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MORPHOLOGICAL VARIATION AMONG SOME CASSAVA (*Manihot esculenta* CRANTZ) VARIETIES EVALUATED IN IBADAN, SOUTH WEST, NIGERIA

[1]A. AKINYEMI, *[1]B. OLASANMI, [1,2]I. O. UDEMBA, [1]M. EFOLI

[1]Department of Crop and Horticultural sciences, University of Ibadan, Ibadan, Nigeria.
[2]Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria
*Corresponding Author: bunminadeco@yahoo.com **Tel:** 07039822177

ABSTRACT

Cassava is a highly heterogeneous crop; hence, there exists high diversity among different genotypes in their response to different biotic and abiotic environmental factors. Morphological variation among cassava genotypes, which depicts their genetic diversity, had proven useful and cost effective in identification and selection of cassava varieties by farmers and in breeding programmes. The morphological variation also affects to an extent level of adoption by farmers because these traits determine how each cassava variety fits into the prevailing cropping system in each locality. This study assessed the genetic diversity among ninety-three (93) cassava varieties based on their morphological characteristics. The experiment was conducted at the Teaching and Research Farm, Department of Crop and Horticultural Sciences, University of Ibadan, Nigeria, during the 2021 cropping season. The cassava varieties were planted following a randomized complete block design with two replicates. Data were collected monthly on plant height, height at first branching point, canopy diameter and number of branches per plant from 2-5 months after planting. The data were subjected to descriptive statistics; correlation, and principal component analyses. The main traits responsible for variation among the cassava varieties were plant height, canopy diameter and number of branches. The varieties were grouped into three major clusters. The first three principal components accounted for about 77.41% of the total variation observed. Meanwhile, plant height correlated positively with all the evaluated morphological parameters. The existing variation among the cassava varieties for the morphological traits studied can be explored for selection and improvement of the crop.

Keywords: Morphological traits; Genetic diversity; *Manihot esculenta*; Identification; Selection

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is ranked 6th most important and widely consumed food crop in the world (Amelework and Bairu, 2022), offering significant wellspring of nourishment as a major source of calories for over seven hundred million individuals in tropical developing nations (Byju and Suja, 2020). This places cassava among the major crops in these nations, where it is mostly cultivated by small and medium scale farmers (Ridwan *et al.*, 2022). Although cassava is very hardy and more resistant to climate change than other crops (Murpakati and Tanyaniwa, 2017), average global yield of cassava from most small farm holdings is about 10 t/ha, which is lower than its potential yield of 90 t/ha (Martin *et al.,* 2018). The yield reduction can be attributed to lack of well adapted varieties and use of low-quality planting materials among other factors (Wossen *et al.,* 2020). This calls for improvement of present cassava yield considering the number of people that depend on it as a major staple and the forecast imminent doubling of the world population by 2050 (O'Sullivan, 2023). Hence varietal selection of cassava becomes paramount, as an initial step for its improvement.

Cassava has many genotypes which respond differently to diverse environmental and biotic elements (Dixon *et al.*, 2002). Each variety is characterized by morphological and physiological traits which are products of the genotype, environment and their interaction (Benti and Degafa, 2017). For instance, cassava plant height ranges from 1 to 4 m in the course of a year and its stems can either be branched or non-branching with varying numbers of branches per plant (Sayre *et al.*, 2011; Kouakou *et al.*, 2016). Most small and medium scale farmers prefer the erect plant type (Ceballos et al., 2020) or slightly branched cultivars that fit into their prevailing cropping system of multiple cropping. According to Elias et al. (2001), there exists heritable genetic variation in morphological traits of cassava. Propagation of cassava from stem cutting therefore ensures the new plants are true to type, ensuring homogeneity on the plots grown to a particular cultivar. This allows farmers to plan cultural operations such as weeding, fertiliser application and harvesting, with little or no difficulty that may emanate from diversity in factors such as nutrient requirement, growth habits, in-ground storability and maturity period. Thus, morphological traits of cassava had been used as a quick, cost effective and easy tool for identifying the extent of diversity among cassava germplasm in different environments across the globe (Asare *et al.*, 2011; Agnes *et al.*, 2015; Nadjiam *et al*, 2016; Karim *et al.*, 2019; Amarullah, 2021; Ridwan *et al.*, 2022). All these studies revealed heterogeneity among cassava genotypes based on morphological traits, indicating true diversity as perceived by farmers. Fukuda *et al.* (2010) pointed out that evaluation of existing genetic variability in a cassava germplasm is necessary and must be based on appropriate recognisable agro-morphological descriptors.

Majority of the previous studies on morphological characterization of cassava utilized traits relating to leaves and stems, with aspects related to plant height and height at first branching point receiving limited attention. However, plant height in many crops (including cassava) had been reported to be directly linked with productive potential (Law-Ogbomo and Ajayi, 2009). Udemba (2023) reported positive correlation between plant height and fresh storage root yield of some cassava varieties. The branching pattern of cassava relates to leaf area index, stem diameter, inflorescence formation, canopy development, light penetration, photosynthesis, dry matter partitioning and fresh storage root yield (El-Sharkawy, 2003; Phoncharoen *et al.*, 2019). Variation in morphological traits of cassava can cause differences in photosynthetic activities which will consequently affect fresh storage root yield (Misganaw and Bayou, 2020). This study was therefore conducted with the aim of characterizing 93 cassava varieties based on their morphological traits of plant height, number of branches, height at first branching point and canopy diameter. It was aimed at identifying the major traits that contribute most to the variation pattern and to ascertain the relationship among the studied morphological traits. Information on the above objectives will support decisions for genetic resource selection for varietal improvement and cultivation purposes.

MATERIALS AND METHODS

This field experiment was carried out at the Teaching and Research Farm, Department of Crop and Horticultural Sciences, University of Ibadan, Nigeria with the coordinate longitude of 03°53.24'E and latitude of 07° 27.8'N. The land at the experimental site was cleared manually and partitioned into plots. Ninety-three varieties of cassava sourced from the cassava germplasm of the University of Ibadan, Nigeria were planted (one variety per plot) in May, 2021 using spacing of 1 × 1 m. The experiment was laid out using randomized complete block design with two replicates, due to logistics of size. Weeding of the experimental field was carried out manually to minimise interference between weeds and the cassava plants. On a monthly basis from 2 to 5 months after planting (MAP), data were collected on plant height, height at first branching, number of branches per plant and canopy diameter of the cassava genotypes. Plant height was measured from soil surface to the apex of the plant using metre rule; height at first branching point was measured from soil surface to the point where the cassava plants first forked and canopy diameter was measured using a metre rule. Data collected were subjected to descriptive statistics; correlation and principal component analysis using R software version 4.1.0 and R studio version 1.4.1106.

RESULTS

From 2-5 MAP, there was increase in mean of all the cassava morphological traits; the differences between the lower and upper limits were wide. Across the sampling dates, the lowest range (0-2) was observed at 2 MAP and was recorded for number of branches while the widest range of 53.5-221.5 was noted at 5 MAP from plant height (Table 1). Canopy diameter consistently had the least coefficient of variation (CV) from 2 -5 MAP, while the CV of height at first branching point and number of branches were highest from 2-3 and 4-5 MAP, respectively (Table 1). There was positive correlation between plant height canopy diameter, number of branches per plant and height at first branching point (Table 2). There was positive correlation between number of branches per plant and canopy diameter; height at first branching point and canopy diameter and number of branches per plant (Table 2).

Of the six principal components (PCs), only the first three had Eigen value greater than one and were cumulatively responsible for approximately 77.41 % of the total variation (Table 3). The first three PCs were linked with plant height, canopy diameter and number of branches per plant. Specifically, the first principal component axis with Eigen value of 7.12 accounted for 44.52% of the total variation and positively associated with plant height and canopy diameter at 3, 4 and 5 MAP (Table 3). The second principal component axis with Eigen value of 3.55 was responsible for 22.18% of the diversity which was negatively associated with number of branches produced by the cassava plants at 2 and 3 MAP (Table 3). At the third principal component axis, the Eigen value of 1.71 accounted for 10.71% of the observed variability and was positively related with plant height and canopy diameter at 2 MAP. About 5.78% of the diversity in the cassava varieties was linked to the fourth principal component axis (with Eigen value of 0.93) which was positively related to height at first branching of the cassava genotypes from 3 to 5 MAP. The fifth Eigen value of 0.80 and the sixth Eigen value of 0.58 principal component axes accounted for 4.97%, and 3.63% of the recorded variability, respectively. The fifth and sixth PC axes were negatively associated with canopy diameter at 4 and 5 MAP and plant height at 5 MAP, respectively. The 93 cassava varieties were grouped into 3 main broad clusters. Clusters 1, 2 and 3 comprised of 6, 25 and 62 varieties, respectively (Figure 1). The varieties in clusters 1 and 2 were characterized mainly by similarity in plant height and canopy diameter while varieties in cluster 3 were related by similarity in all the four morphological traits evaluated with the exception of number of branches (Table 4).

Table 1: Descriptive statistics for some morphological parameters of ninety-three cassava genotypes evaluated in Ibadan in 2021

Variable	2 MAP				3 MAP				4 MAP				5 MAP			
	Range	Mean	SD	CV	Range	Mean	SD	CV	Range	Mean	SD	CV	Range	Mean	SD	CV
Plant height	10- 59	36.09	9.89	0.27	22.5-115	67.84	18.82	0.28	36.0-177.0	107.03	28.60	0.26	53.5-221.5	140.35	37.40	0.27
Canopy diameter	24-92.5	61.70	13.42	0.22	40.5-105.5	78.22	12.47	0.16	46.5-126.5	89.69	12.40	0.13	58-163	102.80	18.58	0.18
Height at first branching	0- 27.5	1.11	4.09	3.68	0-103.5	10.38	19.39	1.86	0.0-136.5	47.85	38.94	0.81	0- 40	61.70	39.96	0.64
Number of branches per plant	0-2	0.13	0.47	3.61	0-3	0.58	0.96	1.65	0.0-12.5	2.51	2.41	0.96	0-26	6.67	4.94	0.74

MAP: Month after planting; SD: Standard deviation; CV: Coefficient of variation

Table 2: Pearson coefficient of correlation among some morphological traits of 93 cassava genotypes evaluated in Ibadan in 2021

Variables	Plant height	Canopy diameter	Number of branches
Plant height			
Canopy Diameter	0.75		
Number of branches	0.39	0.46	
Height at first branching	0.72	0.62	0.54

Table 3: Principal components for morphological traits of 93 cassava genotypes evaluated

Variables	Eigen vectors					
	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6
PH2MAP	0.22	0.16	**0.44**		0.40	0.10
PH3MAP	**0.32**	0.14			0.33	-0.25
PH4MAP	**0.34**	0.12				-0.39
PH5MAP	**0.32**	0.11	-0.16			**-0.48**
CD2MAP	0.21	0.13	**0.52**			0.39
CD3MAP	**0.30**	0.10	0.25		-0.29	
CD4MAP	**0.31**			0.23	**-0.48**	
CD5MAP	**0.30**		-0.16		**-0.48**	
NB2MAP		**-0.43**	0.33	-0.31		-0.28
NB3MAP	0.15	**-0.43**		0.31	0.21	0.11
NB4MAP	0.22	-0.36	-0.14		0.13	0.26
NB5MAP	0.26	-0.27	-0.20	-0.22		0.32
HB2MAP		-0.41	0.37	-0.31	-0.10	-0.28
HB3MAP	0.18	-0.34	-0.14	**0.41**	0.25	
HB4MAP	0.29		-0.18	**-0.42**		0.17
HB5MAP	0.25	0.19	-0.15	**-0.45**	0.15	0.11
Eigenvalue	7.12	3.55	1.71	0.93	0.80	0.58
Difference	3.57	1.84	0.78	0.13	0.22	0.15
Proportion	44.52	22.18	10.71	5.78	4.97	3.63
Cumulative	44.52	66.70	77.41	83.19	88.16	91.79

PH: plant height, CD: Canopy Diameter, HB: Height at first branching, NB: Number of branches. The values in the blank spaces are negligible to be considered. Bold figures signify traits that made the highest negative or positive contributions to the percentage variation

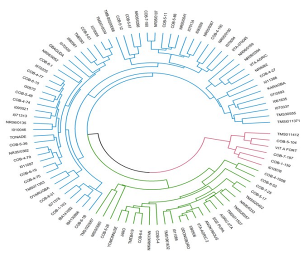

Figure 1: Dendrogram of grouping of 93 cassava genotypes into three clusters based on morphological traits

Table 4: Mean of morphological traits characterizing cassava varieties in each cluster of the 93 varieties in University of Ibadan germplasm

Clusters	PH	CD	NB	HB
1	83.74	83.42	3.46	31.66
2	72.99	74.99	0.52	10.33
3	107.11	90.56	3.14	47.76

PH: Plant height; CD: Canopy diameter; NB: Number of branches; HB: Height at first branching point

DISCUSSION

Characterization of cassava genetic diversity using morphological traits could be used to evaluate the potential root productivity of cassava, as these traits reflect genotypic variability and are closely associated with agronomic performance (Roslim *et al.*, 2016). Corresponding increase in the mean values of all the morphological traits with increase in plant age could be due to plant growth which is the progressive development of an organism, an irreversible increase in volume due to division and enlargement of cells (Lastdrager *et al.*, 2014).

The wide range recorded for all the morphological traits of the 93 cassava varieties could be exploited for varietal improvement in breeding programmes. However, the least range recorded for number of branches at 2 MAP can be attributed to no or few branches produced by majority of the cassava varieties at this plant age. Branching in cassava starts at about two months after planting. The high coefficient of variation observed for the traits indicate the presence of high heterogeneity within the cassava population for these traits. The variation reflects the genetic constitution of the varieties and depicts the diversity within the cassava germplasm used in this research. The wide variation recorded in this study for all the morphological traits is consistent with the report of Nadjiam *et al.* (2016) that several studies carried out in the world using morphological and agronomic traits of cassava revealed heterogeneity within cassava cultivars held by farmers. Specifically, Lyimo *et al.* (2013) noted that high diversity has been recorded for African cassava germplasm.

The high positive contribution of plant height to distinguishing varieties in the first principal component axis shows the usefulness of plant height in identifying diversity in the present germplasm and suggests it as a key trait that can be relevant for selection of varieties and genetic improvement of cassava. Law-Ogbomo and Ajayi (2009) submitted that crop plant height is directly linked with their productive potential; Udemba (2023) observed positive correlation between cassava plant height and fresh storage root yield. This implies that taller plants in this germplasm have the potential to have higher fresh storage root yield. Hence, plant height of the cassava varieties in this germplasm can be used as an easy, fast and cost-effective tool for selecting them for fresh storage root yield and farmers can use it to identify these cassava varieties (Asare *et al.*, 2011; and Mezette *et al.*, 2013).

The positive correlation between plant

height and the other three evaluated morphological traits connotes that increase in plant height will lead to the production of more branches, increase in canopy diameter and height at first branching point. These will enhance photosynthetic activities by increasing light penetration and interception which will consequently result to higher fresh storage root yield and dry matter accumulation (Misganaw and Bayou, 2020). This finding also suggests that plant height can be used to select for canopy diameter, height at first branching point of cassava and number of branches produced by the crop. Positive correlation observed between plant height and height at first branching point also implies that varieties that have the potential to be very tall will branch at a reasonable height above the ground which can encourage intercropping and cultivation of such varieties as sole crops will require more efforts in weed control.

The observed positive correlation between number of branches and each of canopy diameter and height at first branching point indicates that number of branches produced by any cassava variety in the germplasm can be used to determine its canopy diameter and height at first branching point. Therefore, number of branches can be used to select for the two traits among the cassava varieties.

The grouping of the 93 cassava varieties into three distinct clusters, based on the four morphological traits suggests that the varieties differ from each other and are also similar in one or more morphological traits. This suggests the usefulness of the morphological traits in their genotypic differentiation and identification. Varieties sharing many similarities in traits are closely related and grouped into a cluster (Raden *et al.*, 2017) while those having many differences show distant relationships (Jan *et al.*, 2012).

The principal component analysis (PCA) is an important technique used for reducing large number of related variables to a small number that is autonomous and valuable. The first 3 principal components revealed that plant height, canopy diameter and number of branches contributed the most to the variation present among the 93 cassava varieties in the U.I. germplasm. The observed highest positive contribution by plant height to the first PCA further shows the importance of this trait in determining the level of diversity among the cassava varieties evaluated in this study. These findings imply that plant height, canopy diameter and number of branches can be key traits for genotypic identification, genetic diversity studies and selection among these cassava varieties in improvement programmes.

CONCLUSIONS

From the study, the extent of differences and relationship among the 93 cassava varieties were identified using some morphological traits. There was wide variation in the cassava germplasm; important morphological traits of cassava that influence their diversity were plant height, canopy diameter and number of branches per plant. Plant height of the cassava varieties maintained a positive relationship with all the evaluated traits, and could be an index for these traits. Therefore, farmers and breeders can utilize number of branches, canopy diameter and plant height of cassava to identify and select the crop for cultivation and improvement programmes. Varieties with desired traits could be integrated into cassava improvement breeding programmes and farming systems.

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