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Morphology and Genetic Analysis of Vegetative Characterization of Four Grain Amaranth Accessions

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On the African continent, Amaranth is one of the most widely grown and consumed indigenous crops. The genus *Amaranth* is one of the most grown leaf vegetables, cereals or decorative plants. Weather factors, the environment, genotype and production practice all influence Amaranth's vegetative development. Most farmed Amaranth cultivars have low leaf and grain yields, owing to a paucity of good variations. Grain Amaranth growth can be enhanced with the use of suitable cultivars. The objective of this study was to look at the traits of the Amaranths that were chosen as well as compare their morphological and physiological characteristics. During June 2019, field experiments using four accessions as treatments were undertaken at the Osun State University Teaching and Research Farm. The four accessions were reproduced three times in a randomized complete block design at each site. The number of leaves, leaf area index, stem girth, plant height and number of branches were all gathered as growth metrics. The vegetative characteristics of the accessions differed significantly ($p \leq .05$). Num-Amaranth had the greatest leaf area index (16.28). The principal component analysis (PCA) results also showed that the Amaranth characteristics studied could be grouped into three components accounting for 90% of the total variation. The first principal component (PC) contributed 63% of the overall variance. PCA also revealed the morphological differences among the varieties, showing their geographical diversity and their possible utilization in future breeding programs.

Keywords: Vegetable Amaranth, Vegetative stage, correlation coefficient, Principal Component

INTRODUCTION

The genus *Amaranth* belongs to the family Amaranthaceae, and Amaranth is the collective term for the domesticated species of the genus. This family of plants is one of the world's oldest food crops, with evidence of cultivation reaching back more than 6700 years in Puebla, Mexico (Onyango (2010)). According to Kadereit et al. (2003), the diversity centers for Amaranth include South America, South Africa and Australia. *Amaranthus cruentus*, for example, is a widely grown crop in tropical Africa today. Grubben and Denton (2004) reported that A. cruentus is a prominent leafy vegetable in several African nations, such as Benin, Togo and Sierra Leone and is extremely important in many lowland areas, particularly in Southern Nigeria, the Democratic Republic of Congo, Kenya and Tanzania. Furthermore, according to Tejaswini et al. (2017), Amaranth has been established as a potential food crop during the last 20 years due to its capacity to withstand heat stress, drought, disease and pests, as well as the high nutritional value of both seeds. The crop also contains a significant quantity of protein, dietary fiber, dietary minerals and antioxidant components, such as ascorbic acid and beta carotenoids. Sarker et al. (2014) revealed that Amaranth has a flavor that is equal to or better than that of spinach. It also consists of significantly more protein (14-30% dry weight), minerals (Fe, Mn, and Zn) and antioxidants such as beta carotenoids (90-200mg/kg) and ascorbic acid (approximately 28mg/100g) than any other leafy vegetable.

However, due to a lack of several factors such as producer knowledge of the crop's nutritional benefits, acceptable high-yielding varieties and better production techniques, the production of Amaranth has declined, particularly the productions of Num-Amaranth, White Amaranth, Celosia and Red-Amaranth. In every crop improvement initiative, assessing germplasm variability is a preliminary step that will aid in selecting types with high variability and desirable yield-

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enhancing characteristics. Since yield is a complex character that is impacted by several component characteristics, knowledge of the size and direction of connection between yield and its component traits would aid in the establishment of selection criteria for improved genotype selection. Despite its great economic importance and the availability of a significant genetic variety in plant and reproductive characteristics, the genetic potentialities of Grain Amaranth remain largely unexplored, with few attempts to enhance its genetics done thus far.

By assembling diverse genetic stocks of any crop, a new variety can be developed to meet the needs of farmers which will increase the overall Amaranth productivity. Breeders can also enhance selection efficiency of the crop by understanding the interrelationship between the characteristics. We attempted to analyze the features of the selected Amaranths as well as compare their morphological and physiological characteristics in this study.

MATERIALS AND METHODS

The experiment was carried out at the Osun State University Teaching and Research Farm during June 2019. Four accessions of Amaranth (Num-Amaranth, White Amaranth, Celosia and Red-Amaranth) were obtained from the Institute of Agricultural Research and Training (IAR&T). The experimental site was cleared of its vegetation using a tractor, then mapped out and divided into three 2.5m by 2.5m blocks. Four grain Amaranth accessions were sown in a Randomized Complete Block Design (RCBD) within the three blocks. Three seeds of each variety were sown per hole with a spacing of 0.5m by 0.75m between them, and the plants were then thinned to one plant standing for two weeks after emergence. The varieties were grown during the early season in 2020. Every five days, data were collected on the number of leaves. The leaf area index was calculated using the formula: flag leaf length $\times$ leaf breadth $\times$ 0.75, stem girth was measured as the diameter of the root using a vernier caliper, plant height was measured from the soil surface to the top of the plant at a four-day interval, and the number of branches was counted and measured on three randomly selected plants per replication. Pest and weeds were also controlled using chemical pesticides at the rate of 2.5kg/habefore planting.

Analysis of variance (ANOVA) was carried out on all agronomic parameters. The Least Mean Square was calculated for significant values of the accession mean sum of squares using the GLM procedure of SAS (Version 9.4), and the graphs were plotted using Microsoft Excel version 2010. The associations between yield and component traits and correlations among component traits were worked out based on the average performance of genotypes as a genotypic correlation coefficient (Sarwar et al., 2021).

RESULTS

Variation in Morphological Characteristics

Table 1hows the results of the analysis of variance for the characteristics of the four grain Amaranth varieties that were tested for yield potential. For stem girth, the sum of squares was highly significant (1.11). However, characteristics such as the total sum of squares for leaf width (38.88cm), number of branches (42.74), leaf area (114.56cm^2), number of leaves (1033.73), and plant height (1379.44cm) were revealed to be nonsignificant. For every characteristic, the error sum of squares was typically less than the variety sum of squares. The coefficient of variation had a range of 19.56% (leaf area index) to 37.91% (number of branches).

Correlation Analysis

Table 2 shows the relationship between the characteristics of four different Amaranth types produced during the rainy season. Leaf width had a substantial negative relationship with the number of branches (-0.03), while the remaining characteristics had no significant relationship with leaf width. The number of branches had a highly significant positive correlation (0.31) with plant height. Furthermore, there was a highly significant positive association (0.71) between plant height and stem girth.

The four Grain Amaranth varieties' growth performance is improving

Table 3 shows the growth performance of the four grain Amaranth cultivars. Num-Amaranth had the greatest leaf area index (16.28), followed by White Amaranth (14.32). The leaf area index for Celosia was the lowest (7.69). Celosia had the widest leaves (3.07), which were considerably different from the other kinds. Furthermore, Red Amaranth and Celosia had the same number of branches (12.44), but Num-Amaranth (11.67) and White Amaranth (7.89) had substantially fewer branches. The largest number of leaves (68.22) was found in Num-Amaranth and Red Amaranth, whereas Celosia had the lowest significant value (43.22). The tallest plants were Num-Amaranth (65.36) and Red-Amaranth (61.67), and the lowest plants were White Amaranth (44.77) and Celosia (38.56). Finally, Num-Amaranth had the largest stem girth value (1.63), which was substantially higher than Celosia (0.83) which had the lowest score for the same characteristic.

Principal Component Analysis

Table 4 shows the findings of the PCA. At each axis of differentiation, PCA indicates the importance of the biggest contributor to the overall variance (Sharma (1998)). The eigenvalues are frequently used to determine the number of components to keep. The number of variables is generally equal to the sum of the eigenvalues.

Furthermore, 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. As a result, the first PCA exhibited positive loading for leaf area index (0.48), leaf width (0.48), and stem girth (0.48). Plant height contributed favorably (0.20) to the second PCA, whereas the number of leaves contributed positively (0.83) to the third PCA. However, the number of branches adversely contributed to the third PCA (-0.53). Overall, the PCA revealed that the variable could be divided into three components that in total accounted for 90% of the overall variance in grain yield. Vectors I, II and III were responsible for 63%, 81% and 90% of the overall variation in the characteristics examined respectively; however, the vector I and II axes were the most important, contributing to 81 % of the multivariate variance across the Amaranth genotypes. Therefore, the characteristics put on those axes were utilized to categorize the genotypes.

DISCUSSION AND CONCLUSION

The significance of stem girth from the results revealed a wider variability among the accessions of Amaranth used. The presence of varying mean significance sum of squares for the stem circumference indicates that the four varieties of Amaranth utilized in this study were genetically distinct for this characteristic. Abdoulamir and Amir (2017) made a similar observation. The highest value for the variety sum of squares for all characteristics showed that genetic impact is heavily influencing the Amaranth grain properties of the investigated varieties. From the study, leaf area index, leaf breadth, number of branches, number of leaves and plant height showed a nonsignificant influence on the yield; this indicates that they were indifferent in their expression and cannot be used for varietal selection (Nazir et al., 2010). Abdoulamir and Amir (2017) had also found a nonsignificant difference in plant diameter and number of leaves in their study.

Furthermore, 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). The negative relationship between leaf width and the number of branches suggests that selecting accessions based on leaf size would result in a small number of branches. This association might be explained by food being transported to the leaf via the branches, which is typical in nutrient-deficient environments. The genetic diversity among the types studied was shown by their grouping pattern. Three groups were realized from this pattern. Similar findings were reported by Liu and Stutzel (2002). Kanthaswamy (2006) classified 74 Amaranth genotypes into 12 groups, Oboh (2007) found four groups of 16 Amaranth (A. hybridus), Shukla et al. (2010) found six groups for 39 Amaranth strains and Akther et al. (2013) found four groups of 17 Amaranth genotypes.

As shown by the results, Num-Amaranth had the greatest values for various characteristics, including leaf area index, leaf breadth, number of leaves, plant height and stem circumference. This means that this variety was superior to others with respect to those characteristics. However, it is also important to note that abiotic stress could have caused Celosia to have the lowest values for leaf area index, leaf breadth, number of leaves, plant height, and stem circumference.

Since the photosynthetic capability of a plant with longer leaves is predicted to be higher than that of a plant with shorter leaves (Chapin et al. (2007)) and features such as a high leaf area index, leaf length, stem circumference and plant height enable optimal crop output when water is accessible as an essential agricultural input in sufficient quantities (Onasanya et al., 2009), then based on its superior characteristics, Num-Amaranth should be selected for future breeding programs so as to ascertain the maximum exploitation of Grain Amaranth's potential for high yield.

Key: ns = nonsignificant, * = significant at $p \leq .05$, ** = highly significant at $p \leq .01$, CV% = Coefficient of Variation, SOV = Sources of Variation, DF = Degree of Freedom, Lf. Wth. = Leaf Width, N. Brn. = Number of Branches, Lf. Ar. = Leaf Area Index, Stm. Gt. = Stem Girth, No. Lf. = Number of Leaves, Plt. Hgt. = Plant Height.

Key: ns = nonsignificant, * = significant at $p \leq .05$, ** = highly significant at $p \leq .01$, Lf. Ar. = Leaf Area Index, Lf. Wth. = Leaf Width, N. Brn. = Number of Branches, No. Lf. = Number of Leaves, Plt. Hgt. = Plant Height, Stm. Gt. = Stem Girth.

Key: ^{ab} = characteristics on the same row with different superscripts are significantly different. (*p* < .05), Lf. Ar. = Leaf Area Index, Lf. Wth = Leaf Width, Stm. Gt. = Stem Girth, N. Brn. = Number of Branches, Plt. Hgt. = Plant Height, No. Lf. = Number of Leaves.

(Bold-faced scripts show component score coefficient matrix: The high value indicates a high correlation between the traits and PC).

REFERENCES

Abdoulamir, R., and Amir, R. S. (2017). Performance comparison of three varieties of Amaranth (Amaranthus hypochondriacus L.) at different harvest time. *International Journal of Research Studies in Agricultural Sciences (IJRSAS)*, 3, 1-6.

Akter, N., Mian, M. A. K., Islam, M. M., Alim, M. A. and Islam, M. N. (2005). Estimation of genetic parameters, character association and path analysis in jute (C. olitorius L.) germplasm. *Bangladesh Journal of Plant Breeding and Genetics*, 18(I), 35-38.

Akther, C. A., Hassan, M., Raihan, M. S., Hossain, M. M. and Mian, M. A. K. (2013). Genetic divergence in stem Amaranth (Amaranthus tricolor L.) genotypes for yield and its component characters. *The Agriculturist*, 11(1), 82-88.

Table 1. Analysis of Variance of four Amaranth characteristics grown in the rainy season production.

Sn.	S OV	D F	Lf. Wth.	N. Brn.	Lf. Ar.	Stm. Gt.	No. Lf.	Plt. Hgt.
1.	Replicate	2	0.35	16.44	13.06	0.11	2297.69	483.53
2.	Variety	3	38.88^{ns}	42.74^{ns}	114.56^{ns}	1.11^{**}	1033.73^{ns}	1379.44^{ns}
3.	Error	30	1.90	17.75	6.48	0.09	272.05	307.16
4.	Total	35						
5.	CV (%)		22.65	37.91	19.56	23.76	29.53	33.61

Table 2. Correlation matrix of the variables used in the PC of four grain Amaranth genotypes evaluated during the rainy season.

	Lf. Ar.	Lf. Wth.	N. Brn.	No. Lf.	Plt. Hgt.	Stm. Gt.
Lf. Ar.	1.00	0.92^{ns}	0.14^{ns}	0.67^{ns}	0.63^{ns}	0.85^{ns}
Lf. Wth.		1.00	-0.03^{*}	0.53^{ns}	0.59^{ns}	0.79^{ns}
N. Brn.			1.00	0.23^{ns}	0.31^{**}	0.19^{ns}
No. Lf.				1.00	0.51^{ns}	0.67^{ns}
Plt. Hgt.					1.00	0.74^{**}
Stm. Gth.						1.00

Table 3. Vegetative growth performance effect of season on characters of grain Amaranths varieties.

Sn.	Varieties	Lf. Ar.	Lf. Wth.	Stm. Gt.	N. Brn.	Plt. Hgt.	No. Lf.
1.	Num-Amaranth	16.28^{a}	7.80^{a}	1.63^{a}	11.67^{ab}	63.56^{a}	68.22^{a}
2.	White Amaranth	14.32^{ab}	6.90^{a}	1.26^{ab}	7.89^{b}	44.78^{b}	52.00^{ab}
3.	Red Amaranth	13.50^{b}	6.58^{a}	1.50^{ab}	12.44^{a}	61.67^{a}	60.00^{a}
4.	Celosia	7.96^{c}	3.07^{b}	0.83^{c}	12.44^{a}	38.56^{b}	43.22^{b}

Table 4. Eigenvectors and Eigenvalues of the first three principal components (Vector I, Vector II and Vector III) axes for four lines evaluated for growth yield during the rainy season.

Characteristics	Vector I	Vector II	Vector III
Leaf Area Index	**0.48**	-0.16	0.02
Leaf Width	**0.45**	-0.33	-0.18
Number Branches	0.13	0.90	**-0.53**
Number Leaf	0.39	0.11	**0.83**
Plant Height	0.41	**0.20**	-0.52
Stem Girth	**0.48**	-0.04	-0.08
Eigen value (ROOT)	3.82	1.08	0.51
Proportion Variation accounted for by PC	0.63	0.18	0.08
Cumulative Variance Expected	0.63	0.82	0.90

Chahal, G. S., and Gosal, S. S. (2002). *Principles and procedures of plant breeding: Biotechnology and conventional approaches,*. New Delhi: Narosa Publishing House.

Chapin, F. S., Eviner, V. T. and Garg, N. (2007). Genetic diversity in round gourd [Praecitrullusfistulosus (Stocks) Pangalo] accessions introduced from USDA for various qualitative and quantitative traits. *Treatise on Geochemistry*, 6, 801-815.

Grubben, G. J. H., and Denton. (2004). *Plant Resources of Tropical Africa,* Vol. 2. Vegetables, Wageningen, Netherlands: PROTA Foundation.

Kadereit, G., Borsch, T., Weising, K. and Freitag, H. (2003). Phylogeny of Amaranthaceae and Chenopodiaceae and the Evolution of C4 Photosynthesis. *International Journal of Plant Sciences*, 164(6), 959-986. doi: 10.1086/378649

Kanthaswamy, V. (2006). Studies on multivariate analysis in amarantus. *International Journal of Agricultural Science*, 2(2), 317-319.

Liu, F., and Stutzel, H. (2002). Leaf expansion, stomatal conductance and transpiration of vegetable Amaranth (Amaranthus sp.) in response to soil drying. *Journal of the American Society for Horticultural Science*, 127(5), 878-883.

Munguatosha, N., Tsvetelina, S., Tileye, F. and Patrick, A. (2017). Characterization of orphological diversity of jute mallow (Corchorus spp. *International Journal of Agronomy*, 6460498.

Nazir, H., Zaman, Q., Amjad, M. and Aziz, N. A. (2010). Responses of maize varieties under agro-ecological conditions of Dera Ismail Khan. *Journal of Agricultural research*, 48(1), 59-63.

Oboh, B. (2007). Multivariate analysis of the diversity among some Nigerian accessions of Amaranthushybridus. *International Journal of Plant Breeding and Genetics*, 1, 89-94.

Onasanya, O., Olaiya, P., Onasanya, A. and Oikeh, S. O. (2009). Growth and Yield Response of Maize (Zeamays L.) to Different Rates of Nitrogen and Phosphorus Fertilizers in Southern Nigeria. *Onyango, C.M. (2010) Pre-harvest and postharvest factors affecting yield and nutrient contents of vegetable Amaranth (Var. Amaranthus hypochondriacus), thesis*, 5, 400-407.

Onyango, C. M. (2010, April). *Preharvest and Postharvest Factors Affecting Yield and Nutrient Contents of Vegetable Amaranth (Var. Amaranthus hypochondriacus).,*. Wageningen, the Netherlands. Retrieved from https://library.wur.nl/WebQuery/wurpubs/fulltext/136215

Sarker, U., Islam, M. T., Rabbani, M. G. and Oba, S. (2014). Genotypic variability for nutrient, antioxidant, yield and yield contributing traits in vegetable Amaranth. *Agriculture & Environment*, 12(3&4), 168-174.

Sarwar, G., Nazir, A., Rizwan, M., Shahzadi, E. and Mahmood, A. (2021). Genetic diversity among cotton genotypes for Earliness, yield and fiber Quality tusing correlation, Principal Component and Cluster Analyses. *Sarhad Journal of Agriculture*, 37(1), 307-314.

Sharma, J. R. (1998). *Statistical and Biometrical Techniques in Plant Breeding,*. New Delshi: New Age International (P) Limited Publishers.

Shukla, S., Bhargava, A., Chatterjee, A., Pandeya, A. C. and Mishra, B. K. (2010). Diversity in phenotypic and nutritional traits in vegetable Amaranth (Amaranthus tricolor), a nutritionally underutilised crop. *Journal of the science of food and agriculture*, 90(1), 139-144.

Tejaswini, N. K., Ravinder, R. P. and Ramesh, T. (2017). Correlation and Path Coefficient Analysis in Vegetable Amaranth (Amaranthus tricolor L.) Genotypes. *International Journal of Current Microbiology and Applied Sciences*, 6(6), 2977-2996.