EVALUATION OF YIELD AND YIELD RELATED TRAITS OF EXOTIC GRAIN AMARANTH (*Amaranthus* spp.) ACCESSIONS

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ABSTRACT

Amaranth grain yield varies widely in response to environment, weather conditions, species, genotype and production techniques. With appropriate varieties, yields of grain amaranth can be improved. The objective of this study was to assess the extent of yield variability in exotic grain amaranth accessions between locations. Field trials involving 28 accessions as treatments were conducted at two locations namely the Vegetable Research Farm of the National Horticultural Research Institute (NIHORT), Idi-Ishin Ibadan and the Teaching & Research Farm of Ladoke Akintola University of Technology (LAUTECH), Ogbomoso. The two locations are in Oyo State, South-West, Nigeria, with Ibadan typifying Forest-Savanna transition zone and Ogbomoso Derived Savanna zone. The field trials were undertaken from August to December 2013. The 28 accessions were replicated three times in a randomized complete block design in each location. Data were collected on growth and yield parameters; inflorescence length, inflorescence weight, 1000-grain weight, grain production efficiency, and grain yield. Variability existed among the accessions of grain amaranth. There were significant ($p < 0.05$) differences in grain yield of the accessions. Accessions 74-43, RRC1351, RRC399, RRC8 and RRC551 (all of which are Amaranthus Caudatus spp.) produced higher grain yields in both locations compared to the rest of the accessions. The top high-yielding accessions included RRC1351 (1.9 t ha^{-1}), RRC399 (1.8 t ha^{-1}), 74-43 (1.7 t ha^{-1}), RRC8 (1.4 t ha^{-1}) and RRC551 (1.3 t ha^{-1}). Yield of grain amaranth was significantly lower in the more humid Ibadan than the less humid Ogbomoso.

Key words: grain production efficiency, inflorescence length, weight and location

INTRODUCTION

Often times exotic accessions of vegetable crops outperform local ones (Oraegbunam *et al*., 2016). Amaranth belongs to the genus *Amaranthus* of the family *Amaranthaceae*. Nigeria is regarded as the center of diversity for *Amaranthus* spp. (Dulloo and Engles, 2003). Morphological characters are needed to describe plant growth habit and inflorescence characteristics (Kurlovich, 1998), and are influenced by consumer's preference, socio-economic status and natural selection (Ghafoor *et al.*, 2001). Amaranthus shows a wide range in yield diversity within certain species (Grubben, 2004). Current interest in amaranths resides in the fact that they have high nutritional value due to higher amount of protein with balanced essential amino acid contents, (Gamel *et al.*, 2004; Mnkeni *et al.*, 2007). Stable genotypes are particularly needed in Nigeria where amaranths are grown under varied environmental conditions (Dulloo and Engles, 2003).

Amaranth shows a wide variety of morphological diversity within its certain species. They have broad genetic variability in plant type (erect to prostate), number of inflorescences (one to several), seed colour, earliness, protein content, plant height, seed and green matter yield, resistance to pest and diseases and adaptability to pH, climate, rainfall and day length (Jacobsen *et al*., 2001). Genotypic and species differences in yield and yield attributes have been documented in amaranths (Vijayakumar, 1980; Campbell and Abbott, 1982). Therefore, the current research was to assess the extent of yield variability existing among 28 grain amaranth accessions for vegetable crop improvement.

MATERIALS AND METHODS

Field trials were conducted from August to December late cropping season 2013 in two locations. They are the Vegetable Research Farm of the National Horticultural Research Institute (NIHORT), Idi-Ishin, Ibadan (3° 56′ E and 7° 33′ N; 168 m above sea level) within the Forest-Savanna transition agro-ecology and Teaching & Research Farm, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso (4° 10′E and 8° 10′ N; 275 m above sea level) within the Derived Savanna agro-ecology of Nigeria. Monthly rainfall, temperature and relative humidity for the two experimental sites in 2013 are presented in Table 1.

Table 1: Mean monthly temperature, relative humidity and rainfall of Ibadan and Ogbomoso 2013 cropping seasons

Month	Ibadan				Ogbomoso			
	Max Temp $^{\circ}$C	Min Temp $^{\circ}$C	RH (%)	Rainfall (mm)	Max Temp $^{\circ}$C	Min Temp $^{\circ}$C	RH (%)	Rainfall (mm)
Jan	33.6	22.1	87	00	35.1	22.6	73	00
Feb	34.6	24.2	88	00	36.7	22.8	73	41
Mar	34.4	24.1	89	208	34.9	23.1	76	439
Apr	33.1	23.4	87	237	34.2	23.6	81	103
May	31.5	23.0	88	150	31.2	22.8	85	157
Jun	30.8	23.0	89	141	30.7	22.6	87	167
Jul	29.5	23.0	91	98	28.5	21.3	91	77
Aug	28.2	22.6	89	28	28.2	21.5	94	88
Sep	29.9	22.4	92	215	29.2	21.5	89	117
Oct	30.2	24.8	92	136	30.3	21.5	88	109
Nov	32.1	22.1	91	113	31.8	21.8	83	145
Dec	34.5	23.1	89	00	33.5	20.7	70	0.0
Mean	31.87	23.15	89	111	32.0	22.2	83	12

Ibadan climate data sourced from NIHORT Metrological station Ibadan. Ogbomoso climate data sourced from Nigeria Meteorological Station, International Airport Ilorin, Kwara State. RH - Relative Humidity; Max - Maximum; Min - Minimum; Temp - Temperature

Soil samples were collected in both fields at a depth of 0-15 cm for physical and chemical analysis. The samples were bulked to form a composite sample from which a representative sample was taken which was air-dried and crushed. The soil at Ogbomoso belongs to the order Alfisol (Smyth and Montgomery, 1962) derived from fine-grained gnesis. The soil is moderately drained, ferruginous soil with a sandy loam texture.

Soil samples were taken randomly prior to planting to assess the nutrient status of the soil before planting in both locations. The textural class of the soils is sandy loam, but the clay content of Ogbomoso soil is slightly higher than at Ibadan (Table 2). The field was ploughed followed by harrowing. The field was marked out to give a plot size of 3.5 m × 1.4 m (4.9 m^2) with 1 m between plots and 1 m between replicates. Twenty-eight accessions of grain amaranth sourced from the North Central Regional Plant Introduction Station (NCRPIS) of the United States National Plant Germplasm System by NIHORT, Ibadan, Nigeria were used as treatments for the trials (Table 3). The experiment was laid out in a randomized complete block design replicated three times. The total experimental area was 66.5 m × 12.5 m (831.25 m^2).

Table 2: Physico-chemical characteristics of soil of the experimental sites

Soil properties 0-15 cm depth	2013	
	Ibadan	Ogbomoso
Chemical properties		
pH (H$_2$O)	5.80	5.80
Organic carbon (g kg^{-1})	3.84	3.23
Total N (g kg^{-1})	0.30	0.28
Available P (g kg^{-1})	3.80	6.00
Ex. K (cmol kg^{-1})	0.34	0.31
Ex. Na (cmol kg^{-1})	0.26	0.26
Ex. Ca (cmol kg^{-1})	3.11	3.42
Ex. Mg (cmol kg^{-1})	0.58	0.7
Ex. acidity (cmol kg^{-1})	0.28	0.08
CEC (cmol kg^{-1})	5.17	5.20
Physical properties (g kg^{-1})		
Sand	868	860
Clay	12	20
Silt	120	120
Textural class	Sandy loam	Sandy loam

Table 3: Passport data of grain amaranth accessions used for the study

	Accession number	Origin/Source	Seed colour
A	*AmaranthusCaudatus*		
1	RRC711	Peru,Cuzco	Golden, brown, black
2	86-12	India,Uttar Pradesh	Cream
3	RRC11	India	Cream
4	RRC1392	Argentina	Cream
5	MaliChua	India	Pink
6	74-43	India,Gujarat	Cream
7	LSK267	Peru	Cream, pink
8	RRC551	Argentina	Cream
9	Quinoa	Argentina	Cream
10	Coime	Bolivia, Tarija	Cream, pink
11	RRC8	Napal	Cream
12	RRC125	Sweden ,Malmohus	Cream
13	RRC399	Sweden, Malmohus	Cream
14	DB2001949	U.S.A, Iowa	Cream
15	RRC1395	Pakistan, Azad Kashmir	Black
16	108U22	India, Himachal Pradesh	Cream
17	RRC880	Peru Cuzco	Cream, black
18	RRC882	Peru Cuzco	Black
19	RRC889	Peru, Cuzco	Black
20	RRC1351	Napal	Cream
B	*Amaranthuscruentus*		
21	RRC 1041	Mexico	Cream
22	HH 100	Mexico	Cream, black
23	Y-004-W	U.S.A, Iowa	Cream
C	*Amaranthushybridus*		
24	RRC 19A	India, Tamil Nadu	Cream,black
25	Quihuicha	Peru	Black
26	No.22	Mexico, Sonora	Golden, cream,brown
D	*Amaranthushypochondriacus*		
27	RRC K125	U.S.A, Pennsylvana	Cream,black
28	RRC 383	U.S.A, California	Brown

Source: North Central Regional Plant Introduction Station

The seeds were sown directly on the field at a spacing of 50 cm × 35 cm after which thinning was done at 2 weeks after sowing (WAS) giving rise to 40 plants per plot, corresponding to 57,142 plants per hectare. Manual weeding using hoe was carried out whenever weeds were noticed in and around the plots. Data collection from 10 central plants started 6 WAS till maturity at 12 WAS. The following growth and yield parameters were assessed:

- Inflorescence length (cm): This was measured with meter rule starting from the last node on the base up to the tip of the inflorescence.
- Inflorescence weight (g): Mature inflorescence was harvested and weighed before seed removal.
- 1000-grain weight (g): a thousand grains were counted per accession and weighed.
- Grain yield: the inflorescence was harvested when mature to recover the grains.

Grain production efficiency was computed according to Ogunbodede and Ogunremi (1986) thus:

$$GPE = \frac{grainweight / plant(g)}{Inflorescenceweight / plant(g)} \times 100$$

Data collected were subjected to analysis of variance (ANOVA) using SAS (2009) software to establish significant effects. Least significant difference was used to separate the means at 5% probability level. The yield parameters were analyzed by numerical taxonomic technique using the procedure for single linkage cluster analysis (SLCA) to show the relationship among the accessions which were employed to summarize the position of accession on a dendogram (Sneath and Sokal, 1973). Pearson moment correlation was done to determine the level of association between the yield parameters.

RESULTS

Grain Yield and Yield Components of 28 Accessions of Grain Amaranth in Two Locations
There were significant differences in the length of inflorescence among the grain amaranth accessions (Table 4). The longest inflorescence was produced on RRC551 (27.9 cm) and was followed by accession 86-12 (26.73 cm). They were not significantly different from Quinoa (25.2 cm) RRC8 (23.07 cm) and RRC880 (23.9 cm), while the shortest length was obtained from RRC1392 (4.1 cm).

Table 4: Grain yield and yield components of 28 accessions of grain amaranth accessions as affected in two locations.

Accession	Inflorescence length (cm)	Inflorescence weight (g)	Grain yield (t ha⁻¹)	1000 Grain Weight (g)	GPE (%)
RRC711	9.83	94.60	0.2	0.80	7.14
86-12	26.73	99.40	0.53	1.24	12.36
RRC11	19.07	123.75	0.16	0.71	2.21
RRC1392	4.05	29.80	0.32	0.98	19.30
MaliChua	9.15	43.08	0.16	0.83	4.61
74-43	13.35	242.95	1.71	0.86	34.13
LSK267	20.88	202.33	1.21	0.89	11.24
RRC551	27.93	93.52	1.25	0.97	39.67
Quinoa	25.23	31.47	0.87	0.84	36.78
Coime	8.65	33.22	0.7	0.76	27.13
RRC8	23.07	32.81	1.4	0.83	44.49
RRC125	7.40	28.75	0.4	0.86	17.71
RRC399	6.94	31.42	1.78	1.10	70.25
DB2001949	14.82	25.59	0.27	0.99	12.69
RRC 1395	15.37	27.76	0.23	0.70	10.27
108U22	9.02	22.26	0.26	0.71	15.83
RRC880	23.93	31.26	0.35	0.76	15.39
RRC882	10.28	63.10	0.4	0.84	8.81
RRC889	14.26	54.87	0.47	0.79	11.51
RRC1351	11.78	55.50	1.89	1.06	44.41
RRC1041	10.25	55.32	0.36	0.87	7.85
HH100	17.42	53.07	0.37	0.74	8.84
Y-004-W	8.05	40.10	0.51	0.61	17.28
RRC19A	12.61	21.24	0.27	0.60	18.53
Quihuicha	5.87	24.24	0.2	0.58	14.72
No.22	13.37	22.19	0.56	0.66	33.01
RRCK125	17.20	24.46	0.34	0.75	14.18
RRC383	15.82	39.62	0.2	0.38	8.50
Location					
Ibadan	14.63	75.17	0.66	0.80	22.58
Ogbomoso	14.10	42.52	0.57	0.82	18.79
LSD₀.₀₅					
Accession	4.95	59.03	0.11	0.22	9.58
Location	1.32	15.78	0.73	0.06	2.56
Location × Accession	**	**	**	**	**

WAS - week after sowing, LSD$_{0.05}$ - Least significant different at 5% probability, GPE - Grain Production Efficiency,
*Significant at $p = 0.05$, **Significant at $p = 0.01$

Accession 74-43 had the highest inflorescence weight of 243.0 g/plant and was not significantly different from LSK267 (202.3 g/plant) while the lowest weight was recorded on accession Quihuicha (21.24 g/plant). Accession 86-12 had the highest 1000-grain weight among other accessions (1.24 g), though not significantly ($p < 0.05$) different from RRC399 (1.1 g) and RRC1351 (1.1 g), while RRC383 had the lowest 1000-grain weight of 0.4 g which was similar with Quihuicha (0.6 g). RRC399 had the highest grain production efficiency among other accessions (70.3%) and the lowest was obtained from RRC11 which had 2.2% (Table 4).

There were no significant ($p < 0.05$) differences in inflorescence length between the two locations (Ibadan and Ogbomoso), but inflorescence produced in Ibadan (75.2 g/ plant) significantly ($p < 0.05$) weighed more than that of Ogbomoso (42.5 g/plant) (Table 4). Higher inflorescence weight obtained in Ibadan resulted in significantly ($p < 0.05$) higher grain yield (0.66 t ha^{-1}) compared to Ogbomoso (0.57 t ha^{-1}) (Table 4). The 1000-grain weight obtained at Ogbomoso (0.82 g) was not significantly ($p > 0.05$) different from that at Ibadan (0.80 g) (Table 4). Grain production efficiency was higher in grain amaranth accessions planted in Ibadan (22.6%) than that in Ogbomoso (18.8%). The location by accession interaction was highly significant ($p < 0.05$) in terms of the inflorescence length and weight, grain yield, thousand grain weight and grain production efficiency (Table 4).

Effect of Accession by Location on Yield Components of Grain Amaranth

The effects of the accessions planted in the two locations on the yield parameter of grain amaranth accessions are presented in Table 5. The longest inflorescence was recorded in LSK267 at Ogbomoso (35.4 cm) though not significantly different from RRC551 planted in Ogbomoso and accession 86-12 planted in Ibadan (30.7 and 29.0 cm, respectively), while lowest was obtained from RRC1392 at Ogbomoso (2.9 cm). Accession 74-43 planted in Ibadan had the highest inflorescence weight (451.9 g/plant) and was significantly ($p < 0.05$) different from accession No.22 in the same location that had the lowest (14.2 g/plant) among all the accessions in both locations. Accession 86-12 planted in Ogbomoso produced the highest 1000-grain weight per plant (1.6 g), while the lowest was obtained from RRC383 in the same location (Ogbomoso) with 0.3 g (Table 5). Grain production efficiency was highest in RRC399 planted in Ibadan (76.6%) and was not significantly ($p < 0.05$) different from the same accession (RRC399) planted in Ogbomoso (63.9%) and Accession 74-43 (63.3%) also in Ogbomoso, while the lowest was from RRC711 (1.57%) planted in Ibadan and was not significantly ($p < 0.05$) different from RRC11 (1.36%) also from Ibadan, RRC711 (3.06%), MaliChua (3.21%) and Quihuicha (2.49%) in Ogbomoso (Table 5).

Effect of Accessions by Location on Grain Yield of Amaranth

The grain yield was highest in RRC1351 planted in Ibadan (1.67 t ha^{-1}) though not significantly ($p < 0.05$) different from LSK267 in the same location (1.91 t ha^{-1}), while the lowest was obtained in accession Quihuicha planted in Ogbomoso with 0.07 t ha^{-1} (Figure 1). The best five accessions that were stable across locations and outperformed others were Accession 74-43 with grain yields of 1.67 and 1.74 t ha^{-1} in Ibadan and Ogbomoso, respectively; RRC1351 with grain yield of 1.98 and 1.81 t ha^{-1} in Ibadan and Ogbomoso, respectively; RC399 with grain yields of 1.82 and 1.75 t ha^{-1} in Ibadan and Ogbomoso, respectively; RRC8 with grain yields of 1.57 and 1.22 t ha^{-1} in Ibadan and Ogbomoso, respectively; and RRC551 with grain yields of 1.50 and 1.00 t ha^{-1} in Ibadan and Ogbomoso, respectively (Figure 1). The highest grain yield was obtained from RRC1351 (1.89 t ha^{-1}), while the lowest yield was obtained from RRC11 (0.16 t ha^{-1}), as seen in Table 4.

Cluster Analysis of 28 Accessions of Amaranth

In this study, cluster analysis revealed four groups of the accessions at 75% similarity level based on yield indices (Figure 2). The dendogram based on the single linkage cluster analysis is shown in Figure 2. Group 1 had Accession 74-43 which had inflorescence length of 13.35 cm, inflorescence weight of 242.95 g, grain production efficiency of 34.13% and grain yield 1.7 t ha^{-1}, with distinguishing characteristics. Group 2 comprised one accession (Accession RRC8) which had inflorescence length of 23.67 cm, inflorescence weight of 32.81 g; grain production efficiency of 54.49% and grain yield of 1.57 t ha^{-1}. Group 3 comprised one accession (Accession LSK267) which had inflorescence length of 20.88 cm, inflorescence weight of 202.33 g, grain production efficiency of 11.24% and grain yield of 1.21 t ha^{-1}. Group 4 had 25 out of 28 accessions which included Quinoa, RRC711, RRC551, RRC11, Coime, RRC1395, 86-12, RRC399, RRC125, MaliChua, among others. This implies that these 25 accessions of grain amaranth had similarity among them.

Correlation between Grain Yield and Yield Components of Amaranth

There was correlation between inflorescence length and the weight produced, and this inflorescence length was highly correlated with fresh and dry shoot and root weight of Amaranth. Inflorescence weight was highly positively correlated with seed (grain) and was negatively correlated with the grain production efficiency (Table 6). Grain weight, 1000-grain weight and grain production efficiency were all positively correlated ($r = 0.01$). Grain production efficiency and 1000-grain weight were highly positively correlated (Table 6).

Table 5: Interaction effect of accession x location on yield components of grain amaranth in Ibadan and Ogbomoso

Accession	Inflorescence length (cm)			Inflorescence weight (g)			1000 Grain Weight (g)			Grain Production Efficiency (%)		
	Iba-dan	Ogbo-moso	mean	Iba-dan	Ogbo-moso	mean	Iba-dan	Ogbo-moso	mean	Iba-dan	Ogbo-moso	mean
RRC711	10.17	9.50	9.84	165.23	23.97	94.60	0.96	0.64	0.80	1.57	13.26	7.42
86-12	29.00	24.45	26.73	149.70	49.09	99.40	0.87	1.61	1.24	5.51	19.20	12.36
RRC11	20.47	17.67	19.07	199.30	48.19	123.75	0.67	0.76	0.72	1.36	3.06	2.21
RRC1392	5.20	2.90	4.05	26.33	33.27	29.80	0.76	1.19	0.98	25.52	13.08	19.30
MaliChua	8.90	9.40	9.15	46.80	39.37	43.09	0.93	0.72	0.83	6.00	3.21	4.61
74-43	18.34	8.37	13.36	451.87	34.03	242.95	0.83	0.89	0.86	4.92	63.34	34.13
LSK267	6.37	35.40	20.89	326.47	78.20	202.34	1.00	0.79	0.90	14.62	7.87	11.25
RRC551	25.13	30.73	27.93	148.35	38.68	93.52	1.10	0.84	0.97	42.10	37.24	39.67
Quinoa	25.00	25.47	25.24	21.26	41.71	31.49	0.89	0.79	0.84	44.49	29.07	36.78
Coime	9.52	7.77	8.65	24.61	41.82	33.22	0.73	0.80	0.77	31.95	22.31	27.13
RRC8	21.70	24.43	23.07	33.15	32.47	32.81	0.84	0.81	0.83	63.94	48.04	55.99
RRC125	7.70	7.10	7.40	23.87	33.63	28.75	0.82	0.90	0.86	18.43	16.99	17.71
RRC399	7.94	5.93	6.94	29.38	33.47	31.43	1.00	1.20	1.10	76.64	63.85	70.25
DB2001949	14.33	15.30	14.82	23.92	27.26	25.59	0.94	1.04	0.99	12.23	13.15	12.69
RRC1395	17.10	13.63	15.37	24.58	30.95	27.77	0.67	0.73	0.70	11.83	8.72	10.28
108U22	11.57	6.47	9.02	17.64	26.88	22.26	0.66	0.76	0.71	21.21	10.44	15.83
RRC880	23.73	24.13	23.93	23.83	38.68	31.26	0.76	0.75	0.76	20.86	9.92	15.39
RRC882	10.53	10.03	10.28	53.87	72.33	63.10	0.86	0.83	0.85	10.62	7.00	8.81
RRC889	14.71	13.80	14.26	44.95	64.80	54.88	0.75	0.82	0.79	12.27	10.74	11.51
RRC1351	14.13	9.43	11.78	46.29	64.72	55.51	1.05	1.06	1.06	54.10	34.72	44.41
RRC1041	12.93	7.57	10.25	45.13	65.50	55.32	0.60	1.14	0.87	7.91	7.79	7.85
HH100	17.33	17.50	17.42	44.83	61.31	53.07	0.76	0.73	0.75	10.11	7.56	8.84
Y-004-W	12.67	3.43	8.05	32.98	47.21	40.10	0.73	0.48	0.61	21.10	13.46	17.28
RRC19A	5.11	20.10	12.61	21.62	20.85	21.24	0.52	0.68	0.60	16.51	20.55	18.53
Quihuicha	5.90	5.83	5.87	14.88	33.60	24.24	0.73	0.43	0.58	26.94	2.49	14.72
No.22	19.74	7.00	13.37	14.21	30.17	22.19	0.66	0.67	0.67	38.69	27.33	33.01
RRCK125	17.07	17.33	17.20	16.25	32.27	24.26	0.88	0.62	0.75	20.40	7.95	14.18
RRC383	17.47	14.17	15.82	33.43	45.83	39.63	0.42	0.33	0.38	13.28	3.72	8.50
LSD $_{0.05}$	6.99			83.27			0.32			13.55		

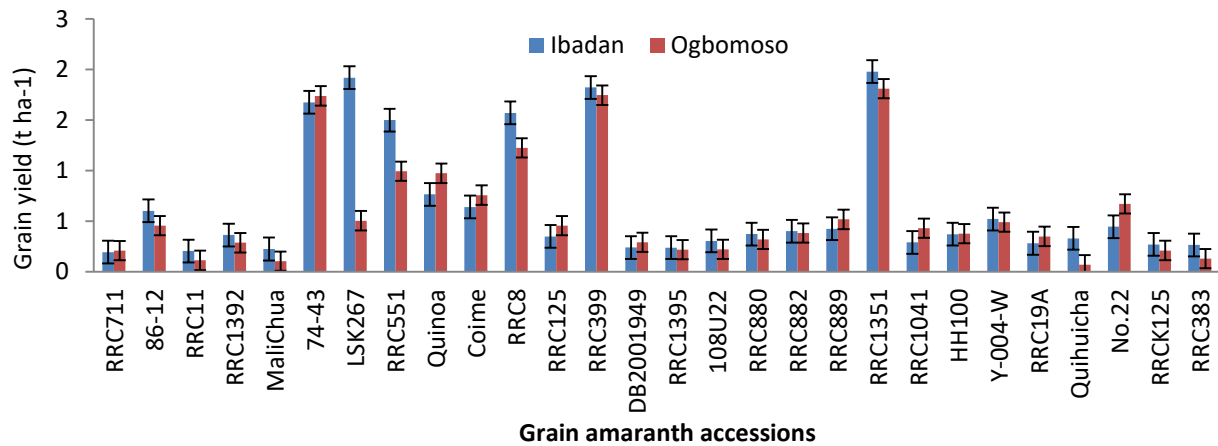LSD $_{0.05}$ - least significant different at 5% probability, WAS - week after sowing

Figure 1: interaction between accessions and locations on grain yield
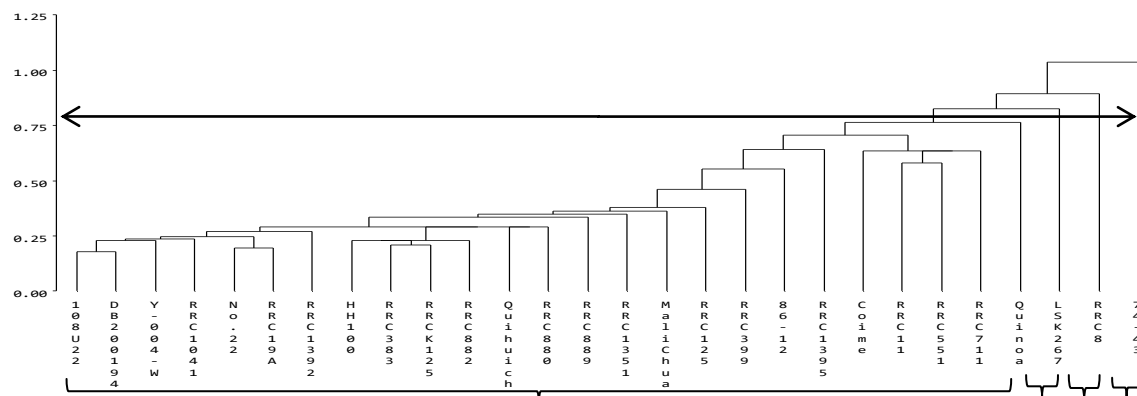

Figure 2: Dendogram resulting from Ward method cluster analysis of 28 accessions of grain amaranth
Key: I – Group 1, II - Group 2, III - Group 3, IV - Group 4

DISCUSSION

In order to maintain, evaluate and utilize germplasm effectively in hybridization programme for development of high-yielding grain accessions, it is important to assess the extent of genetic morphological diversity existing among grain amaranth accessions. Smith and Smith (1989) considered morphological characterization as an important first step in description and classification of crop germplasm because a breeding programme mainly depends upon the magnitude of genetic variability (Smith *et al*., 1991).

A considerable level of variability for qualitative characters such as leaf pigmentation, petiole pigmentation, inflorescence colour, inflorescence density index, terminal inflorescence attitude, terminal inflorescence shape, and seed colour was observed in the newly introduced 28 accessions which were from 24 countries. This variability may be related strongly to the diverse geographical origins of the newly introduced 28 accessions. A strong relationship of diversity and geographical origin has been reported in crops such as vegetable amaranth (Shukla *et al*., 2010), oats (Rezai and Frey, 1990), maize (Alika *et al*., 1993) and bambara groundnut (Ntundu *et al*., 2006). Laghetti *et al*. (1998) advocated that maximum genetic conservation would be achieved by sampling populations from as many environments as possible. Some of the accessions possessed good genes for more than one character and hence could be utilized directly or included in hybrid programme for varietal development (Ghafoor *et al*., 2001).

Variations in growth, biomass and grain yield of the accessions were attributed to variations in the origins of the plant since the 28 accessions were from different countries. The adaptability of the different accessions to Nigeria climatic condition was because of inherent genetic variation leading to high chances of survival. Myers and Robert (1998) and Liu and Stützel (2002) noted that amaranth has a combination of traits responsible for its capacity to adapt to unfavourable growing conditions, such as low availability of nutrients and a wide range of soil moisture and temperature.

Gruben (2004) reported similarly that for the conventional accessions, there was genotypic variation in seed survival and other parameters taken. Research has shown that grain amaranth yields are extremely variable depending upon species and genotype, site, soil and weather conditions, growing season and agronomic practices. Grain yields from 1000 to 3000 kg ha^{-1} have been achieved in the United States and in several countries of Northern Europe (Pospisil *et al*., 2006), 1800-2300 kg ha^{-1} and exceptionally 4500 kg ha^{-1} in Argentina (Tosi and Ré, 2003), 5000 kg ha^{-1} or even more under intensive cultivation in China (Wu *et al*., 2000) and 1200-6700 kg ha^{-1} in southern Italy (Alba *et al*., 1997; Lovelli*et al*., 2005).

This result corroborates Hoheisel (1998) that crop production has been largely influenced by environmental factors that affect all the processes from metabolism to gene expression during plant growth and development. Also, Yao *et al*. (2008) noted that differences in the agronomic parameters could be adduced to variety, environmental and cultural practices. Research has shown that both abiotic and biotic factors cause variations in growth and yields of crops (Ramegowda and Senthil-Kumar, 2015; Prasch and Sonnewald, 2015). All the accessions had good yield biomass in both locations for grain amaranth. These results agree with Grubben (2004) that vegetable amaranths grow well at day temperatures above 25°C and night temperatures not lower than 15°C. Any efforts towards increasing the acidic pH of the soils occurring in the locations of the present study to near-neutral values may further improve the yield of the crop in those locations (Okorie *et al*., 2017).

CONCLUSION

Variability existed among the accessions of grain amaranth evaluated for yield parameters. There were significant differences ($p < 0.05$) in the grain yield of the accessions. Out of the 28 accessions planted, accession 74-43, RRC1351, RRC399, RRC8 and RRC551 had significantly higher yields in Ibadan and Ogbomoso. These accessions are all *Amaranthus Caudatus* spp. Accessions 74-43 (India), RRC1351 (Nepal), RRC399 (Sweden), RRC8 (Nepal) and RRC551 (Argentina) from different countries adapt well in the tropical region of Africa. The top high-yielding accessions were RRC1351, RRC399, 74-43, RRC8 and RRC551. Furthermore, irrespective of the accessions, the two agro-ecological zones are suitable for high grain yield of grain amaranth but Ogbomoso gave higher yields than Ibadan. For increases in grain yield of grain amaranth, Ogbomoso (derived savanna zone) is preferred to Ibadan (forest-savanna transition zone) as a growing environment for the crop. This can be attributed to better adaptation of the accessions in low humidity. Growing any of the selected five accessions including 74-43, RRC1351, RRC399, RRC8 and RRC551 in either of the two locations can give grain yield in excess of 1.00 t ha^{-1}.

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