

# Evaluation of 27 *Amaranthus* Accessions for Seed Yield

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**Abstract:** *The Amaranthus species are cultivated as pseudo-cereal because of their high content of carbohydrates, proteins and fats, comparable or even superior to cereals. Many accessions of the crop exist and these have not been explored for a number of agronomic variables. The aim of this study was to determine seed yield components of the 27 Amaranthus accessions; and to select accessions that have high seed yield. For this reason, a field experiment was conducted at the University of Ibadan, Department of Agronomy Research Farm on 27 Amaranthus accessions. The following variables were measured: seed germination, plant survival at 4 and 12 weeks after transplanting (WAT), plant height at flowering and 12 WAT, days to anthesis, inflorescence length at 12 WAT, fresh and dry inflorescence weight, harvest index and seed weight (kg/ha). The highest seed weight was recorded for NGB/06/104; while NG/TO/JUN/09/008 gave the least seed yield among the accessions. Correlation coefficients among agronomic variables ranged from -0.0 (between plant height at flowering and percent harvest index; also, dry inflorescence weight as percent of fresh inflorescence weight and seed weight in kg/ha) to 0.98 (between plant height at 12 WAT and plant height at flowering). Most of the 27 accessions evaluated varied in their inflorescence colour. Five of the accessions: NGB/06/104, UI/OP/Mar/010/009, NHA/34BP1576468, NH/EL/Feb/010/006, and NG/OA/Aug/09/001 were selected in terms of higher seed weight, percent harvest index, plant height at 12 WAT, plant survival at 12 WAT, inflorescence length, and general superiority based on a multidimensional assessment determined by sum of weighted indices.*

**Keywords:** *Amaranthus Accessions, Correlation Coefficients, Inflorescence Length, Seed Yield*

## I. INTRODUCTION

The genus *Amaranthus* consists of approximately 60 species, however, only a limited number of species are of the cultivated types, while most are considered weedy species. Amaranth is a versatile plant since it can grow under a broad range of climate, soil and cultivar systems (Bertoni, 1999). Several species are raised for amaranth grain in Asia and the Americas. Ancient amaranth grains still

used till this day include the three species, *Amaranthus caudatus*, *Amaranthus cruentus*, and *Amaranthus hypochondriacus* (Williams and Brenner, 1995). The weed amaranth comes from *A. retroflexus* and is considered one of the world worst weeds (NRC, 1984). While various species of grain and vegetable types can be distinguished, often, both the grain and leaves are consumed by both human and livestock (Tucker, 1986). Amaranth uses the C<sub>4</sub> pathway and has a high efficiency of CO<sub>2</sub> utilization, high photosynthesis rate at high temperature and drought tolerance (Williams and Brenner, 1995), which make it possible to be grown in areas not suitable for other crops (Lehman, 1996). Amaranthaceae family consists of hardy, weedy, herbaceous, fast-growing, cereal-like plants (Lehman, 1996); with a seed yield of up to 3 tonnes/hectare when grown in monoculture for 3-4 months and a vegetable yield of 4.5 tonnes dry matter/hectare after 4 weeks of planting (Grubben and van Sloten, 1981). Amaranth is one of those rare plants whose leaves are eaten as a vegetable while the seeds as cereals (Saunders and Becker, 1984). Therefore the objectives of this study are to determine agronomic variables that contribute to seed yield of the crop and to select accessions that have high seed yield.

## II. MATERIALS AND METHODS

### Experimental Site and Field Layout

The study was carried out at the University of Ibadan, Department of Agronomy Teaching and Research Farm, Parry road (Lat. 07° 27' N and Long. 03 53' E). Prior to planting, soil samples were collected using soil auger at 0-15 cm for pre-planting soil analysis. The experiment was laid out in a randomized complete block design (RCBD) with 2 replicates. Land area for the experiment was 300 m<sup>2</sup>; each plot was 3.0 x 2.0m<sup>2</sup>. Seeds were raised in nursery pots containing 5 kg soils for 3 weeks where watering was done in the morning and evening of everyday. Seedlings were transplanted to the field on ridges of about 0.3 m tall at spacing of

50 cm x 50 cm with 1 seedling per hole. 2 weeks after transplanting, compound fertilizer (NPK 15:15:15) was applied to supply 100kg N/ha before flowering. Plants were sprayed with insecticide, cypermethrin at a concentration of 10mls in 5 litres of water, as a precaution against insect – transmitted virus and other insect damage. Spraying was carried out forth-nightly from six weeks after transplanting. Plots were weeded manually with hoe as necessary. Secateurs were used to harvest the fresh inflorescence of each accession at 12 weeks after transplanting. The inflorescence was air-dried and threshed; and were blown in the direction of air to separate the seeds from the chaff.

#### Seed Sources

A total of 33 accessions of amaranths seeds were collected from different sources such as; National Horticultural Research Institute (NIHORT), National Centre for Genetic Resources and Biotechnology (NACGRAB), different sources such as at Idi-ishin, Ibadan, (NACGRAB) Department of Agronomy, University of Ibadan and markets, all in Ibadan, Oyo State Nigeria. Some of the accessions were identified by their locations, collectors' initials, month of collection, year of collection and serial number.

#### Laboratory Germination Test

Prior to nursery planting, laboratory germination test was done at the Department of Agronomy plant breeding laboratory using blotting papers. The papers were saturated with water, 50 seeds of each accession were arranged on each blotting paper and placed on the germinator tray after which the surface was covered with tissue paper to prevent evaporation. Water was applied intermittently, and germination percentage was recorded on the third day. Out of the 33 accessions collected, 27 were selected for this study based on their high germination percentage on the third day.

#### Data Collection

Data were collected on above ground characteristics at intervals. Some were taken before planting while others were taken at 4, 8, and 12 weeks after transplanting (WAT). The dry weight of inflorescence was expressed as percentage of fresh inflorescence weight thus: (Dry inflorescence weight/Wet inflorescence weight) x 100. Also, the harvest index was calculated thus: HI (%) = (economic yield/ biological yield) x 100, where the economic yield is the weight of seed produced, and the biological yield comprises of the dry inflorescence before threshing out the seed. Plant height at flowering and 12 WAT was also measured and the initial and final plant populations (to calculate the percentage plant survival).

#### Data Analysis

Simple linear correlation of the agronomic characteristics of the 27 *Amaranthus* accessions was done using Statistical Package for the Social Sciences; SPSS and Multidimensional Analysis, MDA, based on seed weight, percent harvest index, plant height at 12 WAT, plant survival at 12 WAT, and dry inflorescence weight as percent of fresh inflorescence weight. These are weighted as 3, 2, 2, 1, 1, respectively in order of their essentiality and desirability.

### III. RESULTS

#### Soil of the plot

The result of the pre-planting analysis of soil in the experimental plot which was previously cropped to yam is presented in Table 4.1. The soil has an organic carbon content of 16g/kg and total nitrogen content of 1.4g/kg. It is a slightly acidic soil with pH of 6.5 and the Cation Exchange Capacity is 4.3cmol/kg. Available Phosphorus, Iron and Zinc are in adequate amounts of 11mg/kg, 88mg/kg and 15mg/kg respectively.

Table 4.1. Physical and chemical properties of soils of the experimental plots before planting

Parameters	Units	Values
pH (H <sub>2</sub> O)	-	6.5
Organic carbon	g/kg	16
Total nitrogen	g/kg	1.4
Available phosphorus	mg/kg	11
Exchangeable bases	cmol/kg	
K		0.4
Na		0.9

Mg		1.8
Ca		0.9
Exchangeable Acidity	cmol/kg	0.3
Cation Exchange Capacity	cmol/kg	4.3
Exchangeable Micronutrients	mg/kg	
Mn		215
Fe		88
Cu		2
Zn		15
Particle size distribution	g/kg	
Sand		825
Silt		107
Clay		67
Textural class		Sandy loam.

#### Assessment of qualitative characters

There were variations in the agronomic characteristics of the 27 accessions studied. Table 4.1 shows the summary of the measured characteristics. Table 4.2 shows the inflorescence colour variation. The predominant leaf colour was green and inflorescence showed varying degree of colouration. NH/EI/FEB/010/006 stood out conspicuously different from the rest as its inflorescence was totally red. Illustration of the various inflorescence and seed colour of the accessions are represented on plate 1, 2 and 3 respectively. Those with red inflorescence gave high % harvest index. The predominant seed colour of the accessions was dark brown. Exceptions were UI/MA/FEB/010/004 (gold), as well as NG/06/103, NGB/06/105 and NH/EI/FEB/010/006 that were cream colour. Figure 2 shows the mean seed weight (g/plant) of 27 *Amaranthus* accessions used in this study.

#### Simple Linear Correlation of the Agronomic Characteristics

The correlation coefficient among agronomic characteristics of 27 *amaranthus* accessions is given in table 4.5. The most significant correlation existed between plant height at 12 WAT, and plant height at flowering ( $r=0.98$ ). This was closely followed by the correlation between percent plant survival at 4 WAT and percent plant survival at 12 WAT ( $r=0.87$ ). Both correlations were at  $P \leq 0.01$ . Percent germination also correlated significantly with percent plant survival at 4 WAT (0.78). Percent germination correlated with percent survival at 12 WAT ( $r=0.60$ ,  $P \leq 0.01$ ); length of inflorescence at 12 WAT correlated significantly with plant height at 12 WAT ( $r=0.57$ ,  $P \leq 0.01$ ); percent survival at 4 WAT

significantly correlated with plant height at flowering (0.43,  $P \leq 0.05$ ); plant height at 12 WAT significantly correlated with days to anthesis (0.41,  $P \leq 0.05$ ) There was a negative correlation between % harvest index and days to anthesis ( $r=-0.31$ ) and another negative correlation between percent plant survival at 12 WAT and seed weight (kg/ha) which was (-0.05). These two correlations are not significant.

Between pairs of agronomic variables, eleven (11) of the possible fifty-five (55) pairs of correlation are positively significant both at 5 and 1% level of significance. Twenty-two (22) pairs of correlation are not significant and twenty-two (22) pairs are negatively correlated. None of these negative correlations are however significant.

#### Multidimensional Analysis (MDA)

Multidimensional analysis is a statistical tool used to rank materials using indices generated from variables to which weights are attached. This was carried out by determining the character of interest. The characters were then weighted based on their essentiality. The final figure arrived at is called an index of preference denoted as  $\sum I$  which is used to rank and select entities. Therefore,

$$\sum I = K_1W_1 + K_2W_2 + \dots + K_nW_n$$

K is the item of dimension.

W is the weight of essentiality.

Agronomic characteristics of seeds used in the MDA analysis include seed weight (g/plant) which was weighted 3; harvest index (%) and plant height

at 12 WAT were weighted 2. Plant survival at 12 WAT, and dry inflorescence weight of fresh inflorescence weight (%) were weighted 1. The summation of indices obtained for the accessions

were ranked. Selections were made based on the rank. 5 out of the 27 accessions that have high seed yield were selected.

Table 4.2. Agronomic variables of 27 *Amaranthus* accessions used in this study.

s/n	<i>Amaranthus</i> accessions	No. of seeds that germinated	No. of plants at transplanting	No. of Plants at 4 WAT	No. of plants at 12WAT	Fresh inflorescence weight (g)	Dry inflorescence weight (g)	Dry weight of chaff (g)
1	Ames 1975 RRC 18D	32	19	15	11	3290	1309	1050
2	NHAc3	26	15	12	8	3425	975	680
3	NHA/ 39A P1576469	4	16	12	9	2140	514	326
4	Ames 2057 RRC 119	17	9	5	3	1730	477	310
5	Ames 2056 RRC 118	2	18	12	10	1400	435	380
6	NHA/34B P1576468	26	22	18	15	3970	845	590
7	UI/MO/Feb/010/008	47	25	22	13	5230	1287	1090
8	OG/EI/Feb/010/002	47	30	28	21	1140	496	300
9	NG/OE/Mar/09/010	28	16	14	12	1290	442	270
10	NG/OE/Mar/09/011	42	12	11	8	500	141	60
11	NG/TO/Jun/09/008	40	22	20	16	540	153	70
12	NG/06/102	17	14	10	7	520	174	108
13	NH/EI/Feb/010/006	42	51	45	42	2550	755	420
14	UI/OP/Mar/010/009	43	20	19	15	2130	552	342
15	OS/OE/Mar/010/007	37	33	28	25	2370	507	360
16	UI/MA/Feb/010/003	38	24	20	18	1590	494	320
17	OG/EI/Feb/010/001	32	42	38	38	2100	656	440
18	NH/ME/Feb/010/005	38	24	20	15	1270	462	283
19	NG/TO/Aug/09/007	11	35	18	7	890	256	160
20	NGB/06/105	41	38	34	31	2530	686	438
21	NG/MR/May/09/011	39	41	35	27	2340	402	280
22	NGB/06/104	46	45	41	32	5420	1605	1100
23	NG/OA/Aug/09/001	20	38	35	34	4110	1005	678
24	UI/MA/Feb/010/004	45	27	23	22	1780	230	130
25	NG/MR/May/09/013	32	52	45	42	2590	690	402
26	NGB/06/103	35	43	41	37	1620	630	350
27	NG/SA/Dec/07/0425	43	39	35	34	1890	652	440

WAT: weeks after transplanting.

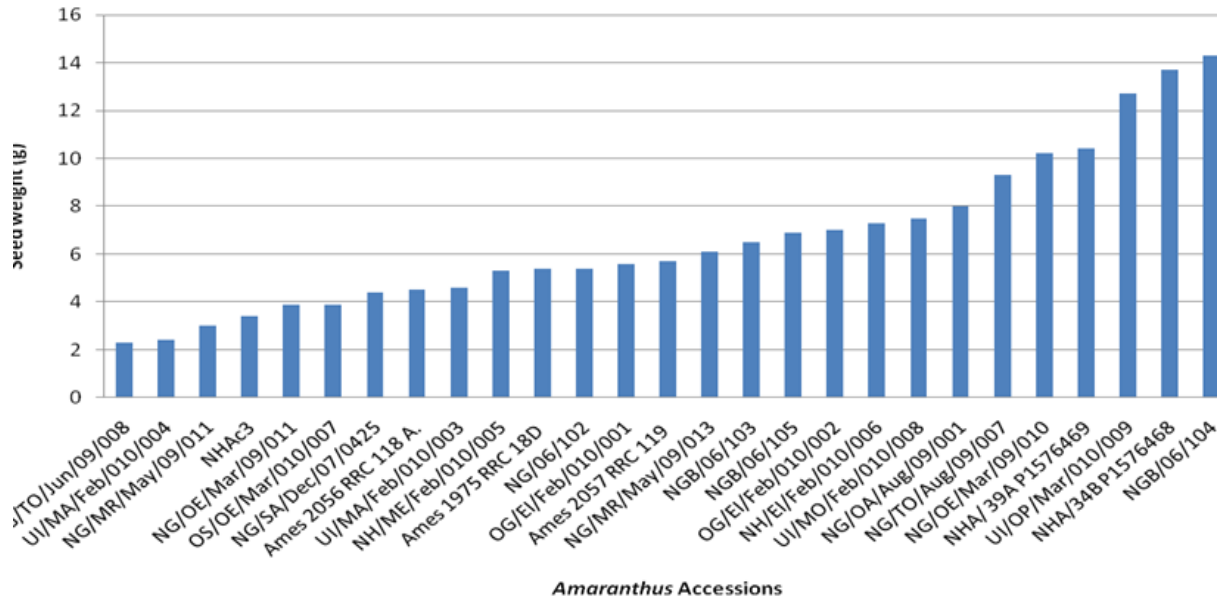


Figure 1: Mean seed weight (g/plant) of the 27 *Amaranthus* accessions used in this study.

Table 4.3: Agronomic variables of the 27 accessions of *Amaranthus* studied at various stages of production.

s/n	<i>Amaranthus</i> accessions	Germi-nation (%)	PS at 4 WAT (%)	PS at 12 WAT (%)	PH at 12 WAT (cm)	PH at flowering (cm)	Days to anthesis	LOI at 3 MAT (cm)	Infl. weight (g/plant)	DIW of FIW (%)	Harvest index (%)	seed weight (kg/ha)
1	Ames 1975 RRC 18D	64.0	78.9	57.9	113.1	70.5	58.0	44.1	299.1	0.4	4.5	205.2
2	NHAc3	52.0	80.0	53.3	93.4	48.6	62.0	45.8	428.1	0.3	20.0	129.2
3	NHA/ 39A P1576469	8.0	75.0	56.3	108.3	71.8	61.0	36.5	237.8	0.2	18.3	395.2
4	Ames 2057 RRC 119	34.0	55.6	33.3	94.1	47.7	56.0	46.0	425.7	0.3	31.9	216.6
5	Ames 2056 RRC 118	4.0	66.7	55.6	80.4	50.4	60.0	30.5	140.0	0.3	10.3	171.0
6	NHA/34B P1576468	52.0	81.8	68.2	107.2	59.7	55.0	42.2	264.7	0.2	24.3	520.6
7	UI/MO/Feb/010/008	94.0	88.0	59.1	202.7	148.9	72.0	51.0	402.3	0.2	7.5	285.0
8	OG/EI/Feb/010/002	94.0	93.3	70.0	118.0	82.1	52.0	35.0	54.3	0.4	29.4	266.0
9	NG/OE/Mar/09/010	56.0	87.5	75.0	124.0	85.4	55.0	38.0	107.5	0.3	27.6	387.6
10	NG/OE/Mar/09/011	84.0	91.7	66.7	100.5	70.4	58.0	30.1	62.5	0.3	22.0	148.2
11	NG/TO/Jan/09/008	80.0	90.9	72.7	93.5	59.8	62.0	32.9	33.8	0.3	22.2	87.4
12	NG/06/102	34.0	71.4	50.5	67.5	42.3	52.0	23.2	74.3	0.3	21.8	205.2
13	NH/EL/Feb/010/006	84.0	88.2	82.4	125.9	87.9	56.0	36.2	60.7	0.3	40.4	277.4
14	UI/OP/Mar/010/009	86.0	95.0	75.0	113.8	75.3	62.0	36.5	142.0	0.3	34.4	482.6
15	OS/OE/Mar/010/007	74.0	84.8	75.8	126.8	91.5	60.0	35.9	94.8	0.2	19.1	148.2
16	UI/MA/Feb/010/003	76.0	83.3	75.0	128.1	93.0	55.0	35.2	88.3	0.3	16.6	174.8
17	OG/EI/Feb/010/001	64.0	90.5	90.5	123.5	92.4	58.0	30.1	55.3	0.3	32.6	212.8
18	NH/ME/Feb/010/005	76.0	83.3	62.5	121.8	87.8	65.0	33.1	84.7	0.4	17.1	201.4
19	NG/TO/Aug/09/007	2.0	51.4	20.5	124.7	81.6	52.0	43.7	127.1	0.3	25.4	353.4
20	NGB/06/105	82.0	89.5	81.6	129.3	94.8	57.0	35.5	81.6	0.3	31.0	262.2
21	NG/MR/May/09/011	78.0	85.4	65.8	155.8	119.5	53.0	38.3	86.7	0.2	20.4	114.0
22	NGB/06/104	92.0	91.1	71.1	182.5	136.9	62.0	43.0	169.4	0.3	28.5	543.4

Table 4.3. Continued

s/n	<i>Amaranthus</i> accessions	Germination (%)	PS at 4 WAT (%)	PS at 12 WAT (%)	PH at 12 WAT (cm)	PH at flowering (cm)	Days to anthesis	LOI at 12 WAT (cm)	FIW (g/plant)	DIW of FIW (%)	Harvest index (%)	Seed weight (kg/ha)
23	NG/OA/Aug/09/001	40.0	92.1	89.5	151.5	106.5	65.0	44.0	120.9	0.2	27.1	304.0
24	UI/MA/Feb/010/004	90.0	85.2	81.5	105.0	71.2	60.0	34.0	80.9	0.1	22.6	91.2
25	NG/MR/May/09/013	64.0	86.5	80.8	139.6	94.5	60.0	44.8	61.7	0.3	37.2	231.8
26	NGB/06/103	70.0	95.3	86.0	109.2	75.2	56.0	33.0	43.8	0.4	38.2	247.0
27	NG/SA/Dec/07/0425	86.0	89.7	87.2	122.6	84.3	67.0	36.3	55.6	0.3	23.0	167.2
	Mean	63.70	83.41	68.29	120.84	82.59	58.93	37.59	143.83	0.29	24.2	6.7
	Minimum	2.0	51.4	20.5	67.5	42.3	52.0	23.20	33.75	0.1	4.5	2.3
	Maximum	94.0	95.3	90.5	202.7	148.9	72.0	51.00	428.13	0.4	40.4	14.3
	Standard Deviation	27.41	11.04	16.56	28.55	25.30	4.86	6.24	119.03	0.07	8.89	3.27
	C.V. (%)	43.03	13.23	24.25	23.62	30.63	8.23	16.60	90.50	24.14	36.73	48.81
	Standard Error	5.28	2.12	3.19	5.49	4.87	0.94	35.06	117.33	0.01	1.71	0.63

WAT = weeks after transplanting; RRC = Rodale Research Centre; PS = Plant survival; PH = Plant height; DIW = Dry Inflorescence weight; FIW = Fresh inflorescence weight; Infl. = inflorescence; LOI = Length of inflorescence; C.V. = Coefficient of Variation.

Table 4.4 Correlation matrix of the measured agronomic variables of 27 *Amaranthus* accessions

		B	C	D	E	F	G	H	I	J	K
A	Germination (%)	0.78**	0.60**	0.42*	0.47*	0.25	-0.02	-0.26	0.06	0.16	-0.12
B	PS at 4 WAT (%)		0.87**	0.36	0.43*	0.31	-0.16	-0.41	0.03	0.26	0.04
C	PS at 12 WAT (%)			0.24	0.32	0.24	-0.26	-0.54	-0.09	0.36	-0.05
D	PH at 12 WAT (cm)				0.98**	0.41*	0.57**	0.09	-0.22	-0.02	0.32
E	PH at flowering (cm)					0.37	0.39*	-0.08	-0.20	-0.01	0.24
F	Days to Anthesis						0.33	0.27	-0.21	-0.31	-0.03
G	LOI at 12 WAT (cm)							0.70**	-0.18	-0.1	0.31
H	Infl. Weight (g/plant)								-0.14	-0.38	0.19
I	DIW of FIW (%)									0.15	-0.01
J	Harvest index (%)										0.28
K	Seed weight (kg/ha)										

WAT = Weeks after transplanting; PS = Plant Survival; PH = Plant height; DAT = Days to Anthesis, LOI = Length of Inflorescence,

DIW = Dry inflorescence weight; FIW = Fresh inflorescence weight; Infl. = Inflorescence.

\* = Significant at 5% level; \*\* = Significant at 1% level.

Table 4.5. Multidimensional analysis of 27 accessions of *Amaranthus* used in this study with regard to their seed productivity.

Character	Seed weight (kg/ha)	Harvest index (%)	PH at 12 WAT (cm)	PS at 12WAT (%)	DIW of FIW (%)		
Relative weight	→ 3	2	2	1	1	∑I	Rank
NGB/06/104	3.00	1.41	1.80	0.79	0.75	7.75	1
UI/OP/Mar/010/009	2.66	1.70	1.12	0.83	0.75	7.06	2
NH/EI/Feb/010/006	1.57	2.00	1.24	0.91	0.75	6.47	3
NHA/34B P1576468	2.87	1.20	1.06	0.75	0.50	6.38	4
NG/OE/Mar/09/010	2.14	1.37	1.22	0.83	0.75	6.31	5
NGB/06/103	1.36	1.89	1.08	0.95	1.00	6.28	6
NG/MR/May/09/013	1.28	1.84	1.38	0.89	0.75	6.14	7

NG/OA/Aug/09/001	1.68	1.34	1.49	0.99	0.50	6.00	8
NGB/06/105	1.45	1.53	1.28	0.90	0.75	5.91	9
OG/EI/Feb/010/002	1.47	1.45	1.16	0.77	1.00	5.85	10
OG/EI/Feb/010/001	1.17	1.61	1.22	1.00	0.70	5.70	11
NG/TO/Aug/09/007	1.95	1.26	1.23	0.23	0.75	5.42	12
NHA/ 39A P1576469	2.18	0.91	1.07	0.62	0.50	5.28	13
UI/MO/Feb/010/008	1.57	0.37	2.00	0.65	0.50	5.09	14
NG/SA/Dec/07/0425	0.92	1.14	1.21	0.96	0.75	4.98	15
NH/ME/Feb/010/005	1.11	0.87	1.20	0.69	1.00	4.87	16
Ames 2057 RRC 119	1.20	1.58	0.93	0.37	0.75	4.83	17
UI/MA/Feb/010/003	0.97	0.82	1.26	0.83	0.75	4.63	18
NG/MR/May/09/011	0.63	1.01	1.54	0.73	0.50	4.41	19
OS/OE/May/010/007	0.82	0.94	1.25	0.84	0.50	4.35	20
NG/TO/Jun/09/008	0.67	1.10	0.92	0.80	0.75	4.24	21
NG/OE/Mar/09/011	0.82	0.99	0.99	0.74	0.75	4.29	22
NG/06/102	1.13	1.08	0.67	0.56	0.75	4.19	23
Ames 1975 RRC 18D	1.13	0.22	1.12	0.64	1.00	4.11	24
NHAc3	0.71	1.00	0.92	0.59	0.75	3.97	25
UI/MA/Feb/010/004	0.50	1.12	1.04	0.90	0.25	3.81	26
Ames 2056 RRC 118	0.94	0.51	0.79	0.62	0.75	3.61	27

PH = Plant height; PS = Plant survival; WAT = weeks after transplanting; DIW = Dry inflorescence weight; FIW = Fresh inflorescence weight,  $\sum I$  = Sum of indices.

#### IV. DISCUSSION

The ever increasing world population requires that more food be provided from the same or perhaps less land area to meet the attendant rise in food needs. It is often believed that the bulk of the increase in world population is concentrated in resource poor developing countries. Ironically, these regions produce less and less food while the developed country with not so much population increases production. Crop like *Amaranthus* provide a means of readily meeting these food needs in terms of protein and amino acids. *Amaranthus* species are probably the most widely occurring leafy vegetables in South Africa and Africa in general (Jansen van Rensburg *et al.*, 2004). Use of grain amaranth seed provides dietary diversity, a goal of an ever increasing number of people. Owing to the outstanding nutritional, industrial and pharmacological applications, international demand for this grain is increasing.

Most of the characters are not significantly correlated with each other but few of the correlation coefficients are significantly and positively correlated as to conclude that selection for one will influence another. Plant height at flowering

significantly correlated with percent plant survival at 4 WAT. This result is in accordance with plant population study of Guillen-Portal *et al.*, 1999 who found the effect of plant population (survival) on plant height to be subjected to environmental conditions, especially to soil water availability.

Plant height at 12 WAT and length of inflorescence at 12 WAT are significantly correlated. This was in relation to the findings of Ana Pospíšil *et al.* (2006) who recorded positive, very strong correlation between plant height and inflorescence length at 5% level of probability. Also, significant correlation was recorded between plant height at harvest and seed yield of grain amaranth, inflorescence length and seed yield respectively (Ana Pospíšil *et al.*, 2006). The result of this research does not show significant correlation between these variables. This may be due to the fact that grain yields vary widely and are dependent on site and genotype.

Several studies revealed only a moderate response (Guillen-Portal *et al.*, 1999) or even no response of grain yield to plant density (Myers, 1996). This was in relation to the negative correlation between percent plant survival at 12 WAT and seed weight (kg/ha). Henderson *et al.* (2000) stressed that yield

response of grain amaranth to plant density is influenced by environmental conditions, as known from other crops, e.g. Oilseed rape (Shrief et al., 1990). In general, harvest index of amaranth limits potential yield. It is low compared to other crops (Kaul et al., 2002). In this research work, there was a low positive correlation, between percent harvest index and seed weight (kg/ha). Different sowing dates and environmental conditions might be responsible for this. The high correlation coefficient between percent plant survival at 4 WAT and percent germination on one hand and percent plant survival at 12 WAT on the other hand shows the effective drought resistance of *Amaranthus* plant and that the seedling emergence rate of amaranth is crucial in establishing productive crops under field conditions (Putnam, 1990).

Five *Amaranthus* accessions from the twenty-seven evaluated could be selected based on the results of the Multidimensional Analysis (Table 4.5). They were selected because they performed better than the rest on the basis of the variables used which were, seed yield (g/plant), percent harvest index, plant height at 3 months after transplanting, percent survival at 3 months after transplanting, dry inflorescence weight expressed as percent of fresh inflorescence weight. These five accessions had the highest sum of indices and they are NGB/06/104, UI/OP/Mar/010/009, NH/EI/Feb/010/006, NHA/34B P1576468, and NG/OE/Mar/09/010 in descending order.

## V. SUMMARY AND CONCLUSIONS

This study was carried out to determine the agronomic variables that contribute to seed yield of the crop and to select the accessions that have high seed yield. One major problem encountered in this study is obtaining sufficient quantities of seeds to be planted and some weedy species were mixed with the accessions. Due to this reason, the accession numbers were reduced to 27 and there was uneven germination of the planted seeds which when transplanted to the field resulted to uneven replication. The 27 accessions were planted on different dates due to the unavailability of space; hence, planting was done in batches. Most of the inflorescence is green in colour which produces brown to black seeds which have low harvest indices when compared with red inflorescence which produces cream to gold colour seeds.

Moreover, diseases and pests infestation causes a great loss in the number of survived plant stands and seed quality which results in the low harvest indices exhibited by most of the accessions. Maintenance of the *Amaranthus* plot was done in accordance to the farmers' practices. Weeding was done at two, four, six and ten weeks after transplanting. Fertilizer (NPK 15-15-15) was applied at two weeks after transplanting so as to promote vegetative growth of the plant. Insecticide (cypermethrin) was applied to ward off lygus bug (*Lygus lineolaris*).

Although some of the characteristics assessed showed similarity, majority of them showed a great diversity. High level of diversity (variation) is important because it can be exploited to meet various uses, needs and desires of consumers and farmers. Research findings indicate that *Amaranthus* has various uses, and that there is no clear distinctions between the vegetable and grain type, it could be concluded that plant survival at harvest, plant height and harvest index would be quite good criteria for selection of *Amaranthus* accessions that will give high seed yield. However, a multidimensional analysis of the *Amaranthus* accessions used in this study reveal that to all intents and purposes of the various end users; NGB/06/104, UI/OP/Mar/010/009, NH/EI/Feb/010/006, NHA/34B P1576468 and NG/OE/Mar/09/010 are strictly selected for their seed yield.

## VI. RECOMMENDATIONS

Based on this study on amaranth seed production, the following recommendations are made.

1. There is need for researchers to serve as middle men between research institutes and local farmers in order to make improved seeds readily available for them.
2. There is need to embark on serious awareness and enlightenment programmes for the people on the enormous nutritive and dietary value of the crop.
3. There is need for the introduction of high yielding species through the research institutes of each state. This will arouse farmers' interest in the cultivation of the crop. Therefore, NGB/06/104, UI/OP/Mar/010/009, NH/EI/Feb/010/006, NHA/34B P1576468, and NG/OE/Mar/09/010 are recommended based on this study.

4. Grain Amaranth products exhibition is of paramount importance to let the people be informed that processing of the crop can take many forms and that it can be used in various ways.

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