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VARIATION IN MORPHOLOGICAL CHARACTERS OF AMARANTHUS (*AMARANTHUS SPP*) GENOTYPES IN MAKURDI, NIGERIA

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Abstract
Nine genotypes *of Amaranthus viz Local Benue, AM-1, AM-4, AM-5, AM-7, AM-10, AM-13, Grain Amaranthus and Large green were used for the estimation of morphological characters of Amaranthus, at the Teaching and Research Farm of Joseph Sarwuan Tarka University, Makurdi during the 2021 cropping season. The experiment was laid out in a Randomized Complete Block Design, with three replications. The results revealed a wide morphological variation among the characters of Amaranthus* genotypes studied. *Data collected for analysis from each individual plot are: plant height, number of leaves, leaf area, chorophyll content, days to first and 50 % flowering and leaf area at 50 % flowering. Furthermore, results showed that AM-7 was the tallest and had highest numbers of leaves (14.33and 32.67 respectively) with wide leave area, and high chlorophyll content (32.43). Furthermore, Grain Amaranth genotype also had tall plants and recorded considerable number of leaves and wide leaf area (33.90 and 92.33 respectively) with high chlorophyll content (36.50). The PCA result showed that most important descriptors (plant height and leaf number) of variability obtained are those associated with PCA 1. AM-7 and Grain Amaranthus can be cultivated by farmers in Makurdi environs as a result of their good morphological characters (plant height, number of leaves and leaf area). Thus, Amaranth breeders can also use the two genotypes for improvement of the crop, especially when plant height, number of leaves and leaf area are the major target traits.*

Keywords: Morphological characters; Amaranthus Genotypes, Principal component Analysis (Add one more keyword)

Introduction
Amaranthus, collectively known as Amaranth, is a genus of annual or short-lived perennial plants which belongs to *Amaranthaceae* family (Petruzzello 2016). The word Amaranth is derived from Greek word “ama´rantos” which means “unfading flower” (ama´r for unfading and a´nthos for flower) (Liddell and Robert, 1940)

The genus *Amaranthus* includes 50 - 60 species cultivated for leaf as well as for grains, few are ornamental and wild species. *Amaranthus* leaves come in varied colors ranging from green, purple, red and gold and are found in all parts of Nigeria. These are the most important leafy vegetables of the tropical countries in the South Asia, South East Asia, Central Africa, West Africa, Ethiopia, and the Pacific (Khurana *et al.,* 2013)

Amaranthus forms an integral part of various regional cuisines in the country. It is commonly known as Aliefu in Nigeria. It is one of the cheapest grown leafy vegetable with low production cost and therefore often considered as "Poor man's Spinach". It is suitable for kitchen gardens and fits well in crop rotation because of its very short duration and large yield of edible matter per unit area and time. It is biotic and abiotic stress tolerant with wider adaptability (Lee *et al.,* 2008) and can be grown round the year under varied soil and agro climatic conditions (Katiyar *et al.,* 2000 and Shukla and Singh, 2000) except extreme winters. (Delete this please)

Amaranthus is a rich source of nutrients and serves as an alternative source of nutrition for people in developing countries where bulk of population has little access to protein rich food (Prakash and Pal, 1991; Shukla and Singh, 2003). Amaranth seeds contain exceptionally complete protein from plant sources to man. Besides protein, they proved to be a good source of dietary fibres and dietary minerals such as iron, magnesium, phosphorus, copper and especially manganese. The leaves are also consumed as a nutritious leaf vegetable, being used both for cooking and salads. Hence, it is touted as a "grain of the future" for its good nutritional value (Amaranth - New World Encyclopedia, 2016).

Production of Amaranths in Nigeria is low and falls short of demands despite cultivation acquiring increasing importance in parts of Nigeria where the available species are grown for their leaves (Along *et al.,* 2007; Musa *et al.,* 2014). Women account for a majority of the production in Nigeria where it contributes to family income and nutritional requirements. In the study by Mensah *et al.* (2008), wherein they compared commonly consumed vegetables, their results suggest that amaranths are the most frequently used in parts of South–South Nigeria. In a similar study, the results from Arowosegbe *et al.,* (2018) showed that amaranth is second most important vegetable after *Corchorus olitorius* L. in Southwestern Nigeria. The highest producers of grain amaranth are Mexico, Russia, China, India, Nepal, Argentina, Peru and Kenya. (Deletethis write-up please).

Studies on vegetable Amaranths showed the presence of wide range of diversity in both agronomic and qualitative traits especially in leaf and stem traits (Xiao *et al.,* 2000 and Wu *et al.,* 2000). A total of 16 accessions of *A. hybridus* from NIHORT, Ibadan, evaluated by Oboh (2007) for multivariate analysis showed a wide range of diversity in most of the quantitative characters. Classification of these accessions revealed 4 distinct groups; which could serve as breeding lines for the genetic improvement of *A. hybridus.*

Crop improvement activities in Amaranth are limited due to inadequate information on association among characters and variation for morphological and agronomic characters. Diversity studies based on morphological and agronomic characters among accessions of amaranthus will help breeders and taxonomists; determine plant characters which cause dissimilarity and the contribution of each character to total variation.

Amaranthus, is gaining attention of consumers in respect of its nutritional quality. However due to limited availability of improved cultigens, the crop has not been commercially exploited to its fully potentials. Characterization and evaluation of genetic resources can provide breeders with valuable information on effective utilization of genetic resources for the breeding programs. Collection, evaluation of germplasm including land races may offer considerable scope to identify suitable types for any particular region. Since there are limited study undertaken on the crop in Nigeria, environment till date in this behalf, hence a planned effort has been undertaken to evaluate different genotypes of Amaranth under the agro-climatic conditions of Makurdi. (delete this please)

The objectives of this research are as follows:

i. To determine the morphological variations among the characters of *Amaranthus* genotypes under study
ii. To identify and select *Amaranthus* genotypes that are promising for high vegetable??? Or high grain yield??? in Makurdi environ.

Materials and Methods

The experiment was conducted during the 2021 cropping season at the Teaching and Research Farm, Molecular Biology Laboratory, Joseph Sarwuan Tarka University, Makurdi, located at Latitude $7^0$14' North and longitude $8^0$24' East, 98 m elevation, which falls within the Southern Guinea Savannah agro-ecological zone of Nigeria.

Nine amaranthus genotypes were used for the study; of which three were sourced from Markudi, while the remaining the seven were obtained from National Horticultural Research Institute Bagauda Station Kano through Molecular Biology Labolatory, Joseph Sarwuan Tarka University Makurdi.

The experiment was laid out in a Randomized Complete Block Design (RCBD), with three replications. The treatments consisted of the nine *Amaranthus* genotypes: Local Benue, AM-1, AM-4, AM-5, AM-7, AM-10, AM-13 including Grain *Amaranthus* and Large green *Amaranthus*.

The land was manually cleared and ridges were made three days after clearing using hand hoe and then the plots were demarcated into three replications with spacing's 1m apart, for each replicate consisting of nine plots. At the nursery, 25 grams of *Amaranthus* seeds were broadcast?? or drilled at a spacing 4 cm between rows and seedlings were later transplanted to the field two weeks after sowing. The weeding of the research plots were done manually as at when necessary.

What about fertilizer and insecticide application?????

Data Collection

Data was collected for analysis from each individual plot on the following parameters: plant height, number of leaves, leaf area, chlorophyll content, days to first and 50 % flowering and leaf area at 50 % flowering of plants (Arrange in the order of the Tables presented i.e. DFF, D50%F, plant height……. etc).

Data Analysis.

All the data collected were subjected to analysis of variance (ANOVA) using the GENSTAT software seventeenth edition (reference???). Means that were significant were separated using the Turkey Least Significant Difference at 5% level of probability. Pearson's correlation co-efficient was used to test for a correlation between all parameters measured (No correlation Table in text, so delete).

Results and Discussion

Analysis of Variance for Morphological Characters of Amaranthus Genotypes

Mean square values of morphological characters of Amaranthus is presented in Table 1. All parameters measured (days to first and 50% flowering, plant height at 35 DAS, plant height 4 WAT, plant height at 50% flowering, numbers of leaves at 2 WAT, numbers of leaves at 4 WAT, Leaf area at 4 WAT including leaf area at 50% flowering including chlorophyll content showed significant difference ($P \leq 0.01$), except for leaf area at 2 WAT that was not statistically significant. These result confirmed the presence of variability among the genotypes of amaranthus as earlier reported by the following researchers (Get recent researchers work & name them……….).

Mean Values Showing Morphological Character of *Amaranthus* Genotypes

The mean performance of the morphological characters of *Amaranthus* genotypes is presented in Table 2. Local Benue flowered earlier than all the other genotypes of *Amaranthus*, while the other genotypes took 66 - 71 days to flower (late maturing). Local Benue also had its 50% flowering earlier than the other genotypes (64 days). The Local Benue genotype was significantly different from the others with respect to earliness (get relevant literatures to support the result you obtained).

For plant height traits, genotypes AM-7 was the tallest at 35 DAS, 4 WAT and 50%F (14.60, 55.53, and 54.63 cm respectively) among all the genotypes evaluated, followed by genotype AM-4, while the shortest was AM-1 genotype.

At 2 and 4 WAT, genotypes AM-7 had the highest number of leaves among the genotypes evaluated (14.33 and 32.67 respectively) and the least number of leaves was recorded by genotype AM-1 (Support result obtained with previous researchers).

All the nine *Amaranthus* genotypes evaluated showed a non-significant difference for leave area at 2 WAT, but the grain *Amaranthus* recorded the highest leave area at 4 WAT, followed by AM-1. Furthermore, genotype AM-1 and grain *Amaranthus* had the highest estimates of leave area at 4 WAT and leaf area at 50% flowering, although the two genotypes were statistically similar with AM-7 (Support result obtained with previous researchers). Chlorophyll content at 4 WAT was highest for AM-13 genotype (36.8), followed by grain amaranthus (36.50), while the least was AM-5 genotype (support result obtained with previous researchers).

Principal Component Analysis.

The results of the Principal Component Axes (Table 3) showed that five of the fourteen principal component axes (PCA) had Eigen values greater than one and the five PCA's accounted for 88.0 % of the total variation among the *Amaranthus* genotypes. The first two accounted for 56.0 % with PCA 1 accounting for 33.0 %, while PCA 2 accounting for 23.0 %. For PCA 1, variation was loaded as a result of plant height and number of leaves traits, while the remaining variables had weak or no discriminating power. The result of this study thus revealed that the most important descriptors of variability are these two traits found in PCA 1. (Support your result with previous researchers).

Table 1: The Mean Square Values for Morphological Characters of Amaranthus in 2021 Cropping Season

SOV	DFF	D50%F	PHT at 35 DAS	PHT at 4 WAT	PHT at 50%F	NO L at 2 WAT	NOL at 4 WAT	LA at 2 WAT	LA at 4 WAT	LA at 50% F	CHYII 4 WAT
Rep	7.26	0.04	17.5	42.87	28.36	0.26	13.37	30.19	45.91	155.42	0.37
Gen	67.15**	78.51**	12.29**	251.43**	217.56**	18.59**	103.98**	188.06^{NS}	881.21**	712.84**	77.08**
Error	7.26	0.04	1.05	21.91	31.78	0.43	5.37	105.9	29.02	36.71	3.09
TOTAL											

KEY: ** = Highly significant at $P \leq 0.01$; ns = not significant. SOV = Sources of variation, df = Degree of freedom???, DFF = Days to first flowering, D50%F = number of days to 50% flowering, P/HT@35DAS = Plant height at 35 days after sowing, P/HT@4WAT = Plant height at four weeks after transplant, P/HT@50%F = Plant height at 50% flowering, No.L@2WAT = Numbers of leaves at two weeks after transplant, No.L@4WAT = Numbers of, leaves at four weeks after transplant, Leaf area@2WAT = Leaf area at two weeks after transplant, Leaf area@4WAT = Leaf area at four weeks after transplant, Leaf area@50%F = Leaf area at 50% Flowering, CHYII 4 WAT = Chlorophyll content at four weeks after transplant, Rep = Replication and Gen = Genotypes. (Correct the above abbreviations on the Tables 1 and 2 appropriately)

Table 2: Mean Performance of Amaranthus Genotypes

GENIABLES→ Treatment↓	DFF	D50%F	P/HT@ 35 DAS	P/HT@ 4WAT	P/HT@ 50%F	NO. L@ 2WAT	NO. L@ 4WAT	LA @ 2WAT	LA @ 4WAT	LA @ 50%F	CHYII 4 WAT
AM-1	71.00^{a}	79.00^{b}	9.73^{cd}	27.97^{d}	25.37^{c}	7.67^{e}	12.33^{d}	26.63^{a}	90.67^{a}	90.67^{a}	27.93^{d}
AM-4	71.00^{a}	78.67^{b}	11.53^{bc}	47.00^{ab}	46.97^{ab}	12.33^{b}	21.00^{b}	28.97^{a}	57.33^{b}	57.33^{cd}	28.27^{bc}
AM-5	71.00^{a}	79.00^{b}	9.73^{cd}	33.53^{cd}	34.97^{bc}	9.00^{de}	13.67^{cd}	16.40^{a}	66.83^{b}	66.17^{bc}	22.93^{d}
AM-7	66.33^{a}	81.00^{a}	14.60^{a}	55.53^{a}	54.63^{a}	14.33^{a}	32.67^{a}	35.23^{a}	83.33^{a}	76.67^{ab}	32.43^{ab}
AM-10	71.00^{a}	79.00^{b}	9.93^{bcd}	38.53^{bcd}	40.87^{abc}	7.33^{e}	20.00^{bc}	35.83^{a}	60.43^{b}	60.43^{bc}	35.13^{a}
AM-13	71.00^{a}	79.00^{b}	11.53^{bc}	29.33^{d}	35.20^{bc}	8.00^{de}	16.33^{bcd}	20.03^{a}	56.87^{bc}	56.87^{cd}	36.80^{a}
Grain Amaranth	71.00^{a}	79.00^{b}	10.00^{bcd}	43.40^{abc}	47.53^{ab}	12.00^{b}	21.33^{b}	33.90^{a}	92.33^{a}	85.67^{a}	36.50^{a}
Large green	71.00^{a}	79.00^{b}	12.80^{ab}	38.30^{bcd}	40.80^{abc}	11.00^{bc}	20.67^{b}	40.90^{a}	66.33^{b}	66.33^{bc}	25.20^{cd}
Local Benue	57.00^{b}	64.00^{c}	7.70^{d}	30.43^{cd}	42.23^{ab}	9.67^{cd}	18.33^{bcd}	26.40^{a}	41.33^{c}	41.33^{d}	27.67^{bcd}

KEY: Means that do not share a letter are significantly different, DFF = Days to first flowering, D50%F = number of days to 50 % flowering, P/HT@35DAS = Plant height at 35 days after sowing, P/HT@4WAT = Plant height at 4 WAT, P/HT@50%F = Plant height at 50% flowering, No.L@2WAT = Numbers of leaves at 2 WAT, No.L@4WAT = Numbers of leaves at 4 WAT, Leafarea@2WAT = Leaf area at 2WAT, Leafarea@4WAT = Leaf area at 4 WAT, Leafarea@50 %F = Leaf area at 50 % Flowering, CHYII 4 WAT = Chlorophyll content at 4WAT (Correct this appropriately)

Table 3: Eigen Values and Vectors for 14 Principal Component Axes estimated for Morphological Characters of *Amaranthus* in 2021 Cropping Season.

Axes→ Variables↓	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14
DFF	0.13	0.42	-0.32	-0.11	-0.20	0.26	0.14	0.16	0.55	0.30	0.17	0.21	0.23	-0.17
D50% F	0.28	0.37	-0.25	-0.05	-0.10	0.00	-0.18	0.15	-0.12	-0.35	-0.37	0.24	-0.08	0.57
PHT at 35 DAS	0.34	-0.03	-0.21	-0.14	-0.11	-0.66	-0.45	-0.10	0.13	0.24	0.14	-0.26	0.01	-0.02
PHT at 4 WAT	0.40	-0.16	-0.04	-0.10	-0.09	0.16	-0.01	-0.46	-0.07	-0.49	0.45	0.24	0.18	-0.11
PHT 50% F	0.32	0.37	0.09	-0.21	-0.03	0.29	0.08	-0.36	0.36	0.11	-0.56	-0.26	-0.06	0.06
NOL at 2 WAT	0.38	-0.21	0.70	0.22	0.02	0.07	0.35	0.40	0.10	0.01	0.37	-0.37	-0.00	0.44
NOL at 4 WAT	0.37	-0.23	0.14	-0.08	-0.03	0.29	-0.28	0.24	-0.42	0.51	0.01	0.36	-0.03	-0.07
Leaf area 2 WAT	0.17	-0.02	0.05	-0.29	0.79	-0.27	0.23	0.11	0.13	-0.01	-0.07	0.29	0.14	-0.01
Leaf area 4 WAT	0.24	0.37	0.17	0.30	0.27	0.11	-0.12	-0.17	0.14	0.03	0.15	-0.01	-0.70	-0.15
Leaf area 50% F	0.19	0.40	0.14	0.34	0.25	0.15	-0.16	-0.14	-0.22	0.05	-0.12	-0.36	0.59	-0.09
CHYII 4 WAT	0.11	0.16	0.50	-0.42	-0.17	0.02	-0.16	0.44	0.09	-0.36	-0.03	-0.20	-0.01	-0.32
EIGEN VALUE	**4.62**	**3.19**	**1.79**	**1.65**	**1.04**	**0.56**	**0.35**	**0.25**	**0.18**	**0.01**	**0.11**	**0.07**	**0.02**	**0.06**
PROPORTION %	**0.33**	**0.23**	**0.13**	**0.12**	**0.12**	**0.07**	**0.04**	**0.03**	**0.02**	**0.01**	**0.01**	**0.01**	**0.00**	**0.00**
CUMULATIVE %	**0.33**	**0.56**	**0.69**	**0.80**	**0.88**	**0.92**	**0.94**	**0.96**	**0.97**	**0.98**	**0.99**	**0.10**	**0.10**	**1.00**

KEY: DFF = Days to first flowering, D50%F = number of days to 50% flowering, P/HT@35DAS = Plant height at 35 days after sowing, P/HT@4WAT = Plant height at four weeks after transplant, P/HT@50%F = Plant height at 50% flowering, N0.L@2WAT = Numbers of leaves at two weeks after transplant, No.L@4WAT = Numbers of leaves at four weeks after transplant, Leafarea@2WAT = Leaf area at two weeks after transplant, Leafarea@4WAT = Leaf area at four weeks after transplant, Leafarea@50%F = Leaf area at 50% Flowering, CHYII 4 WAT = Chlorophyll content at four weeks after transplant. (Correct the above abbreviations on the table 1 and 2 appropriately)

Analysis of variance for all measured traits showed high significant variability among the genotypes. This variation observed among the nine (9) Amaranthus genotypes evaluated may be attributed to the different genetic makeup of the genotypes studied which gives an ample scope for improvement in population through various breeding approaches. Amir and Abdoulamir (2017) made a similar observations and reported high level of significant variations among the genotypes evaluated.

The early flowering character demonstrated by Benue Local in days to first flowering, which was still manifested in days to 50% flowering and the consistency of flowering of the other genotypes observed shows that, flowering is controlled by genotype, environmental condition or genotype by environment interactions. AM-7 and Grain Amaranth outperformed other genotypes for all parameters in plant height, numbers of leaves, leave area and chlorophyll content, this superiority could be attributed to it inherent genetic qualities, Abiola, (2022) also recorded similar findings in his research and concluded that this superiority could be as a result of the genotype and its suitability to the local environment. AM-1 although had wide leaf area, was shorter than every other genotypes and had the least numbers of leaves, this is in tandem with Abiola, (2022), as he asserted from his research that the significant positive correlation between plant height and number of branches indicates that selecting accessions with taller plant heights would result in a greater number of branches, which is necessary for the production of leafy vegetables; similar conclusions were reached by Akter *et al.* (2005) and Munguatosha *et al.* (2017). According to Chahal and Gosal (2002), characteristics having the highest absolute value, closer to unity inside the first main component, impact clustering more than those with a lower absolute value, closer to zero, PCA point out some traits that particularly distinguished the genotypes evaluated by their morphology. Pick relevant literatures and fix appropriately in your discussion section, since from your sub title is Results & Discussion)

Conclusion and Recommendations

The nine genotypes of *Amaranthus* studied exhibited considerable variability based on the morphological traits (flowering traits, plant height, number of leaves, leaf area at 4 WAT and Chlorophyll content).

Genotype AM-7 was the tallest and had highest number of leaves with wide leaf area and high chlorophyll content, which was followed by grain *Amaranthus*. Therefore, Amaranthus breeders can utilize these two genotypes for improvement of *Amaranthus*.

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