Arid Zone Journal of Engineering, Technology and Environment, March, 2018; Vol. 14(1):61-71

Print ISSN: 1596-2490, Electronic ISSN: 2545-5818, www.azojete.com.ng

VARIATION IN FOLIAGE YIELD AND YIELD COMPONENT TRAITS AND PREFERENCE FOR LEAF QUALITY TRAITS IN *AMARANTHUS CRUENTUS* [L.] GENOTYPES

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Abstract
Amaranthus cruentus is a traditional leaf vegetable in Nigeria. At present, there are few commercial varieties. Development of new varieties requires systematic assessment of foliage yield and yield contributing traits. The objectives of this study are to evaluate variation for foliage yield and yield traits, determine the influence of time of harvest (4 or 5 weeks after sowing) on foliage yield, and assess preference for genotypes, leaf yield and leaf quality traits. Nine *Amaranthus cruentus* genotypes were grown in a randomized complete blocks design with three replications. Sunken beds were made at 1 m x 2 m, each bed was separated by alley of 1m. A total of 16 beds constituted a replicate, 8 beds were allotted to harvest at 4 weeks, another 8 beds to harvest at 5 weeks. Each bed was treated with 4 Kg of matured farmyard manure. Combined analysis of variance was performed on mean data. Participatory selection was conducted to identify preferred genotypes and horticultural traits. Genotypes were similar or dissimilar for foliage yield and yield component traits at 4 and 5 weeks harvest. Genotype by Year Interaction revealed statistically significant mean squares at 4 and 5 weeks harvest for some traits. Considering multiple traits at 4 weeks harvest, AM 25 and AM 45 performed best for leaves/plant and leaf dry weight, while AM 42 is promising for leaf yield, leaf length and leaf width. At 5 weeks harvest, AM 45 performed best for leaf yield, leaf fresh weight and dry weight. AM 25, AM 42, AM 45 and AMLOC are capable of developing rapidly and producing large quantities of biomass under short cycle harvest.

Keyword: Amaranthus cruentus, short cycle harvest, genotype by year interaction, leaf quality, amaranth growers, leaf colour, leaf freshness

1. Introduction

Amaranthus cruentus (2n = 32) belongs to the family Amaranthaceae, it is known for its C4 cycle of photosynthesis where growth rate is optimized by high temperatures, bright light and adequate water and minerals. It is the most commonly grown high value indigenous leaf vegetable (Maundu *et al.*, 1999) rich in lysine an essential amino acids high levels of carotene, vitamin C and iron and calcium. It is an alternative source of protein and supplementing cereals grain diets in most rural communities in developing countries. Year round cultivation of amaranth is common in Africa. In Nigeria, amaranth production is carried out during hot summer months and cold season. Early morning cold during the winter months followed by heat and water stresses slows seed germination, vegetative growth and availability of fresh leaves. Amaranth can be grown under varied soil and agro-climatic conditions (Katiyar *et al.,* 2000; Shukla and Singh 2000). Direct sowing is the common practice in Nigeria, Uganda and in western Kenya (Grubben, 2004). Amaranth is cultivated in gardens and fields for neighbourhood and short distance markets. Leaf amaranth is ready for harvest 25 to 45 days after sowing depending on varieties (AVRDC, 2008). The choice of harvest time for leaf amaranth depends on prevailing soil and climatic conditions, varieties, labour availability, market demand and target market. Different farming communities use different harvesting techniques.

Harvesting methods for vegetable amaranth are uprooting the whole plant and re sowing, continuous harvest with topping, and continuous harvesting without topping. Evaluation of harvesting techniques showed that continuous harvesting with topping (removal of flowers) gave the highest economic leaf yield (32.0 t ha^{-1}), continuous harvesting without topping gave the lowest (17.8 t ha^{-1}). Uprooting the whole plant after two planting and two harvests was the second highest yielding method with 29.8 t ha^{-1} and plants harvested with this method had the smallest leaf size, but it provided better marketable leaf quality (Oluoch *et al.*, 2009). Leafy amaranth yields of about 40 t ha^{-1} had been recorded in the region of Dar-es-Salaam, while in Benin and Nigeria, the yield of shoots of 4 weeks old *A. cruentus* was about 30 t ha^{-1} (Schippers, 2004). Low leaf yields of 1.2 t ha^{-1} in amaranth (Madulu and Chalamila, 2005) could be attributed to several factors such as environmental, agronomic, low soil fertility and low yielding varieties which have short growth period. The suitability of vegetable amaranth for cultivation depends on agronomic traits such as short time to mature, low husbandry practice, and cheaper cost to final consumer. The sequence of harvest time in amaranth depends on the physiological and genetic attributes of the crop to produce biomass within few weeks after sowing. Early harvest of amaranth leaves is desirable to meet early market demand, supply of fresh leaves to the market, income is generated within a short time and stimulate demand for seeds. Growing vegetable amaranth as food is a traditional practice in farming communities in Nigeria, where low income communities derive considerable self-sufficiency and sustenance. An important post-harvest handling technique among amaranth growers and marketers in the north of Nigeria is air drying of amaranth leaves for use in cooking during prolonged dry season (November and April). At present, there are few commercial amaranth varieties in the country.

Development of new amaranth varieties requires systematic assessment of leaf yield and yield contributing traits, identifying amaranth accessions with high leaf yield and preferred fruit quality traits among existing genotypes at harvest. This study attempts to address two specific questions, first whether amaranth genotypes (varieties and breeding lines) developed and commercialised in East Arica outperform farmer variety (Nigeria) for foliage yield and yield component traits, and foliage quality traits and second, what are the most stable high yielding genotypes that could be used as genetic stock for further improvement in *Amaranthus cruentus*. The objectives of this study are to evaluate variation for foliage yield and yield component traits among *Amaranthus cruentus* genotypes, determine the influence of harvest at 4 and 5 weeks and year on foliage yield and yield contributing traits and evaluate preference for genotypes, foliage yield and foliage quality traits.

2. Materials and Methods

2.1 Location and Germplasm

This research was conducted at the research farm, National Open University of Nigeria, Jalingo, Nigeria (Lat 8° 47′S and Lon 11° 09′E) in May, 2013 and 2014. Jalingo is bounded to the North by Lau Local Government Area, to the East by Yorro Local Government Area, to the South and West by Ardo Kola Local Government Area. Jalingo is characterized by monomodal rainfall regime, the rain season starts during April/May and end in October. Thereafter the cold and dry season (November to January) and the heat season (February to April). The hottest months are between February to March/April. While temperature is influenced by altitude and deforestation. The soil type is clay loam with pH between 6.0 and 6.5. Nine amaranth genotypes (eight breeding lines) received from the World Vegetable Center (AVRDC) and a popular farmer variety (AM local as check) (Table 1) were tested.

Table 1: *Amaranthus cruentus* and Place of collection

Genotypes	Place of collection
AM 42	AVRDC
AM 38-2	AVRDC
AMTZ 01	AVRDC
AM 40	AVRDC
AM 50	AVRDC
EX –Zimbabwe	AVRDC
AM 25	AVRDC
AM 45	AVRDC
AM LOC	Farmers collection, Jalingo, Nigeria

2.2 Experimental design and Data collection

Field experiments were established in May, 2013 and 2014. Nine *Amaranthus cruentus* genotypes were grown in a randomized complete blocks design with three replications. Sunken beds were made at 1 m x 2 m, each bed was separated by alley of 1m. A total of 27 beds constituted a replicate, 9 beds were allotted to treatment A (harvest at 4 weeks after sowing) another 8 beds to treatment B (harvest at 5 weeks after sowing). Each bed was treated with 4 Kg of matured farmyard manure. Prior to field establishment seeds were tested for viability. Thereafter 10 g of viable seeds was uniformly spread on each vegetable bed. The experiment was rain fed with occasional manual irrigation. Weeding was carried out manually and frequently to maintain a weed free plots. Harvesting was done by uprooting at 4 and 5 weeks after sowing. Amaranth plants in each net plot (1 m x 1 m) were used to determine amaranth foliage yield and yield contributing traits. Branches/plant, leaves/plant were estimated on ten randomly picked amaranth plants. The leaf length and width were measured on five randomly picked leaves per plant. Plant height (cm) was measured with a meter rule on ten randomly picked plants per entry. Marketable foliage yield (t/ha) and non-marketable leaf yield were estimated on weigh balance and expressed in t/ha. At harvest three plants were randomly picked per plot, all the leaves were excised, counted and weighed. Thereafter leaves were oven dried at 32°C, the weight (g) of dried leaves was measured on sensitive weight balance. Over trial periods, 50 farmers randomly selected from study areas were involved in selection exercises. During the focus group discussion sessions, farmers provided a list of preferred horticultural traits and responses were ranked. They select best amaranth genotype for specific trait by dropping between one and four seeds (1=extremely poor, 2= poor, 3= good and 4= excellent) in containers placed in front of each accessions.

2.3 Data analysis

Homogeneity of residual variances was tested prior to a combined analysis in each year as well as over and years using Bartlet's test (Steel and Torrie, 1980). The data collected were homogenous and all data showed normal distribution. A combined analysis of variance was performed from the mean data to determine first and second order interaction and to partition the variation due to genotypes, harvest time and year. The combined analysis of variance was performed on mean data using a mixed model on plot means combined across years for all traits using PROC - GLM procedure of SAS (1998) to determine the level of significance and the percentage of contribution of each component to the total variation.

The Genotype (G), Year (Y) and Harvest time (H) were considered to be fixed-effects, while replications were considered as random effects. Moreover, mean comparison using Duncan's Multiple Range Test (DMRT) was performed to explain the significant differences among means of the genotypes. Participatory selection was conducted during 2008 and 2009 evaluation to select accessions, horticultural traits preferred by respondents. Responses during the amaranth stakeholder were adapted to a four point Likert Rating Scale (LRS), as very high (VH) = 4, High (H) = 3, Low (L) = 2, Very low (VL) = 1. The mean score was computed as 4+3+2+1= 10/4= 2.50. Using the interval score of 0.05, the upper limit cut-off was determined as 2.50 ± 0.05 and the lower limit as 2.55 ± 0.05= 2.45. On the basis of this, mean score (MS) below 2.45 (i.e. < 2.45) were ranked 'low', those between 2.45 and 2.54 were considered 'medium' (i.e. 2.45 ≥ MS ≤ 2.54), while the mean score greater than or equal to 2.55 (i.e. MS ≥ 2.55) were considered 'high'. The responses from farmers preferences for genotypes, agronomic and leaf quality traits were categorized into a four point Likert scale test.

3. Results and Discussion

The mean squares for foliage yield and yield component traits at 4 and 5 weeks harvests during 2013 and 2014 cropping seasons are shown in Tables 2a and 2b. At 4 weeks harvest significant differences (P< 0.05 and 0.01) were recorded for all the traits. While at 5 weeks harvest, the genotypes recorded statistically significant (P<0.05 and 0.01) mean squares for all traits except branches/plant. Significant means squares (P<0.05 and 0.01) for all traits except branches/plant suggested large phenotypic variation (within and between years) for foliage yield and yield quality traits at 4 and 5 weeks harvest. Genotypes with stable performance for these traits would be more suitable as cultivar and for further genetic improvement.

Table 2a: Mean squares for foliage yield and yield component traits in nine genotypes of *Amaranthus cruentus* L harvested at 4 weeks after sowing during 2013 and 2014 seasons

Source of variation	Df	Br/Pl	Lvs/Pl	Nmkt LvY(t/ha)	Mkt LvY (t/ha)	Lv Fr wt (g)	Lv Dr wt (g)	Plt Ht (cm)	Lvl (cm)	Lvw (cm)
Genotypes	8	17.70**	90.74***	2.13***	21.17***	5460.17***	0.21	44.46*	0.11	0.15
Year	1	3.93	8.20***	2.87***	133.28***	246.65***	4.09**	173.54***	11.19***	15.04**
Replications	2	2.79	0.50	0.14	42.39**	36.35	0.02	14.35	0.82	0.81
Genotypes x Year	8	1.37	5.03***	0.82	118.42**	195.67***	2.04***	21.12*	2.91**	0.98
Error	34	1.65	0.93	0.07	6.37	16.02	0.13	9.54	0.55	0.52
CV (%)		20	13	21.73	14.61	13.39	19.35	15.78	10.84	17.42
Mean		6.35	7.55	1.27	17.27	29.87	1.88	19.57	6.89	4.16

***, ** and *= indicate respectively significant at P < 0.001, P < 0.01, P < 0.05

Br/plt= Branches/plant, Lvs/pl = leaves/plant, Nmkt LvY (t/ha) = non marketable leaf yield, Nmkt LvY= Non marketable leaf yield, Lv Fwt = Leaf fresh weight, Lv Dwt = Leaf fresh weight, Pht= Plant height, Lvl= Leaf length, Lvw= Leaf width

Table 2b: Mean squares for foliage yield and yield component traits in nine genotypes of *Amaranthus cruentus* L harvested at 5 weeks after sowing during 2013 and 2014 seasons

Source of variation	df	Br/Pl	Lvs/Pl	Mn LvY (t/ha)	Nmkt LvY(t/ha)	Lv Fr wt (g)	Lv Dr wt (g)	Plt Ht (cm)	Lvl (cm)	Lvw (cm)
Genotypes	8	3.25	20.35**	487.32***	0.36	138.07**	7.47**	464.20**	16.24**	6.49**
Year	1	0.67	192.69**	73.50*	16.29***	3472.0***	79.69***	2744.96***	24.00**	0.07
Replication	2	0.13	4.57	4.79	0.14	32.51	1.08	37.38	1.46	0.12
Genotype by Year	8	2.04	13.41**	185.25**	1.30**	99.43*	3.52	759.19***	9.00*	7.57***
Error	34	3.48	3.32	25.58	0.16	33.10	2.05	196.17	4.07	1.91
Mean		11.07	9.15	23.46	2.04	25.79	3.34	54.28	10.29	5.96
CV (%)		14.27	19.92	24.32	19.82	22.30	37.32	25.80	19.59	23.20

***, ** and *= indicate respectively significant at P < 0.001, P < 0.01, P < 0.05

Br/plt= Branches/plant, Lvs/pl = leaves/plant, Nmkt LvY (t/ha) = non marketable leaf yield, Nmkt LvY= Non marketable leaf yield, Lv Fwt = Leaf fresh weight, Lv Dwt = Leaf fresh weight, Pht= Plant height, Lvl= Leaf length, Lvw= Leaf width

At 4 weeks harvest, year effect recorded statistically significant difference ($P \leq 0.05$) for all the traits except leaf dry weight, leaf length and width. In contrast the genotypes recorded insignificant ($P \geq 0.05$) mean squares for branches/plant and leaf width. While at 5 weeks, year effect had significant ($P < 0.05$ and 0.01) mean squares for all traits except branches/plant and leaf width. This suggests that environmental factors during years on which the genotypes were evaluated differed in response for traits. Moreover the genotypes were unstable and inconsistent in their phenotypic expression (except branches/plant, leaf dry weight, leaf length and width) with change in the environment. Significant year effect may have greater effect on some genotypes than others (Falconer, 1981). At 4 weeks harvest, replication was significant ($P \leq 0.05$) for marketable leaf yield (t ha^{-1}), non-marketable leaf yield (t ha^{-1}) and insignificant ($P \geq 0.05$) mean squares for all the traits at 5 weeks harvest. Genotype by Year Interaction recorded significant ($P \leq 0.05$) mean squares at 4 weeks harvest for leaves/plant, marketable leaf yield (t ha^{-1}), non-marketable leaf yield (t ha^{-1}), leaf fresh weight, leaf dry weight. On the other hand, at 5 weeks harvest significant mean squares was recorded for all the traits except branches/plant and leaf dry weight. Significant Genotype by Year Interaction (GYI) showed that environmental factors (precipitation, sun shine hours, temperature and soil types) during trial periods (years) were inconsistent over years and did influence phenotype expression of most traits investigated. Insignificant Genotype by Year Interaction mean squares ($P \geq 0.05$) recorded for branches/plant, leaf width and leaf dry weight suggested that environmental factors during the trial periods were similar with minimal influence on traits.

The mean performances for foliage yield and yield traits at 4 and 5 weeks harvest after sowing are presented in Table 3a and 3b. Over years branches/plant was high in AM 25, AM 42, AMTZ 01 and AM 45 during harvest at 4 weeks. Best genotypes for branches/plant are AM Local, AM 45 and Ex-Zimbabwe. AM 45 was consistent in performance for branches/plant at 4 and 5 weeks. Among the genotypes leaves/plant varied between 5 and 9 at 4 weeks harvest. This result is similar to the findings reported by Olaniyi, (2007) among amaranth accessions from Nigerian Institute for Horticultural Research. While at 5 weeks harvest the leaves/plant ranged from 8 (AM 50) to 12 (Ex – Zimbabwe). Top two genotypes for leaves/plant at 4 weeks harvest are AM 25 and AM 45. At 5 weeks harvest, Ex Zimbabwe, AM 45, Local and AMTZ 01 outperformed other genotypes. Leaves produced are a measure of leaf yield potential. The marketable foliage yield (t ha^{-1}) at 4 weeks harvest was 22.67 (t ha^{-1}) in AMTZ 01, followed by AM 42 (22.30 t ha^{-1}) and AM 50 (21.00 t ha^{-1}). Three genotypes (AM 45, AM 50 and AM40) recorded foliage yield of 35.50 t ha^{-1}, 31.33 t ha^{-1} and 30.67 t ha^{-1} respectively at 5 weeks harvest. In this investigation, AM 45, AM 50 and AM 42 harvested at 5 weeks performed better for foliage yield (t ha^{-1}) compared to *Amaranthus cruentus* genotypes from NIHORT (NH_{g4} 452, NH_{g4} 452, NH_{g4} 493 and NHg4 493-1) harvested at 6 weeks. AM 42, AM 45 and Ex Zimbabwe recorded 42%, 37% and 35% increase respectively in foliage yield over harvest at 4 and 5 weeks after sowing. While AM 25 had 4% decrease in foliage yield over harvest at 4 and 5 weeks. The foliage yield at 4 weeks harvest in AMTZ 01 and AM 42 are low (22.67 t ha^{-1} and 22.30 t ha^{-1}) compared to foliage yield of 29.8 t ha^{-1} in amaranth harvested by uprooting the whole plant (AVRDC, 2008).

Table 3a: The mean performance for foliage yield and yield traits in nine genotypes of *Amaranthus cruentus* L harvested at 4 weeks after sowing during 2013 and 2014 seasons

Genotypes	Br/Pl	Rank	Lvs/Pl	Rank	Mkt LvY (t ha^{-1})	Rank	Nmkt LvY/t ha^{-1}	Rank	Lv Fr wt (g)	Rank	Lv Dwt (g)	Rank	Plt Ht	Rank	Lvl (cm)	Rank	Lvw (cm)	Rank
AM 25	7.17a	1	8.60a	2	16.56b		1.19bc		36.1ab	3	2.65a	1	17.56de		6.00de		4.30b	
AM 42	7.00a	2	8.00ab		22.30a	1	1.82a	1	23.5de		1.48d		25.67ab	2	9.00a	1	6.83a	1
AM TZ 01	7.03a	2	7.00bc		22.67a	2	1.78a	2	36.33ab	2	1.35d		19.17dc		7.50bc		4.33b	3
AM 45	7.00	2	8.68	1	20.67		1.49ab	3	38.20a	1	2.10bc		28.0a	1	8.37ab	2	6.16a	2
AM 40	6.83a		8.16ab		14.83bc		0.99c		23.50de		1.80cd		22.17bc	3	7.70bc	3	4.11b	
LOCAL	5.83ab		7.67abc		21.00a	3	1.43ab		32.33bc		2.37ab	3	17.83de	3	6.83cd		3.00c	
AM 50	5.83ab		6.67c		13.83bcd		0.93c		28.17cd		1.73cd		20.67cd		4.83f		3.50bc	
AM 38-2	5.50ab		5.00a		11.50d		0.86c		21.50e		2.60a	2	10.33e	2	6.33de		3.56bc	
EX Zimbabwe	5.00b		8.33a	3	12.17cd		0.88c		30.16c		0.91e		14.83c		5.50ef		1.55d	

Different superscripts denote significant difference in the same column

Br/plt= Branches/plant, Lvs/pl = leaves/plant, Nmkt LvY = non marketable leaf yield, Nmkt LvY= Non marketable leaf yield, Lv Fwt = Leaf fresh weight, Lv Dwt = Leaf fresh weight, Pht= Plant height, Lvl= Leaf length, Lvw= Leaf width

Table 3b: The mean performance for foliage yield and yield traits in nine genotypes of *Amaranthus cruentus* [L] harvested at 5 weeks after sowing during 2013 and 2014 seasons

5 weeks	Br/Pl	Rank	Lvs/Pl	Rank	Mn LvY (t ha^{-1})	Rank	Nmkt LvY(t/ha^{-1})	Rank	Lv Fr wt (g)	Rank	Lv Dwt (g)	Rank	Plt Ht	Rank	Lvl (cm)	Ran k	Lvw (cm)
AM 45	12a	1	9d		35.50a	1	2.20a-c	3	33.00a	1	5.73a	1	62.33a	1	11.83a	1	6.45ab
Caud	11ab		8d		31.30a	3	2.26ab	2	24.50b-e		3.5b-d		54.83ab		10.67ab		6.67ab
AM 40	11ab		8d		29.50a		1.87bc		22.83c-e		4.11a-c		49.33ab		8.83bc		5.67bc
AM 25	11ab		9c		3514.88c	2	1.80bc		28.33a-c	3	4.51a-c	3	59.66a		10.8ab		6.50ab
AMTZ 01	10c		10b	2	23.50ab		2.47a	1	26.50a-d		3.88a-c		62.83a	2	10.30a-c	3	5.83b
AM 38-2	10c		10a	2	12.33c		1.80bc		20.33de		3.53b-d		53.00ab		10.8ab	2	6.17ab
AM 42	11ab		9c		30.67a		2.05a-c		20.33de		1.95d		44.83ab		8.33bc		6.00bc
Ex Zimbabwe	12a	1	12a	1	22.50b		2.18a-c		31.83ab	2	2.67c-d		38.33b		8.00c		5.00bc
AM 40	12a	1	10b	2	11.00c		1.87bc		26.00a-e		4.67ab	2	63.33a	1	13.0a		7.67a

Different superscripts denote significant difference in the same column

Br/plt= Branches/plant, Lvs/pl = leaves/plant, Nmkt LvY = non marketable leaf yield, Nmkt LvY= Non marketable leaf yield, Lv Fwt = Leaf fresh weight, Lv Dwt = Leaf fresh weight, Pht= Plant height, Lvl= Leaf length, Lvw= Leaf width

At 4 weeks harvest non-marketable foliage yield was high in AM 42, AMTZ 01 and AM 45, this ranged from 1.82 t ha^{-1} to 1.78 t ha^{-1}. The non-marketable leaf yield comprised deformed, weak plants (yellowish green leaves), defoliated leaves, stems and roots. At 5 weeks harvest, non-marketable foliage yield peaked (2.44 t ha^{-1}) in AMTZ 01 followed by AM 50 (2.26 t ha^{-1}). This indicates that as days to harvest increases the quantity of non-marketable foliage yield increase. Preponderance of non-marketable foliage yield in *Amaranthus cruentus* is sequel to overcrowding arising from broadcast method of planting amaranth seeds. Leaf fresh weight/plant was high (38.2 g) in AM 45, followed by 36.33 g in AMTZ 01 and 36 g in AM 25. These values are relatively larger than the grand mean for this trait. At 5 weeks harvest, leaf fresh weight was high (33 g) in AM 45 followed by 31.83 g in Ex Zimbabwe. At 4 weeks harvest, three genotypes (AM 25, AM 38-2 and AM 50) outperformed other genotypes for leaf dry weight. On the other hand, at 5 weeks harvest leaf dry weight ranged from 1.95 g to 5.73 g. Best three genotypes for leaf dry weight are AM 45 (5.73 g), AM 50 (4.67 g) and AM 25 (4.11 g). These genotypes are promising for high dry matter yield and could be preferred by amaranth growers for production of amaranth dry leaves for consumption during prolonged dry season. High dry matter yield in amaranth is associated with net assimilation rate (Shukla, 2003). However, as dry matter yield increases over harvests (3 weeks or more), this will correspond to a decrease in the quality of the foliage.

At 4 weeks harvest, best amaranth genotypes for fresh leaf weight performed poorly for leaf dry weight (Table 3a). In contrast, at 5 weeks harvest AM 45 performed best for leaf dry weight and was consistent for 2013 and 2014. At 4 weeks harvest plant height ranged from 10.33 cm to 28.0 cm, best genotypes for plant height are AM 45, AM 42 and AM 40, these genotypes may develop high leaves/plant, branches/plant, foliage yield due to significant correlation coefficient between these traits Olaniyi, (2007). Best performing amaranth genotypes for plant height at 5 weeks harvest are AM 40 (63.33 cm), followed AMTZ 01 (62.53 cm) and AM 45 (62.33 cm). A comparison of plant height at 4 and 5 weeks harvest showed that AM 25 and AM local recorded 22.68% and 26% increase in plant height over 4 and 5 weeks harvest. Leaves of AM 42 are long (6.83 cm) at 4 weeks harvest compared to other genotypes. Similarly, AM 25 and AMTZ 01 recorded 6.16 cm and 4.33 cm respectively for leaf length. At 5 weeks harvest, leaf length ranged from 8 – 13 cm. AM local outperformed other genotypes for leaf length, this was followed by AM 45, AM, 25 and AM TZ 01. However, AM 40, AM 45, AM 25 recorded 20%, 34%, 36% increase in leaf length over harvest at 4 and 5 weeks. Leaf width among amaranth genotypes ranged from 1.55 cm to 6.83 cm for harvest at 4 weeks, best performing genotypes for leaf width are AM 42, AM 45 and AM TZ 01. At 5 weeks harvest, leaf width was narrow (5.00 cm) in AM 42, Ex Zimbabwe and wide (7.67 cm) in AM 40. Best performing genotypes for leaf width at 4 weeks harvest are not consistent in performance at 5 weeks harvest.

For multiple traits, AM 25 performed best for branches/plant, leaves/plant and leaf dry weight. AM 42 outperformed other genotypes for non-marketable leaf yield, leaf length and width. AM 45 performed best for leaves/plant, leaf fresh weight, and plant height at 4 weeks harvest. Considering harvest at 5 weeks, AM 45 performed better than other genotypes for branches/plant, leaf yield, leaf fresh weight and dry weight.

Also AM local is promising for branches/plant, plant height, leaf length and width. Over harvest periods (4 and 5 weeks) and years, AM 45 was consistent in performance for leaf fresh weight, leaf dry weight and leaf width. Also AMTZ 01 showed similar response over harvests and years for plant height, while AM local performed best for leaves/plant and plant height. Consequently these genotypes are possible donor parent or commercial varieties.

Preference for agronomic and leaf quality traits among *Amaranthus cruentus* genotypes is presented in Table 4. The preference score of 3.36 was recorded leaf colour at 4 weeks harvest compared to 2.90 recorded at 5 weeks. Preference for green leaf colour at 4 weeks harvest is consistent with previous findings by Adeniji and Aloyce (2012) among amaranth stakeholders in Arusha, Tanzania. Preponderance of yellowish-green colour leaves at 5 weeks harvest may be associated with competition for space and nutrient, insect pests attack and water stress. In addition, nitrogen deficiency is a possible cause of yellowish-green colour on amaranth leaves. Preference score for marketable foliage yield at 5 weeks was high, on the other hand leaves harvested at 5 weeks are least preferred for freshness, and crispiness. Amaranth growers delay harvesting from 4 to 5 weeks and beyond due to within season market glut associated with low demand and falling prices and to avoid the adverse effect of early flower induction (Adeniji and Aloyce, 2013). To reduce non-marketable leaf yield at 5 weeks, good agricultural practices specified for amaranth must be practiced by amaranth growers. High preference score (3.54) was recorded for leaves/plant at 5 weeks harvest compared to harvest at 4 weeks harvest (1.44). In another study Adeniji and Aloyce (2012) had reported high preference for amaranth accessions with high leaves/plant. Leaf size at 5 weeks harvest was preferred by amaranth growers. Leaf freshness at 4 weeks harvest was preferred to 5 weeks harvest. In addition, assessment of leaf quality (absence of perforations, deformed shape, yellowing of leaves) among the genotypes indicated that 80% of the respondents showed preference for leaf quality at 4 weeks harvest.

Table 4: Preference for foliage yield and leaf quality traits in nine *Amaranthus cruentus* genotypes harvested at 4 and 5 weeks during 2013 and 2014 planting seasons

Leaf Quality Traits	Liked	Slightly liked	Slightly disliked	Disliked	n	Likert score
Leaf colour at 4 weeks harvest	35 (2.80)	10 (0.80)	3 (0.12)	2(0.04)	50	3.76
Leaf colour at 5 weeks harvest	25(2.00)	10(0.60)	5 (0.20)	5 (0.10)	50	2.90
Marketable weight at 4 weeks harvest	20 (1.60)	10 (0.60)	10 (0.60)	10 (0.20)	50	3.00
Marketable weight at 5 weeks harvest	25 (2.00)	15 (0.90)	5 (0.30)	5 (0.10)	50	3.30
Leaf number at 4 weeks harvest	5 (0.40)	5(0.20)	15 (0.90)	25 (0.50)	50	2.00
Leaf number at 5 weeks harvest	35(2.80)	10 (0.60)	2(0.12)	3 (0.06)	50	3.58
Leaf size at 4 weeks harvest	10 (0.80)	8 (0.48)	10 (0.40)	22 (0.44)	50	2.12
Leaf size at 5 weeks harvest	33 (2.64)	10 (0.60)	4 (0.16)	3 (0.06)	50	3.46
Leaf freshness at 4 weeks harvest	34 (2.72)	10 (0.60)	3 (0.12)	3 (0.06)	50	3.50
Leaf freshness at 5 weeks harvest	25 (2.00)	10 (0.60)	10 (0.40)	5 (0.10)	50	3.10
Leaf quality at 4 weeks harvest	30 (2.40)	10 (0.60)	5 (0.20)	5 (0.10)	50	3.30
Leaf quality at 5 weeks harvest	10 (0.80)	5 (0.30)	25 (1.50)	10 (0.20)	50	2.50

Preference for *Amaranthus cruentus* genotypes by amaranth growers considering agronomic traits at 4 weeks harvest is presented in Table 5. Two genotypes (AM 25 and AM 45) are most preferred for leaf length and width they outperformed other accession for these traits.

The foregoing is consistent with mean values recorded for leaf length (Table 3). Amaranth growers' participatory assessment of plant height indicated that at 4 weeks harvest, AM 45 and AM 42 are preferred. The farmers' preference is similar to mean and rank presented in Table 3. Top two genotypes for leaf dry weight are AM 45 and AM 25, they recorded frequencies of 22 and 18 respectively. Ex-Zimbabwe and AM 25 are preferred amaranth growers for leaves/plant, they recorded frequencies of 22 and 12. For multiple traits amaranth growers indicated that AM 45 performed best for leaf length, leaf width and leaf dry weight. Ex-Zimbabwe had high preference for leaves/plant, leaf width and plant height, AM 25 for leaf length and leaf dry weight. Leaf crispiness varied among the accessions, this was low for most entries except AM 25, AM 45 and AM 42. Five entries (AM 25, AM 45, AM 42, AM Local and AMTZ 01) outperformed other genotypes for overall appearance.

Table 5: Preferences for *Amaranthus cruentus* genotypes by Amaranth growers in Jalingo, Taraba state (n =50)

	Leaf Length	Leaf Width	Plant Height	Leaf Weight	Leaves/ Plant	Leaf Freshness	Leaf Crispiness	Overall appearance	Leaf Size
AM 25	25	2	1	18	12	8	16	9	12
AM 45	20	20	20	22	0	8	15	8	12
AM 40	0	1	2	0	1	2	0	5	1
AM 50	0	1	1	8	9	1	0	5	1
EX ZIM	0	1	0	0	20	2	0	3	1
AM TZ 01	0	0	5	0	1	5	2	4	1
AM 42	5	20	15	0	5	5	15	8	10
ACRU	0	0	1	0	0	3	1	3	2
AM 38-2	0	0	1	0	2	8	2	5	10

4. Conclusion

Considerable variability exist among *Amaranthus cruentus* genotypes for foliage yield and yield related traits at 4 and 5 weeks harvests. The mean performance for foliage yield and yield related traits was influenced by precipitation, sunshine hours, and temperature and soil types. Few genotypes at 4 or 5 weeks harvests over years showed stable mean performance for foliage yield and yield related traits. AMTZ 01 and AM 42 are promising for foliage yield at 4 weeks harvest. AM 25 performed best for branches/plant, leaves/plant and leaf dry weight. While AM 42 outperformed other A*maranthus cruentus* genotypes for leaf length and width. AM 45 performed best for leaves/plant, leaf fresh weight and plant height at 4 weeks harvest. At 5 weeks harvest AM 45 performed best for branches/plant, leaf yield, leaf fresh weight and leaf dry weight. Promising genotypes are recommended for evaluation in multiple environments. The study showed that the AM 25, AM 42, AM 45 and AM Local are capable of developing rapidly and producing large quantities of biomass in a short period of time (4 and 5 weeks after sowing) and with management they will be very productive

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