NPK+100 kg urea.ha^{-1} for amaranth marketable yield and 400 kg NPK.ha^{-1} for seed yield.

Keywords: Sole cropping, Intercropping, Marketable yield, Seed yield, Land equivalent ratio.

INTRODUCTION

Substantial emphasis has been placed on accelerated maize production in the food and nutrition security equation of Nigeria, to provide energy-rich human food, livestock feedstuffs and raw materials for industries (Fakorede, 2001). Unfortunately, maize-rich diets are characterized by low amounts and quality of proteins, especially the deficiency in amino acids lysine and tryptophan (Vassal, 2001). Foodstuffs of animal origin are the major sources of proteins and vitamins but the costs of these have become too high and, in most cases, beyond the reach of resources poor households who have no physical and economic access to adequate amounts to meet dietary requirements (Aphane et al., 2003). Thus, the search continues for new high quality and cheap sources of proteins, calories, vitamins and minerals for inclusion in diets. Vegetables have been identified as cheap sources of these nutrients needed for balanced diets (Van den Heever, 1995) and so are vital to alleviating the problems associated with malnutrition.

The harsh ecological and resources-poor conditions in the rural sector appear to have curtailed the widespread production and consumption of exotic vegetables of known nutritive quality and values whereas several indigenous and adapted species can be grown under these conditions and with few agricultural inputs to produce optimal yields. Amaranth (*Amaranthus* spp) fits into the description of foodstuffs with cheap high quality sources of dietary nutrients. The leaves contain 17.5-38.3% protein on dry weight basis 5% of which is lysine, an essential amino acid lacking in diets based on cereals and root and tubers and so has potential as a protein supplement (Kauffman and Weber, 1990). Amaranth tastes much like spinach but has higher nutritive value as it contains three times more calcium (Ca), niacin and vitamin C than spinach (Mnkeni, 2005). Thus, its production to encourage widespread consumption would be emphasized to prevent nutrition-related illnesses in man (Akingbola et al., 1994) and livestock (Pond and Lehman, 2001; Sleugh et al., 2001).

Vegetable production in Nigeria is mainly from intercropping systems with food crops in the traditional smallholder outlying farms such that cereal-vegetable mixtures are widespread in all agro-ecological zones (Olukosi et al., 1991). Amaranth, locally called ‘efo tete’ or ‘tete’ (Yoruba), is the most consumed leaf vegetable in south-western Nigeria (Denton and Olufolaji, 2000) and commonly grown in combination with food crops, notably

*Corresponding Author E-mail: olubunmishittu@yahoo.com

maize and so gives mixture yield advantages to the farmers (IAR&T, 1991). Thus, maize-amaranth intercropping offers huge prospects for the output expansion needed to meet the demand pressure being generated by the growing awareness of these crops' contributions to nutrition and health status of urban dwellers. The variables whose manipulation would increase mixture productivity should be identified for resolution.

The possibility of attaining greater crop yields per unit area in intercropping systems relates to the compatibility of component crops which, in turn, must give consideration to plant population and stand geometry, soil fertility and nutrient management practices, among others (Okigbo and Greenland, 1976). The factors of plant population and spacing have been resolved by adopting 75x25 cm spacing (53,330 plants.ha^{-1}) recommended for sole maize and 4 kg.ha^{-1} amaranth seed rate, drilled in rows 20 cm apart (Ayodele, 2013). Thus, nutrient management factors need to be considered given that the agricultural lands in Nigeria are dominated by highly weathered and leached soils with low nutrient fertility (Agboola and Aiyelari, 2000). Moreover, nutrient deficiencies, notably of nitrogen (N) and phosphorus (P) are widespread in maize (Anon, 2006) and limit yields of amaranth grown on smallholder farms (Olufolaji and Okelana, 2001). Although amaranth is a low management crop that grows on poor soils, yield is improved by fertilizer application (Palada and Chang, 2003) and so should be routine, to make component crops in maize-amaranth intercropping systems more competitive and enhance their productivity. A study was conducted to evaluate the responses of component crops in maize-amaranth mixture to fertilizer application and so determine the appropriate rates for optimum productivity.

MATERIALS AND METHODS

The studies were carried out during the early rainy seasons of 2010 and 2011 on the Teaching and Research Farm, Ekiti State University, Ado-Ekiti (long. 5^{o}14'E, lat. 7^{o}42'N). The site is about 456 m elevation and experiences a warm sub-humid tropical climate (1367 mm annual rainfall received in 110 days, mean temperature range of 25 to 32^{o}C). The land is gently undulating and had been previously cultivated to arable crops (maize/cassava in 2008/2009 followed by cowpea in late 2009).

The land was ploughed and harrowed, and surface (0-15 cm) soil samples taken randomly and mixed together for a composite sample. The soil sample was air-dried and sieved (<2 mm) and analyzed for particle size distribution, pH, organic carbon, total N, available P and exchangeable bases using the laboratory procedures described in IITA (1979).

The experimental area was marked into plots measuring 6x1.5 m separated by 1 m wide paths. The treatments evaluated consisted of three cropping systems: sole maize, sole amaranth and maize-amaranth; and three fertilizer rates: no fertilizer (control), 400 kg NPK 15-15-15.ha^{-1} and 400 kg NPK 15-15-15+100 kg urea.ha^{-1} as 3x3 factorial in three replicates and laid out in randomized complete block design. The maize was sown 25 cm apart in 75 cm rows to attain 53,330 plants population while 4 kg.ha^{-1} amaranth seed was drilled in 20 cm rows. The maize was established in 2 rows, each containing 24 plants; the amaranth plot consisted of 7 drill rows while maize-amaranth had 7 amaranth rows to 2 rows of maize arranged in such a way that there were 3 rows between maize rows and 2 on the outside. The amaranth seeds were mixed with dry fine sand and drilled in rows on the same day as the maize and slightly covered with soil. Maize was sown at 2 seeds.hill^{-1} and plants thinned to one after emergence. Fertilizer was banded on one side of the amaranth rows and on two sides of each maize plant at 2 weeks after sowing (WAS). The plots were kept weed-free by manual weeding as necessary.

Each plot was divided into three equal parts for harvesting of the leaf amaranth to obtain marketable yield by uprooting and repeated cutting, and seed yield. Seedlings that had attained at least 15 cm in height were uprooted at four weeks after emergence and at weekly intervals for a total of four harvests. The plants were rinsed in water to remove soil from the roots and weighed. Stem portions above the second leaf from the ground surface (up to 15 cm) with leaves of marketable size were cut and weighed. This was repeated at fortnightly intervals and discontinued when the plants had produced inflorescences (heads). Plants in the third portion not harvested for leaf were allowed to produce inflorescences. The inflorescences were cut when they attained physiological maturity as from 12 WAS, sun-dried and bulked for each plot. The seeds were obtained by threshing and winnowing, and weighed. Dry maize cobs were harvested, de-husked and sun-dried. The cobs were shelled and grains further sun-dried before weighing.

The yield data were scaled up to 1 ha and analyzed using the variance ratio and the treatment means separated following the procedure described by Steel et al. (1997). The index of biological efficiency is the Land Equivalent Ratio (LER) calculated as:

$$\frac{Y_{ab} + Y_{ba}}{Y_{aa} + Y_{bb}}$$

where: Y_{ab}, Y_{ba} are the individual crop yields in intercropping, and

Y_{aa}, Y_{bb} are the yields of individual sole crops (John and Mini, 2003)

RESULTS AND DISCUSSION

The characteristics of the soils in the study area are

Table 1. Characteristics of the soils used for the study

Property	2010	2011
Texture	Sandy loam	Loamy sand
pH (water)	4.03	5.86
Organic matter, %	2.12	2.24
Total N, %	0.06	0.11
Available P, mg.kg^{-1}	4.31	6.5
Exchangeable cations (cmol.kg^{-1})		
K	0.14	0.19
Ca	1.30	4.14
Mg	0.70	1.36
Na	0.09	0.11

Table 2. Effect of cropping system and fertilizer application on yield of amaranth harvested by uprooting

	Fertilizer application.ha^{-1}			
Cropping system	Control (No fertilizer)	400 kg NPK 15-15-15	400 kg NPK 15-15-15 + 100 kg urea	Mean
		Yield (MT.ha^{-1})		
		a) **2010**		
Sole amaranth	16.00k	16.40k	18.50j	16.40
Maize-amaranth	7.12l	19.22j	27.70i	16.40
Mean	11.56c	17.80b	23.05a	NS
		b) **2011**		
Sole amaranth	13.60h	18.28g	22.94f	18.27
Maize-amaranth	10.68h	21.42f	23.63f	18.58
Mean	12.14c	19.85b	23.29a	NS

Means and values in each column and for the years followed by the same alphabets do not differ significantly (P=0.05) NS= Not significant

shown in Table 1. In 2010, the soil was a strongly acid sandy loam with 1.04% organic matter, 0.06% total N and 4.3 mg.kg^{-1} available P contents but a moderately acid sandy loam with 2.24% organic matter, 0.11% total N and 6.5 mg.kg^{-1} available P in 2011. The soils belong to low fertility class based on the critical levels at 0.15% total N, 8-10 mg.kg^{-1} available P determined with Bray's P-1 extractant established for soils in Nigeria (Anon, 2006). The very low exchangeable cations and calculated total exchangeable bases (2.23 and 7.50 cmol.kg^{-1}) are typical of the extensively weathered and leached soils developed on basement complex rocks and as modified by extent of previous land use (Agboola and Aiyelari, 2000).

Table 2 shows the effects of cropping systems and fertilizer application on amaranth marketable yield harvested by uprooting. The main factor of cropping system had no effect on the yield but fertilizer significantly (P=0.05) affected yield which increased from 11.56 MT.ha^{-1} in the control to 17.80 and 23.05 MT.ha^{-1} at 400 kg NPK.ha^{-1} and 400 kg NPK+100 kg urea.ha^{-1} in 2010 and from 12.14 MT.ha^{-1} to 19.85 and 23.29 MT.ha^{-1} at 400 kg NPK.ha^{-1} and 400 kg NPK+100 kg urea.ha^{-1} in 2011. The yield increases are 54 and 99.4%; 63.5 and 92% for 2010 and 2011, respectively. Palada and Chang (2003) observed that the primary limiting nutrient in amaranth growth and marketable yield is N which makes the response to applied fertilizer a function of the N in it. Also, Olaniyi et al. (2008) noted that the increase in yield and quality of leaf amaranth species and cultivars with fertilizer treatments was in relation to improvement in plant height, number of leaves, leaf area and biomass production and quality. In sole amaranth, 400 kg NPK+100 kg urea.ha^{-1} produced maximum yield which is significantly higher than other treatments. The yield values at 18.50 and 22.84 MT.ha^{-1} in 2010 and 2011 respectively are comparable to 18.60-20.00 MT.ha^{-1} range obtained as maximum yield of drilled amaranth harvested by uprooting (Olufolaji and Tayo, 1989a). This fertilizer rate would provide 100 kg N.ha^{-1} which is the

Table 3. Marketable yield of amaranth obtained by repeated cutting under different cropping systems and fertilizer application regimes

	Fertilizer application.ha^{-1}			
Cropping system	Control (No fertilizer)	400 kg NPK 15-15-15	400 kg NPK 15-15-15 + 100 kg urea	Mean
		a) 2010		
		Yield (MT.ha^{-1})		
Sole amaranth	12.33f	15.12ef	15.80de	14.42
Maize-amaranth	6.90g	15.80de	18.10d	13.60
Mean	9.62b	15.45a	16.93a	NS
		b) 2011		
Sole amaranth	12.17r	16.79q	19.33p	16.10a
Maize-amaranth	9.62s	16.38q	18.43p	14.81b
Mean	10.90h	16.59g	18.08f	

Means and values in each column followed by same letters do not differ significantly (P=0.05)
NS= Not significant

upper limit of optimum N requirement for amaranth to be harvested by uprooting (Olufolaji and Denton, 2000).

Marketable yields of leaf amaranth harvested by repeated cutting under sole and intercropping systems are shown in Table 3. Cropping system did not affect leaf amaranth marketable yield obtained by repeated cutting in 2010 whereas sole amaranth gave significantly (P=0.05) higher yield than in the intercrop in 2011. The fertilizer effect was significant (P=0.05) in both years; the control treatment produced the least yield while the difference between the two fertilizer treatments was significant only in 2011. In sole and intercropping systems, application of 400 kg NPK+100 kg urea.ha^{-1} gave the highest yield which did not differ from 400 kg NPK.ha^{-1} in 2010 but which differed significantly in 2011. These fertilizer rates contain 60 and 100 kg N.ha^{-1} respectively which are less than 120-150 kgN.ha^{-1} recommended for amaranth to be harvested by repeated cutting (Olufolaji and Tayo, 1989b) as it is expected to take care of the nutrient needs of the larger-sized plants over a longer duration.

Cropping system had no effect on amaranth yield because the plants, being more aggressive and established at high density, were not adversely affected by the few maize plants which tended to grow taller. Open-pollinated maize enters the reproductive phase from 45-55 days after sowing and before which space, light and soil moisture and nutrient resources are under-utilized. Thavaprakaash and Velayudham (2008) suggested that the inclusion of short-duration crops that complete their life cycles or reach harvestable size within 50-55 days in intercropping systems would ensure effective utilization of these production resources. Leaf amaranth is harvested within 28-42 days after sowing when the plants attain at least 15 cm height and still succulent; and beyond which they lose quality, become fibrous and produce inflorescences (Olufolaji and Denton, 2000). Uprooted amaranth gave higher yield (17.45, 18.38 MT.ha^{-1}) than repeated cutting (14.01, 15.46 MT.ha^{-1}) contrary to the results obtained by Olufolaji and Tayo (1989b). The uprooted plants contained roots and stem portions which became bigger with age and were not separated from the leaves as marketable yield whereas repeated cutting, to induce production of lateral branches, reduced the sizes of harvested shoots whose number decreased over time and in response to difficulty in recovery from cutting.

Table 4 shows the influence of cropping system and fertilizer application on the seed yield of leaf amaranth. The main effects of cropping system was significant in 2010 with the higher seed yield in sole amaranth indicating 22% yield reduction by intercropping. This would suggest that the longer period of the crops in the field engendered competitive interaction with the bigger maize plants whose larger leaves would shade the shorter and smaller amaranth plants. This reduction in yield of one or more components in the mixture is one of the demerits of intercropping (Willey, 1990). The effect of fertilizer was significant in both years (P=0.05) as indicated by higher yields from 400 kg NPK and 400 kg NPK +100 kg urea.ha^{-1} than the control treatment but the difference between the two fertilizer rates was not significant. The highest seed yield was produced in sole amaranth with 400kgNPK+100 kg urea.ha^{-1} but which did not differ from 400 kg.ha^{-1} NPK in 2011 while 400 kg NPK.ha^{-1} produced optimum seed yield in the intercrop. Grain production is most limited by N such that there were significant responses to N fertilizer in most environments (Elbehri et al., 1993). Myers (1998) noted that grain yield increased by 43% with N applied from 0-180 kg N.ha^{-1} while Apaza-Gutierrez et al. (2002) and Schulte et al., (2005) obtained linear response of

Table 4. Amaranth seed yield as influenced by cropping system and fertilizer application

	Fertilizer application.ha^{-1}			
Cropping system	Control (No fertilizer)	400 kg NPK 15-15-15	400 kg NPK 15-15-15 + 100 kg urea	Mean
		Yield (MT.ha^{-1})		
		a) **2010**		
Sole amaranth	1.90m	2.54l	2.82k	2.42a
Maize-amaranth	1.12n	2.63kl	2.21m	1.98b
Mean	1.50y	2.59x	2.52x	-
		b) **2011**		
Sole amaranth	1.16k	2.14j	2.46j	1.92
Maize-amaranth	0.96k	2.21j	2.54j	1.90
Mean	1.06b	2.18a	2.50a	NS

Means and values in each column followed by same letters do not differ significantly (P=0.05)

Table 5. Effect of cropping system and fertilizer application on maize dry grain yield in a maize-amaranth mixture

	Fertilizer application.ha^{-1}			
Cropping system	Control (No fertilizer)	400 kg NPK 15-15-15	400 kg NPK 15-15-15 + 100 kg urea	Mean
		Yield (MT.ha^{-1})		
		a) 2010		
Sole amaranth	4.93	5.19	4.73	4.95
Maize-amaranth	4.44	4.63	5.16	4.74
Mean	4.67	4.91	4.95	NS
		b) 2011		
Sole amaranth	1.42g	4.30f	5.12e	3.61
Maize-amaranth	1.26g	3.97f	4.86ef	3.36
Mean	1.34c	4.14b	4.99a	NS

NS= Not significant

Table 6. Land equivalent ratios of maize-amaranth intercropping systems as influenced by fertilizer application

Land Equivalent Ratio (LER)			
Fertilizer Application.ha^{-1}	Leaf Amaranth Marketable Yields: Uprooting	Repeated Cutting	Seed Yield
	a) 2010		
Control (no fertilizer)	1.35	1.46	1.40
400 kg NPK 15-15-15	2.07	1.94	1.93
400 kg NPK 15-15-15 + 100 kg urea	2.59	2.24	1.88
	b) 2011		
Control (no fertilizer)	1.67	1.68	1.72
400 kg NPK 15-15-15	2.09	1.90	1.96
400 kg NPK 15-15-15 + 100 kg urea	1.98	1.90	1.98

amaranth grain yield to chemical fertilizers. The 400kg NPK.ha^{-1} rate which gave optimum seed yield contains 60 kg N.ha^{-1} that produced the highest seed yield in grain amaranth (Asoegwu and Olufolaji, 1988). Smallholder farmers who practice intercropping and rarely use fertilizer would have better yields by applying 400 kg NPK.ha^{-1} whereas 400 kgNPK+100 kg urea.ha^{-1} should be applied to sole leaf amaranth grown for seed.

Table 5 shows the influence of cropping system and fertilizer treatment on grain yield of the maize component. Maize grain yield was not affected by cropping system, fertilizer application and their interaction in 2010 while the fertilizer effect was significant (P=0.05) in 2011. Makinde et al. (2009) had observed that intercropping or time of establishment of an amaranth intercrop by direct seeding had no effect on maize growth and yield. Amaranth is a fast-growing herb like most broad leaf weeds but which yields harvestable product within 4-6 weeks after planting. The recommendation of a weed-free period of 40-45 days after planting for optimum grain yield of maize (Fakorede, 2001) means that harvesting of the leaf amaranth would minimize competition between the component crops. The 400 kg NPK+100 kg urea.ha^{-1} significantly increased maize grain yield over the control and 400 kg NPK.ha^{-1} treatments in 2011. The slight increase of fertilizer treatments over the control in sole and intercropping in 2010 is contrary to the expected response from the low total N content of the soil in the study site. However, one notes that the soil is extremely acidic (pH=4.03) which would affect the response of maize to fertilizer, especially N (Brady and Weil, 2002).

In order to demonstrate the biological efficiency of maize-amaranth intercropping, LER was calculated. The LER values are higher than 1.00 indicating intercropping advantages and so would be recommended for farmers' adoption. Similar mixture advantages have been observed for maize-amaranth (Ayodele, 2013) and maize-grain amaranth (Manga et al., 2003; Olorunnisomo and Ayodele, 2009). LER increased with fertilizer application, being highest at 400 kg NPK+100 kg urea.ha^{-1} for marketable yield obtained by uprooting and repeated cutting and with 400 kg NPK.ha^{-1} for amaranth seed yield in 2010. The 400 kg NPK.ha^{-1} which gave best LER for marketable yield obtained by uprooting and repeated cutting in 2011 would be suggested for amaranth seed production. The N contents of the treatments are 100 and 60 kg.ha^{-1} respectively, which correspond to the requirements for amaranth leaf production (Grubben, 2004) and seed yield (Asoegwu and Olufolaji, 1988). This implies that the fertilizer rate to be recommended for adoption would depend on the target economic produce.

REFERENCES

Agboola AA, Aiyelari EA (2000). Land degradation and soil fertility decline in Africa. In: Johnson, NK, Ndoye A (eds). Role of Fertilizers in Agricultural Production and Food Security in Africa. Proceedings of the Expert Meeting on Fertilizers held at Quagadougou, Burkina Faso on 26-30th July 1999. Special Edition, African Soils 31: 35-53.

Akingbola JO, Adeyemi JA, Sangodoyin SO, Oke OL (1994). Evaluation of amaranth grains for ogi manufacture. Plant Foods for Human Nutrition 46: 19-26.

Anon (2006). Nigeria fertilizer Strategy Report, presented at African Fertilizer Summit held at International Conference Centre, Abuja, 13-16th July 2006. 47pp.

Apaza-Gutierrez V, Romeo-Saravia A, Guillen-Portal FR, Baltensperger DD (2002). Response of grain amaranth to density and fertilization in Tarija, Bolivia. In: Janick J, Whipkey A (eds). Trends in New Crops and New Uses. ASHS Press, Alexandria, VA: 107-109.

Aphane J, Chadha ML, Oluoch MO (2003). Increasing the consumption of micronutrient-rich foods through production of indigenous foods. In: FAO-AVRDC Workshop Proceedings, 5-8th March, 2002, Arusha, Tanzania. AVRDC Pub. No 03-561. 77.

Asoegwu SN, Olufolaji AO (1988). Effect of seed bed and fertilizer on soil heat flux, growth and development of grain amaranth (*Amaranthus cruentus*). International Soil Research Organization, 11th International Conference, Edinburgh, Scotland; 11-15th1988. Proceedings. 2: 555-559.

Ayodele OJ (2013). Amaranth seed rate effects on biological efficiency of maize-amaranth intercropping systems. (In Press).

Brady NC, Weil RR (2002). The Nature and Properties of Soils. 13th Edition. Pearson Educational Publishers, New Delhi, India. 881pp.

Denton OA, Olufolaji AO (2000). Nigeria's most important vegetable crops. In: Akoroda, M.O. (Compiler). Agronomy in Nigeria: A Book in Support of Agronomy Re-Union Day, 04th October, 2000. Department of Agronomy, University of Ibadan: 85-93.

Elbehri A, Putnam DH, Schmitt M (1993). Nitrogen fertilizer and cultivar effects on yield and nitrogen use efficiency of grain amaranth. Agronomy Journal 85: 120-128.

Fakorede MAB (2001). Revolutionizing Nigerian Agriculture with the Golden Seed. In: Saliu, N.B. (Compiler). Nigerian Universities Inaugural Lecture Series 2001. National Universities Commission, Abuja: 51-104.

Grubben GJH (2004). Amaranthus cruentus L. In: Grubben, G.J.H. and Denton, O.A. (eds). Plant Resources of Tropical Africa 2. Vegetables. PROTA Foundation, Wageningen. Buckkuys Publishers, Leiden/CTA, Wageningen, The Netherlands. 667.

IAR&T (1991). Report of the 14th Package of Recommendations for Food Crops and Livestock Production in South-Western Nigeria. Institute of Agricultural Research and Training, Moor Plantation, Ibadan. 101.

IITA (1979). Selected Methods of Soil and Plant Analysis. Manual Series No 1. International Institute of Tropical Agriculture, Ibadan. 70.

John SA, Mini C (2005). Biological efficiency of intercropping in okra (*Abelmoschus esculentus* (L), Moench). J.Trop. Agric. 43:33-36.

Kauffman CS, Weber LE (1990). Grain amaranth. In: Janick, J. and Simon, J.E. (eds) Advances in New Crops. Timber Press, Portland, Oregon: 127-139.

Makinde EA, Ayoola OT, Makinde EA (2009). Intercropping leafy greens and maize on weed infestation, crop development and yield. International J. Veget. Sci. 15:402-411.

Manga AA, Bala MG, Ashafa LW (2003). Evaluation of maize (*Zea mays*, L) and grain amaranth (*Amaranthus cruentus*, L) intercrop. Niger. J. Horticult. Sci. 3:7-10.

Mnkeni AP (2005). The underutilized plant with high nutritional quality and economic potential. ARDRINEWS. Agricultural and Rural Development Research Institute Newsletter, University of Fort Hare, July-Dec. 2005.

Myers R (1998). Nitrogen fertilizer effect on grain amaranth. Agronomy Journal 90: 597-602.

Okigbo BN, Greenland DJ (1976). Intercropping systems in tropical Africa. In: Papendick, R.I. et al., (eds). Multiple Cropping. ASA Special Publication. American Society of Agronomy, Madison, Wisconsin: 27:63-101.

Olaniyi JO, Adelasoye KA, Jegede CO (2008). Influence of nitrogen fertilizer on the growth, yield and quality of grain amaranth varieties. World J. Agric Sciences 4:506-513.

Olorunnisomo OA, Ayodele OJ (2009). Effects of intercropping and fertilizer application on yield and nutritive value of maize and amaranth forages in Nigeria. Grass and Forage Science 64: 413-420

Olufolaji AO, Denton OA (2000). Vegetable Programme. In: Denton OA et al., (eds). NIHORT: 25 Years of Research into Horticultural Crop Development in Nigeria (1975-2000). National Horticultural Research Institute, Ibadan: 29-61.

Olufolaji AO, Okelana OA (2001). Grain amaranth (Amaranthus

cruentus,L) response to plant density and phosphorus nutrition under the humid condition of South-Western Nigeria. Niger. J. Horticult. Sci. 6:58-66.
Olufolaji AO, Tayo TO (1989a). The effects of seeding rate on the performance of direct-seeded Amaranthus. Samaru J. Agricult. Res. 6:83-86.
Olufolaji AO, Tayo TO (1989b). Performance of four morphotypes of Amaranthus cruentus L under two harvesting methods. Tropical Agric. (Trinidad) 66:273-276.
Olukosi JO, Elemo KA, Kumar V, Ognugbile AO (1991). Farming Systems Research and the development of improved crop mixture technologies in the Nigerian savannah. Journal of West African Farming Systems Research Network 1:17-19.
Palada MC, Chang LC (2003). Suggested Cultural Practices for Vegetable Amaranth.n International Co-operators' Guide. AVRDC pub#03-552.
Pond WG, Lehmann JW (2001). Nutritive value of vegetable amaranth cultivar for growing lambs. J. Ani. Sci.67:30-36.
Schulte AEG, Kaul H-P, Kruse M, Aufhammer W (2005). Yield and nitrogen utilization efficiency of the pseudocereals amaranth, quinoa and buckwheat. Eur. J. Agron. 22:95-100.
Sleugh BB, Moore JK, Brummer EC, Knapp AD, Russell J, Gibson L (2001). Forage nutritive value of various amaranth species at different harvesting dates. Crop Sci. 41: 466-468.
Steel RDG, Torrie JH, Dickey DA (1997). Principles and Practices of Statistics: A Biometrical Approach. 3rd Edition, McGraw Hill, New York. 665.
Thavaprakaash N, Velayudham K (2008). Light interception and productivity of baby corn as influenced by crop geometry, intercropping systems and INM practices. Asian J Sci. Res. 1:72-78.
Van den Heever E (1995). The use and conservation of indigenous leafy vegetables in South Africa. Vegetable and Ornamental Plant Institute, Agric. Res. Counc, South Africa.
Vassal SK (2001). High quality protein corn. In: Hallaver, A.R. (ed). Specialty Corns. 2nd Edition. CRC Press LLC, Boca Raton: 85-92.
Willey RW (1990). Resource use in intercropping systems. Agricultural Water Management 17: 215-231.