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Phenotypic evaluation of heritability, agro-morphological and yield characters of sixteen amaranthus linn. Genotypes

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ABSTRACT

The field experiment was conducted to evaluate the heritability, genetic variance, agro-morphological and yield characters of Sixteen Amaranthus genotypes. The seeds of the sixteen (16) genotypes of Amaranthus evaluated in this study were; NG/AA/MAY/09/027, NG/AA/03/11/010, NG/AO/11/08/042, NG/AO/11/08/039, NG/SA/DEC/07/0423, NG/SA/DEC/07/0412, NGB01667, NGB01601, NGB01283, NGB01271, NGB01276, NGB01259, NGB01644, NGB01234, NGB01613 and NGB01662. The results showed that there were variability performances in growth and yield characters of Amaranthus genotypes. NG/AA/MAY/09/027 and NG/AO/11/08/039 had the best growth characters while NG/AO/11/08/042 had best yield performance compared to other genotypes. The stem length recorded the best heritability estimate of 95.5% while weight of dry leaf, weight of fresh and dry inflorescent had least (47.7%). The plant height had a positive significant correlation with number of leaf (r= 0.53), leaf width (r= 0.57), number of branches (r= 0.56) but a strong positive correlation with stem length (r= 0.97), stem girth (r= 0.75), number of inflorescent (r= 0.68), inflorescent length (0.64) and inflorescent width (r= 0.72). Prin. 1 accounted for the highest variation with proportion of 0.3376 and eigenvalue of 4.726919, while Prin. 14 was the least with proportion of 0.0003 and eigenvalue of 0.003826. Therefore, there could be genetic improvement of NG/AA/MAY/09/027 and NG/AO/11/08/039 genotypes for further improvement of Amaranthus.

Key words: *Agro-morphological; Amaranthus; Heritability; variance*

Introduction

The genus Amaranthus of the order Caryophillalales comprises of more than 60 species C4 dicotyledonous herbaceous plants. Amaranthus species are cultivated in Central and South America, Africa, and some parts of Asia as ornamentals, some are a source of highly nutritious pseudo-cereals and vegetables while others are notoriously weeds (Holm et al., 1997; Steckel, 2007). It has received attention due to its essential nutrients for the human diet (Tucker, 1986; Bressani et al., 1992). Amaranthus species are tolerant to infestation by herbivorous insects under field conditions, and can grow successfully under varied soil and agro-climatic conditions such as bright sunlight, high temperatures, and low moisture (Prakash and Pal, 1991; Brenner et al., 2010; Angel and Paulina, 2011). It can also tolerate a variety of unfavorable soil conditions such as high salinity, acidity, or alkalinity (Tucker, 1986). Besides other crops, cultivation of this vegetable will not only increase food production but also provide balanced nutrition, food security, health security and poverty alleviation (Buragohain et al., 2013).

Despite the perceived usefulness and untapped potentials of this vegetable, Amaranthus are underutilized making their potential economic value remaining "underexploited". It has also been reported that it has been neglected for many years by researchers, policy makers and funding agencies and thus currently threatened by extinction. Hence, improvement of this vegetable is highly needed to ensure maximum agronomic yield and high productivity of Amaranthus with a view to conserve the germplasm.

This study aimed at improving the production of Amaranthus spp for proper documentation of Amaranthus germplasm.

Materials And Method

Experimental site and Amaranthus Germplasm

This study was carried out at the Nursery Farm of the Department of Botany, University of Ibadan, Oyo state, Nigeria. The site lies between Latitude 7° 02’ 49″ and 7° 43′ 21″ N

longitude 3° 31′ 58″ and 4° 08′ 20″ E with an altitude of 150m in the valley at 275m above sea level at moderate annual rainfall of 1,205mm (Amanambu and Egbinola, 2013). The seeds of the sixteen Amaranthus spp. Genotypes were sourced from the National Centre for Genetic Resource and Biotechnology (NACGRAB), Moor plantation, Ibadan, Nigeria. The genotypes were NG/AA/MAY/09/027, NG/AA/03/11/010, NG/AO/11/08/042, NG/AO/11/08/039, NG/SA/DEC/07/0423, NG/SA/DEC/07/0412, NGB01667, NGB01601, NGB01283, NGB01271, NGB01276, NGB01259, NGB01644, NGB01234, NGB01613 and NGB01662

Experimental design, Plant spacing and Planting Method

The Experiment was a complete Randomized Design with the polythene bags properly spaced at a distance of 65cm between genotypes and 45cm within genotypes. The young shoots were transplanted in pairs in each labeled polythene bags replicated four times. The seeds were first planted in the nursery through broadcasting for three weeks before transplanting in pairs to the well-labeled experimental polythene bags. The cultivation was monitored and watered daily to resist drought.

Data Collection

After one week of transplanting, data taken on growth characters included plant height (cm), number of leaves, stem length (cm), stem girth (cm), and leaf area (cm^2). The plant height, stem length and leaf area were measured using a meter rule while stem girth was measured with a vernier caliper. Quantitative and qualitative data on flower characters were collected at maturity, this included number of inflorescence, inflorescence width (cm), inflorescence length (cm) and number of branches. The number of inflorescence and number of branches were done by counting, while inflorescence width and inflorescence length were determined by measurement using a metre rule. The inflorescence colour and plant color were also determined by observation. After harvesting, the biomass of fresh and dry inflorescence and leaves were determined for each of the genotype using weighing balance. Heritability and genetic variance was also determined.

Statistical Analysis

The data were subjected to Analysis of Variance (ANOVA) and difference in means was separated using DMRT at 95% probability level ($p<0.05$). The relationship among the quantitative and qualitative traits were established using Pearson correlation coefficient and Principal Component Analysis (PCA). In addition, Heritability, Phenotypic Coefficient of Variance (PCV), Genotypic Coefficient of Variance (GCV) were also determined.

Results

Qualitative traits in Amaranthus genotypes

The qualitative traits observed in genotypes of Amaranthus are shown in Table 1. Genotypes NG/AA/MAY/09/027, NG/AA/03/11/010, NG/AO/11/08/039, NGB01601, NGB01271, NGB01276, NGB01259, NGB01644, NGB01234 and NGB01662 had a plant and spike/inflorescence color of green while NG/AO/11/08/042, NG/SA/DEC/07/0423, NG/SA/DEC/07/0412, NGB01667, NGB01283 and NGB01613 had plant and spike/inflorescence color of green but with a shade of purple. The spike/inflorescence colors were observed to vary from green to green with a shade of purple. The grain colors were observed to be TAN which is a light-brown color across all the genotype.

Mean Square Variance of Growth Characters at different stages in Amaranthus genotypes

The result of the mean square variance of growth character for Amaranthus from Table 2 shows that the genotype and weeks produced highly significant ($P<0.01$) effect on Plant height, Number of leaves, Stem length, Stem girth and Leaf width but non-significant on Leaf length for both genotype and week.

Mean Square Variance of Yield Characters at different stages in Amaranthus genotypes

The result of the mean square variance of yield characters in Table 3 shows that the genotype and weeks produced highly significant effect ($P<0.01$) effect on Number of Inflorescence, Inflorescence length, Inflorescence width, Number of branches, Fresh leaf biomass, Weight of dry leaf, Weight of fresh inflorescent and Weight of dry inflorescent.

Genotypic Effect of Growth Characters in Amaranthus genotypes

The result of the mean performance of genotypic effect on growth character of Amaranthus reveals significant ($P < 0.01$) effect on Amaranthus genotypes as shown in Table 4. NG/AA/MAY/09/027 was significantly higher for Plant height and

Stem length compared to other genotypes. Also, leaf width produced significant effect for NGB01271 while Stem girth and Leaf length were significantly higher for NG/AO/11/08/039 but different from other genotypes. NGB01644 was significantly higher for Number of leaves than other genotypes.

Genotypic Effect of Yield Characters in Amaranthus genotypes

The result in Table 5 shows that the genotypic effect of Amaranthus yield related character was significant at $P < 0.05$. NG/SA/DEC/07/0412 was significantly higher for Number of inflorescence and weight of fresh inflorescent yield compared to other genotypes. Also, Inflorescence length was higher for NG/AO/11/08/039 while Inflorescence width and Fresh leaf biomass were significantly higher for NG/AO/11/08/042 but different from other genotypes. NGB01601 had higher Number of branches than other genotypes while NGB01667 is significant for weight of dry leaf biomass and weight of dry inflorescent.

Heritability and Genotypic variance of Growth and Yield traits of Amaranthus genotype

The result of the component of variance for growth and yield traits in Amaranthus shown in Table 6 reveals that the phenotypic variance of both growth and yield characters were higher than the genotypic variance in all the characters evaluated. The values for the phenotypic and genotypic variance were highest at Number of leaves but least at weight of dry leaf. The stem length recorded the best heritability estimate of 95.5% while weight of dry leaf, weight of fresh and dry inflorescent had least (47.7%).

Principal Components Analysis (PCA) of Growth and Yield Characters of Genotypes of Amaranthus spp

The result from Table 7 delineates the Amaranthus genotype into fourteen principal component axes; Prin. 1, Prin. 2, Prin. 3, Prin. 4, Prin. 5, Prin. 6, Prin. 7, Prin. 8, Prin. 9, Prin. 10, Prin. 11, Prin. 12, Prin. 13 and Prin. 14. Prin. 1 which constituted the highest accounted for 0.3376 of the total proportion with eigenvalue of 4.726919, while Prin. 14 was the least with proportion of 0.0003 and eigenvalue of 0.003826. Weight of dry leaf from Prin. 1 had the highest eigen vector of 0.397389 while Number of leaves was the least with (-.079281). Also Prin. 2 produced the highest eigen vector for Leaf length at 0.380452 while weight of fresh leaf biomass had the least at 0.166918. Prin. 3 produced the highest eigen vector at 0.588319 for number of inflorescent while Leaf length produced the least at (-.007292). Prin. 4 produced the highest eigen vector at 0.618086 for Number of branches while Inflorescent length had the least at (-.020581). Prin. 5 produced the highest eigen vector at 0.481273 for Plant height while weight of fresh leaf biomass had the least at (-.013204). Prin. 6 produced the highest eigen vector at 0.623473 for Number of leaves while Number of Inflorescent had the least at (-.023325). Prin. 7 produced the highest eigen vector at 0.470258 for leaf length while Weight of fresh leaf biomass had the least at (-.009478). Prin. 8 produced the highest eigen vector at 0.428765 for number of inflorescent while Weight of fresh leaf had the least at (-.006583). Prin. 9 produced the highest eigen vector at 0.669205 for inflorescent width while Weight of fresh inflorescent biomass had the least at (-.042782). Prin. 10 produced the highest eigen vector at 0.703826 for Leaf width while Plant height has the least at (-.135051). Prin. 11 produced the highest eigen vector at 0.805744 for Weight of fresh leaf biomass while leaf length has the least at (-.060650). Prin. 12 produced the highest eigen vector at 0.399671 for Weight of dry leaf biomass while leaf length has the least at (-.005104). Prin. 13 produced the highest eigen vector at 0.603020 for plant height while number of Branches has the least at (-.021695). Prin. 14 produced the highest eigen vector at 0.702998 for Weight of dry inflorescent biomass while Stem length has the least at (-.001237)

Correlation Co-efficient among Characters in Genotype of Amaranthus spp

The correlation result is shown in Table 8. The plant height had a positive significant correlation with Number of leaf (r= 0.5331), Leaf width (r= 0.5678), Number of branches (r= 0.5567) but a strong positive correlation with Stem length (r= 0.9746), Stem girth (r= 0.7485), Number of inflorescent (r= 0.6840), Inflorescent length (0.6420), Inflorescent width (r= 0.7217) and Week (r= 0.8919). However, Number of leaf had a positive correlation with Stem length (r= 0.5748), Stem girth (r= 0.5755), Number of branches (r= 0.5712) and Week (r= 0.5257). In addition, Stem length showed a strong positive correlation with Stem girth (r= 0.7909), Leaf width (r= 0.6090), Number of inflorescent (r= 0.6464), Inflorescent width (r= 0.6752), and Week (r= 0.8741) but a positive correlation with Inflorescent length (0.5913) and Number of branches (r= 0.5391). Moreover, Stem girth had a strong positive correlation with Leaf width (r= 0.6603) and Week (r= 0.6648). Leaf length had a strong positive correlation with Leaf width (r= 0.6210). Number of inflorescent had a strong positive correlation with Inflorescent length (r= 0.7503), Inflorescent width (r= 0.8671), Number of branches (r= 0.6351) and Week (r= 0.7279). Inflorescent length had a strong positive correlation with Inflorescent width (r= 0.7537), Number of branches (r= 0.7012), Weight of fresh leaf (r= 0.7165), Weight of dry leaf (r= 0.6918), Weight of fresh inflorescent (r= 0.6964), Weight of dry inflorescent (r= 0.6765) and Week (r= 0.7595). Inflorescent width had a strong positive correlation with Week (r= 0.6756) and a positive correlation with Number of branches (r= 0.5449). Number of branches had a strong positive correlation with Week (r= 0.6756) and a positive correlation with Weight of fresh leaf (r= 0.5296). Weight of fresh leaf had a strong positive correlation with Weight of dry leaf (r= 0.8973), Weight of fresh inflorescent (r= 0.8856), Weight of dry inflorescent (r= 0.8722) and a positive correlation with Week (r= 0.5175). Weight of dry leaf had a strong positive correlation with Weight of fresh inflorescent (r= 0.9210), Weight of dry inflorescent (r= 0.9940) and a positive correlation with Week (r= 0.5271). Weight of fresh inflorescent had a strong positive correlation with Weight of dry inflorescent (r= 0.9321) and a positive correlation with Week (r= 0.5097). While Weight of dry inflorescent had a positive correlation with Week (r= 0.5208)

Dendogram showing the relationship of Yield Characters among the Amaranthus Genotypes

The dendogram showing the relationship of Yield Characters among the Amaranthus Genotypes is shown in figure 1. There are two major clusters sub-divided into four (4) groups. Genotype NG/SA/DEC/07/0423 and NGBO1271 is closely related but different from genotype NGB01613 while genotype NGB01667 and NGB01283 is similar than genotype NGB01276. Also, genotype NGB01259 and NGB01644 are closely related compared to genotype NGB01662. Again, genotype NG/AA/03/11/010 and NG/AA/MAY/09/027 are closely related than genotype NGB01234 while genotype NG/AO/11/08/042 and NG/SA/DEC/07/0412 are similar as also observed in genotype NG/AO/11/08/039 and NGB01601.

Dendogram showing the relationship of Growth Characters among the Amaranthus Genotypes

The relationship of Growth Characters among the Amaranthus Genotypes is depicted in the dendogram as shown in figure 2. There are three major clusters sub-divided into five (5) groups. Genotype NG/AO/11/08/042 and NG/SA/DEC/07/0412 are similar compared to genotype NG/AA/MAY/09/027 while Genotype NGB01667 and NGB01271 are similar but different from NG/SA/DEC/07/0423 and NGB01283. Also, genotype NGB01276 and NGB01613 are closely related compared to genotype NGB01601. Again, Genotype NG/AO/11/08/039 and NGB01234 are similar but different from genotype NGB01259 and NGB01644 while Genotype NG/AA/03/11/010 and NGB01662 are similar as seen in figure 2

Discussions

The findings from this study showed that there are variations in the performance of growth and yield characters studied among the Amaranthus genotypes. This is in accordance with the reports of Nwangburuka et al. (2012) and Olawuyi et al., (2014) who considered genetic variability as essential in crop breeding. The genotypic effect also had significant expression on the traits evaluated in Amaranthus. Variability in performance of genotypes also affected the growth performance of Amaranthus. The variations shown by the characters were due to high genetic diversity, differences of growing type, and differences on the type of adaptation (Kulakow, 1987; Mucjia and Jacobsen, 2003).

The best performance of growth and yield characters exhibited by NG/AA/MAY/09/027, NG/AO/11/08/039 and NG/AO/11/08/042 genotypes could be due to genetic variation of these genotypes. Selections based on this characters and the genetic diversity inherent in the plants could thus improve productivity considerably. These performances shown by Amaranthus also suggest hybridization breeding procedure for crop improvement with desired traits in the parents line.

The findings from correlation coefficient shows that the characters were mostly positively related as similarly observed by Olawuyi et al. (2012). The correlation between the characters implies that selection based on plant height will favour all growth and yield characters. This will enhance the rate of productivity and yield.

Prin 1 accounted for the highest variation as previously observed by Olowe et al. (2013) and Olawuyi et al. (2015). The results of the Principal components analysis reveals the pattern of variation among the characters studied and the characters that accounted most for variation within a group of entries (Ogunbodede, 1997; Aremu et al., 2007). It implies that the Principal Component Analysis (PCA) can be quantified from the contribution of the different variable to each principal component as revealed by the eigen vector (Lezzoni and Pritts, 1991).

This phenotypic expressions might be due to environmental influences; exacerbating this problem is the presence of considerable morphological variation within cultivated populations (Sauer, 1967; Espitia, 1992). This shows that their genotypes and species genetic make-up played a huge role in the phenotypes expressed in this studies.

The phenotypic variance of both growth and yield characters were higher than the genotypic variance in all the characters studied. Heritability of growth traits were higher than yield traits in Amaranthus genotypes. This shows that the proportion of genotypic effect to phenotypic effect was higher at growth than maturity. This conforms to the report of Palaniappan et al. (1999) who observed an improvement in general crop performance. This supported the findings of Chadha and Paul, (1984), Gautam and Srinivas, (1992); Prasad et al. (2004); Singh and Kumar (2005); and Babu and Patil, (2005); who reported high heritability and genetic advance for yield characters for Solanum melongena.

Conclusion And Recommendation

The variations in the genotypes could be sufficient basis for crop improvement. NG/AA/MAY/09/027, NG/AO/11/08/039 and NG/AO/11/08/042 are promising genotypes that could be selected and explored for future breeding in improvement of Amaranthus vegetable. This will further enhance proper documentation and conservation of Amaranthus germplasm.

Table 1 Qualitative traits in Amaranthus genotypes

S/N	GENOTYPES	PLANT COLOR	INFLORESCENCE COLOUR	GRAIN COLOR
1	NG/AA/MAY/09/027	GREEN	GREEN	TAN
2	NG/AA/03/11/010	GREEN	GREEN	TAN
3	NG/AO/11/08/042	GREEN WITH A SHADE OF PURPLE	GREEN WITH SOME PURPLE	TAN
4	NG/AO/11/08/039	GREEN	GREEN	TAN
5	NG/SA/DEC/07/0423	GREEN WITH A SHADE OF PURPLE	GREEN	TAN
6	NG/SA/DEC/07/0412	GREEN WITH A SHADE OF PURPLE	PURPLE	TAN
7	NGB01667	GREEN WITH A SHADE OF PURPLE	GREEN WITH SOME PURPLE	TAN
8	NGB01601	GREEN	GREEN	TAN
9	NGB01283	GREEN WITH A SHADE OF PURPLE	GREEN	TAN
10	NGB01271	GREEN	GREEN	TAN
11	NGB01276	GREEN	GREEN	TAN
12	NGB01259	GREEN	GREEN	TAN
13	NGB01644	GREEN	GREEN	TAN
14	NGB01234	GREEN	GREEN	TAN
15	NGB01613	GREEN WITH A SHADE OF PURPLE	GREEN WITH SOME PURPLE	TAN
16	NGB01662	GREEN	GREEN	TAN

Table 2. Mean Square Variance of Growth Characters at different stages in Amaranthus genotypes

Source of variation	Df	Plant height	Number of leaves	Stem length	Stem girth	Leaf length	Leaf width
Genotype	15	5388.43***	9750.21***	3929.57***	0.69***	130.70^{ns}	28.79***
Weeks	8	85011.33***	1480897***	50962.01***	2.53***	200.01^{ns}	43.57***
Replicates	3	3.97	4.14	2.67	0.03	1.08	0.17
Model	26	29266.49	10182.21	17947.99	1.18	137.07	30.04
Error	549	100.28	267.14	46.09	0.02	3.18	0.60
Corrected total	575						

* = Significant at P<0.05, ** = highly significant at P<0.01, *** = highly significant at P<0.001, ns = non-significant, Df = degree of freedom

Table 3. Mean Square Variance of Yield Characters at different stages in Amaranthus genotypes

Source of variation	Df	Number of Inflorescence	Inflorescence length	Inflorescence width	Number of branches	Fresh leaf biomass	Weight of dry leaf biomass	Weight of fresh inflorescent	Weight of dry inflorescent
Genotype	15	676.76***	317.62***	31.28***	72.69***	4.37***	0.44***	55.02***	10.65***
Weeks	8	13579.17***	12084.07***	718.93***	793.67***	614.38***	92.06***	6001.86***	1691.68***
Replicate	3	216.58^{ns}	14.14^{ns}	6.21^{ns}	8.05^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}
Model	26	4593.63	3903.05	239.97	287.07	191.56	28.58	1878.47	526.66
Error	549	116.32	44.87	4.52	5.95	0.96	0.09	12.03	
Corrected total	575								

* = Significant at P<0.05, ** = highly significant at P<0.01, *** = highly significant at P<0.001, ns = non-significant, Df = degree of freedom

Table 4 Genotypic Effect of Growth Characters in Amaranthus genotypes

Genotype	Plant height (cm)	Number of leaves	Stem length (cm)	Stem girth (cm)	Leaf length (cm)	Leaf width (cm)
NG/AA/MAY/09/027	98.64^{a}	37.28^{efg}	87.31^{a}	1.21^{b}	15.74^{e}	7.49^{de}
NG/AA/03/11/010	51.70^{f}	23.61^{i}	41.48^{i}	0.69^{i}	12.13^{g}	4.83^{j}
NG/AO/11/08/042	88.59^{bc}	48.14^{d}	72.68^{cd}	1.11^{def}	16.36^{cde}	7.11^{fg}
NG/AO/11/08/039	78.09^{d}	60.92^{bc}	68.77^{ef}	1.33^{a}	21.03^{a}	7.89^{bc}
NG/SA/DEC/07/0423	85.12^{c}	32.28^{gh}	67.09^{ef}	1.22^{b}	18.29^{b}	8.11^{b}
NG/SA/DEC/07/0412	91.69^{b}	44.86^{de}	78.09^{b}	1.08^{efg}	18.12^{b}	7.57^{cde}
NGB01667	85.45^{c}	29.33^{ghi}	73.16^{c}	1.14^{cde}	16.70^{cde}	7.98^{b}
NGB01601	73.85^{de}	42.00^{def}	62.49^{g}	1.11^{def}	17.29^{c}	7.84^{bcd}
NGB01283	83.85^{c}	22.81^{i}	69.67^{cde}	1.10def	14.73^{f}	7.25^{ef}
NGB01271	85.29^{c}	27.89^{hi}	69.76^{cde}	1.14^{cde}	16.07^{de}	8.47^{a}
NGB01276	72.64^{e}	34.97^{fgh}	62.63^{g}	1.02^{gh}	16.28^{de}	7.07^{fg}
NGB01259	72.93^{de}	56.56^{c}	62.28^{g}	1.07^{fg}	16.42^{cde}	6.49^{hi}
NGB01644	77.94^{d}	80.83^{a}	69.25^{def}	1.19^{bc}	16.10^{de}	6.81^{gh}
NGB01234	78.03^{d}	66.33^{b}	69.99^{cde}	1.17$_{cde}$	16.68^{cde}	6.71^{gh}
NGB01613	75.15^{de}	32.39^{gh}	65.88^{f}	1.06^{fg}	16.74^{cd}	6.72^{gh}
NGB01662	54.41^{f}	37.11^{efg}	50.09^{h}	0.99^{h}	14.46^{f}	6.14^{i}

Mean with the same letter in the same column are not significantly at P ≥ 0.05 according to Duncan Multiple Range Test (DMRT)

Table 5 Genotypic Effect of Yield Characters in Amaranthus genotypes

Genotype	Number of inflorescence	Inflorescence length (cm)	Inflorescence width (cm)	Number of branches	Fresh leaf biomass (g)	dry leaf biomass (g)	Weight of fresh inflorescent (g)	Weight of Dry inflorescent (g)
NG/AA/MAY/09/027	8.14^{d}	4.50^{e}	1.53^{g}	3.06^{bcde}	1.38^{abc}	0.36^{de}	2.33^{cde}	1.51^{bcd}
NG/AA/03/11/010	9.19^{cd}	5.51^{e}	2.26^{efg}	1.64^{fg}	0.73^{d}	0.16^{f}	1.69^{e}	0.67^{e}
NG/AO/11/08/042	20.31^{a}	11.24^{bc}	4.74^{a}	3.11^{bcde}	1.83^{a}	0.37^{de}	3.83^{bcd}	1.51^{cde}
NG/AO/11/08/039	20.69^{a}	15.61^{a}	4.14^{abc}	4.08^{ab}	1.56^{ab}	0.43^{abcd}	3.98^{abc}	1.81^{abcd}
NG/SA/DEC/07/0423	13.31^{bcd}	9.76^{dc}	3.78^{abcd}	1.06^{gh}	0.89^{cd}	0.56^{ab}	3.29^{cde}	2.52^{a}
NG/SA/DEC/07/0412	21.06^{a}	12.65^{abc}	4.43^{ab}	2.72^{cdef}	0.87^{cd}	0.43^{abcd}	5.76^{a}	2.15^{abc}
NGB01667	12.08^{bcd}	10.44^{c}	3.96^{abc}	0.39^{h}	0.65^{d}	0.58^{a}	4.00^{abc}	2.58^{a}
NGB01601	19.97^{a}	13.92^{ab}	3.19^{cde}	5.00^{a}	1.37^{abc}	0.36^{de}	2.99^{cde}	1.02^{de}
NGB01283	12.83^{bcd}	11.35^{bc}	3.81^{abcd}	0.00^{h}	0.73^{d}	0.44^{abcd}	2.96^{cde}	2.14^{abc}
NGB01271	14.00^{bcd}	9.76^{dc}	3.41^{bcd}	1.19^{gh}	1.02^{cd}	0.54^{abc}	2.61^{cde}	2.31^{ab}
NGB01276	15.86^{ab}	10.25^{c}	3.14^{cde}	2.50^{def}	1.13^{bcd}	0.24^{ef}	2.67^{cde}	1.01^{de}
NGB01259	12.50^{bcd}	$9.36d^{c}$	2.80^{def}	3.97^{abc}	1.11^{bcd}	0.40^{bcde}	2.07^{de}	1.66^{bcd}
NGB01644	11.47^{bcd}	$9.19d^{c}$	2.77^{def}	3.64^{bcd}	0.61^{d}	0.34^{de}	4.19^{abc}	1.63^{bcd}
NGB01234	8.14^{d}	$6.50d^{e}$	1.78^{fg}	3.83^{abc}	1.02^{cd}	0.38^{cde}	5.49^{ab}	1.79^{abcd}
NGB01613	14.14^{bc}	$9.34d^{c}$	3.18^{cde}	2.03^{efg}	0.88^{cd}	0.33^{de}	1.94^{de}	1.35^{cde}
NGB01662	12.33^{bcd}	$6.59d^{e}$	2.23^{efg}	2.92^{bcde}	0.75^{d}	0.46^{abcd}	1.84^{e}	1.76^{abcd}

Mean with the same letter in the same column are not significantly at P ≥ 0.05 according to Duncan Multiple Range Test (DMRT)

Table 6 Heritability and Genotypic variance of Growth and Yield traits of Amaranthus genotype

SOURCE OF VARIATION	GENOTYPIC VARIANCE (σ^2g)	PHENOTYPIC VARIANCE (σ^2p)	HERITABILITY (%)
PLANT HEIGHT	1322.037	1422.320	92.9
NUMBER OF LEAF	2370.768	2637.906	89.9
STEM LENGTH	970.868	1016.967	95.5
STEM GIRTH	0.169	0.184	91.8
LEAF LENGTH	31.879	35.064	90.9
LEAF WIDTH	7.048	7.649	92.1
NUMBER OF INFLORESCENT	140.111	256.426	54.6
INFLORESCENT LENGTH	68.186	113.060	60.3
INFLORESCENT WIDTH	6.689	11.207	59.7
NUMBER OF BRANCHES	16.683	22.638	73.7
WEIGHT OF FRESH LEAF	0.854	1.809	89.4
WEIGHT OF DRY LEAF	0.085	0.181	47.2
WET YELD	10.749	22.776	47.2
WEIGHT OF DRY INFLORESCENT	2.081	4.409	47.2

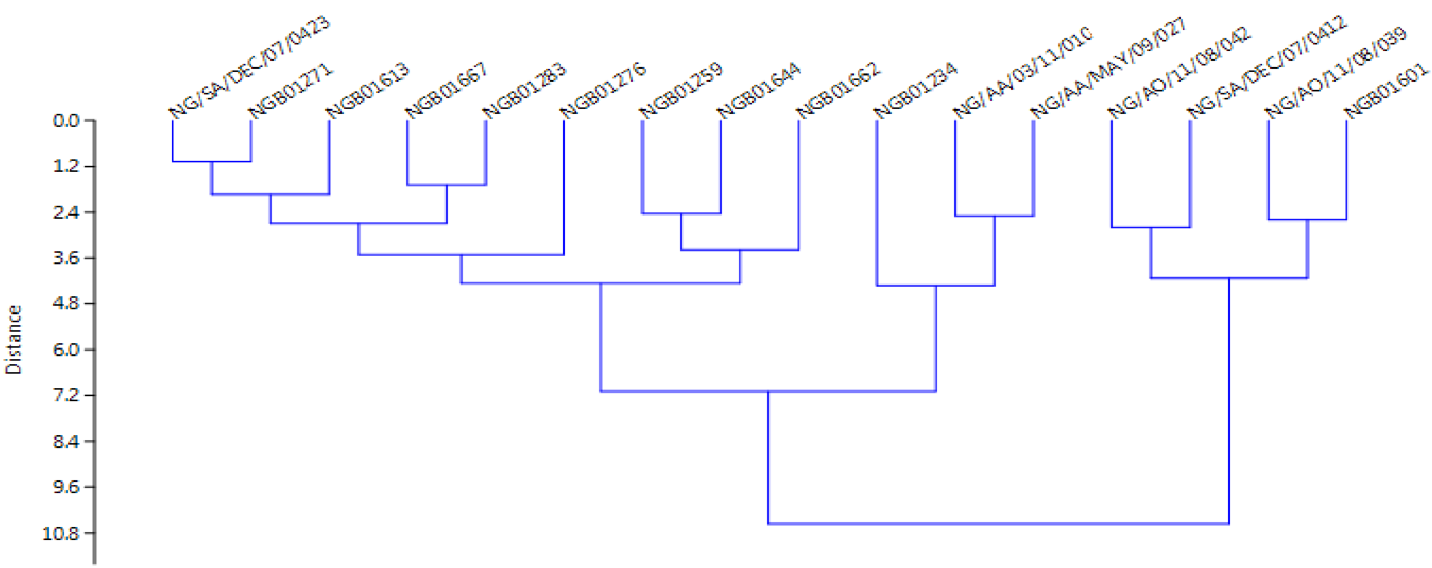

Figure 1: Showing the relationship of Yield Characters among the Amaranthus Genotypes

Table 7 Principal Components Analysis (PCA) of Growth and Yield Characters of Genotypes of Amaranthus spp

CHARACTERS	Prin. 1	Prin. 2	Prin. 3	Prin. 4	Prin. 5	Prin. 6	Prin. 7	Prin. 8	Prin. 9	Prin. 10	Prin. 11	Prin. 12	Prin. 13	Prin. 14
PH	-.2519	0.3319	-.1109	-.1746	0.4813	-.2049	0.2745	-.1748	0.0430	-.1351	-.1294	-.0597	0.6030	-.0037
NL	-.0793	0.2423	-.0578	0.6169	0.2308	0.6235	-.0817	-.0711	-.1436	0.1706	0.1232	0.1214	0.1327	0.0072
SL	-.2922	0.3213	-.1811	-.0807	0.4099	-.1621	0.0811	-.0191	-.0523	0.0349	0.1219	0.1493	-.7278	-.0012
SG	-.1766	0.3794	-.2224	0.1167	-.1888	-.1767	-.7272	0.1763	0.1235	-.2963	-.1586	-.0441	0.0695	-.0063
LL	-.1506	0.3805	-.0073	0.0298	-.5711	0.2148	0.4703	-.1988	0.0316	-.4241	-.0607	-.0051	-.1188	-.0039
LB	-.2769	0.3092	-.0828	-.2519	-.3689	-.0291	0.0325	0.1959	-.0882	0.7038	0.2215	-.0612	0.1579	0.0095
NI	0.0187	0.2209	0.5883	-.0789	0.0800	-.0233	-.0095	0.4288	-.6027	-.2084	0.0034	0.0117	0.0266	0.0059
IL	0.2836	0.2651	0.2814	-.0206	-.0707	-.1949	-.2414	-.7397	-.2199	0.2231	-.1318	0.0521	-.0534	0.0115
IB	0.0173	0.2181	0.5409	-.2649	0.1395	0.3079	-.1209	0.0414	0.6692	0.0290	0.0841	0.0005	-.0529	-.0106
NB	0.1374	0.1679	0.2182	0.6181	-.0439	-.5166	0.2730	0.2163	0.2964	0.1835	-.1041	-.0144	-.0217	0.0106
WEIGHT OF FRESH LEAF	0.3964	0.1669	-.1371	-.0233	-.0132	-.1627	-.0099	-.0066	0.0341	-.2185	0.8057	0.1976	0.1415	0.1083
WEIGHT OF DRY LEAF	0.3974	0.1883	-.1959	-.1415	0.0103	0.0813	0.0702	0.1814	0.0107	0.0716	-.2432	0.3997	0.0239	-.6921
WEIGHT OF FRESH INFLORESCENT	0.3841	0.2196	-.1719	-.0271	0.1214	0.1177	0.0467	0.0682	-.0428	0.0203	0.0147	-.8392	-.1314	-.1201
WEIGHT OF DRY INFLORESCENT	0.3895	0.1929	-.2071	-.1554	0.0372	0.1332	0.0747	0.1947	0.0163	0.0865	-.3626	0.2180	-.0222	0.7029
Eigenvalue	4.7269	2.9902	1.9577	1.3231	0.8779	0.5563	0.4175	0.3249	0.2511	0.2197	0.1618	0.1054	0.0837	0.0038
Proportion	0.3376	0.2136	0.1398	0.0945	0.0627	0.0397	0.0298	0.0232	0.0179	0.0157	0.0116	0.0075	0.0060	0.0003

PH: Plant Height, NL: Number of leaves, SL: Stem Length, SG: Stem Girth, LL: Leaf Length, LB: Leaf Width, NI: Number of Inflorescent, IL: Inflorescent Length, IB: Inflorescent Width, NB: Number of Branches

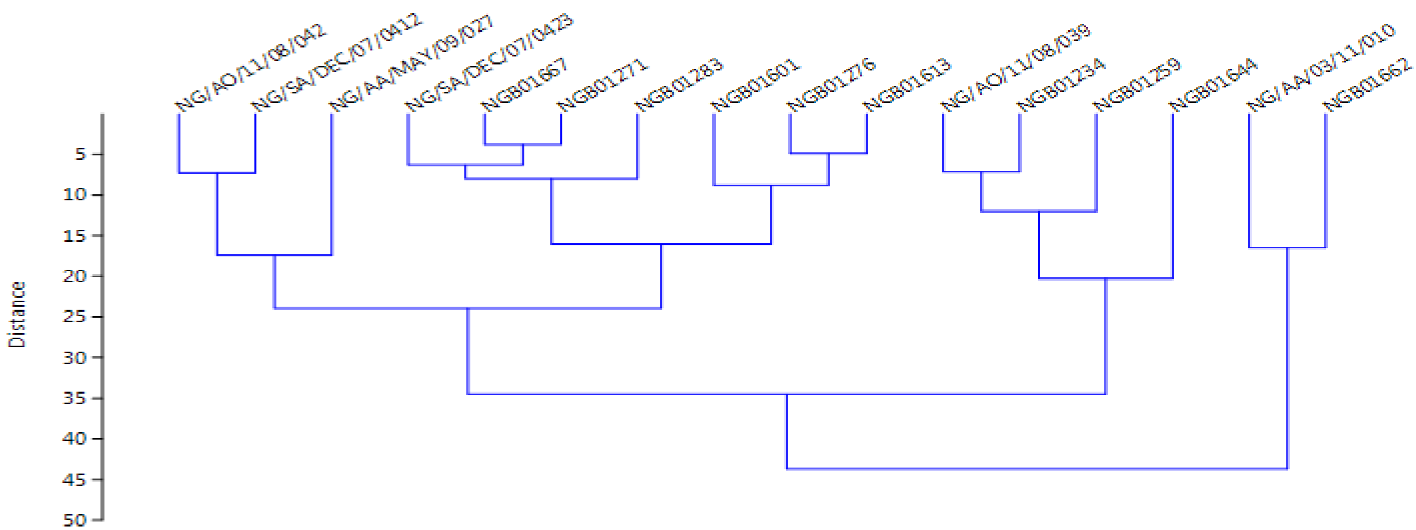

Figure 2: Showing the relationship of Growth Characters among the Amaranthus Genotypes

Table 8.Correlation Coefficient among Characters in Genotype of Amaranthus spp

	PH	NL	SL	SG	LL	LB	NI	IL	IB	NB	WEIGHT OF FRESH LEAF	WEIGHT OF DRY LEAF	WEIGHT OF FRESH INFLORESCENT	WEIGHT OF DRY INFLORESCENT	Genotype	Week
PH																
NL	0.5331*															
SL	0.9746**	0.5748*														
SG	0.7485**	0.5755*	0.7909**													
LL	0.2207	0.2627	0.2362	0.4259												
LB	0.5678*	0.2423	0.6090**	0.6603**	0.6210**											
NI	0.6840**	0.3955	0.6464**	0.4721	0.1630	0.3416										
IL	0.6420**	0.3929	0.5913*	0.4965	0.1064	0.1994	0.7503**									
IB	0.7217**	0.3809	0.6752**	0.4808	0.1565	0.3681	0.8671**	0.7537**								
NB	0.5567*	0.5712*	0.5391*	0.4837	0.1152	0.1129	0.6351**	0.7012**	0.5449*							
WEIGHT OF FRESH LEAF	0.3688	0.2085	0.3267	0.3000	-.0442	-.0585	0.3766	0.7165**	0.3871	0.5296*						
WEIGHT OF DRY LEAF	0.3889	0.2215	0.3443	0.3027	-.0254	-.0020	0.3653	0.6918**	0.4023	0.4548	0.8973**					
WEIGHT OF FRESH INFLORESCENT	0.3957	0.3137	0.3535	0.3116	-.0224	-.0342	0.3740	0.6964**	0.4008	0.4927	0.8856**	0.9210**				
WEIGHT OF DRY INFLORESCENT	0.3928	0.2279	0.3480	0.3029	-.0229	0.0035	0.3561	0.6765**	0.4017	0.4320	0.8722**	0.9940**	0.9321**			
Genotype	-.1166	0.1491	-.0882	-.0121	-.0595	-.1119	-.0466	-.0221	-.0641	0.0371	-.0475	0.0058	-.0083	0.0036		
Week	0.8919**	0.5257*	0.8741**	0.6648**	0.0642	0.3816	0.7279**	0.7595**	0.7530**	0.6756**	0.5175*	0.5271*	0.5097*	0.5208*	0.0000	
Replicate	-.0033	-.0035	-.0023	-.0207	-.0155	-.0032	0.0548	-.0133	0.0174	-.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

* = significant at P< 0.0 5, ** = highly Significant at P< 0.01, ns = non-significant.

PH: Plant Height, NL: Number of leaves, SL: Stem Length, SG: Stem Girth, LL: Leaf Length, LB: Leaf Width, NI: Number of Inflorescent, IL: Inflorescent Length, IB: Inflorescent Width, NB: Number of Branches

Plate 1: Showing the best genotype for growth character

Plate 2: Showing the best yield attribute

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