



SOMA-CLONAL VARIATION IN SELECTED QUALITATIVE TRAITS OF CASSAVA (*Manihot esculenta* Crantz) ACCESSIONS GROWN IN NORTH-WEST AND NORTH-EAST, NIGERIA

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ABSTRACT: Cassava is an important staple, food security, income-generating, and industrial crop in Nigeria. Despite its importance, cassava production in North-east and North-west faces challenges such as limited information on the genetic diversity of available accessions. Field experiment was conducted during 2022/2023 growing season with the aim to assess the extent and pattern of genotypic variation among cassava accessions cultivated in North-west and North-east, Nigeria. Two hundred and ninety-six (296) cassava accessions were sourced from the two regions through germplasm field survey and were assessed on the phenotyping experimental field of Central and West African Virus Epidemiology-Abdullahi Fodio University of Science and Technology, Aliero (WAVE-AFUSTA). The experiment was laid out using Augmented Randomized Block Design (ARBD). Descriptive statistics and multivariate analysis of the 296 x 14 qualitative data were conducted. Cassava accessions assessed showed low to high variation in relation to the qualitative traits. Accessions were grouped into four clusters (I, II, III and IV) based on qualitative traits. The distribution of the 296 accessions showed that nine (9) accessions were in cluster one (1), one (1) in cluster two (2), six (6) in cluster three (3) and 280 in cluster four (4). The grouping of 280 accessions in a cluster indicate that, the accessions are likely duplicates but with different names in different localities. The Factor Analysis of Mixed Data (FAMD) revealed that the variation observed among the studied accessions is driven predominantly by plant architectural and leaf morphological traits. The observed soma-clonal variation in this research highlights the potential of these accessions as valuable genetic resources for cassava improvement programmes. This study provides a foundation for molecular characterization that will screen the duplicates and reduce the germplasm size in Nigeria. This will ensure that accessions with high diversity are retained.

Keywords: Accessions, Soma-clonal variation, Qualitative traits, Northern Nigeria.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) belongs to the *Euphorbiaceae* family which is made up of about

7,200 species, characterised for their notable development of lactiferous vessels, which are made up of secretory cells called laticifers. These produce the milky secretion or “latex”, that characterises members of this family (Ceballos *et al.*, 2012). The genus *Manihot* is native only to the Americas, with species being distributed from southwestern USA

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(33°N) to Argentina (33°S) (Ceballos *et al.*, 2012). Cassava is a perennial shrub that can reach up to 4 meters in height. Its stem is woody and cylindrical, with alternating nodes and internodes. Branches are sympodial, with a stronger and more developed axis (Hillocks *et al.*, 2002).

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Cassava is a utility root crop grown throughout tropical Asia, Africa and Americas (Devi *et al.*, 2022). It remains an important staple food crop that serves as source of carbohydrates for about one billion people across Africa and Asia, and it is ranked sixth most important source of calories in human diet globally (FAOSTAT, 2024). Cassava has many economic, industrial and ecological importance, which helped in alleviating hunger, malnutrition, unemployment and land degradation (Devi *et al.*, 2022). In Nigeria, cassava is virtually cultivated in most states of the federation including Federal Capital Territory (FCT), Abuja (Eni *et al.*, 2020) and it provides two-third of the daily calories' requirement for people across various ethnic groups (Eni *et al.*, 2020). Cassava demand for root consumption and industrial uses is rising in Nigeria (Ikueomonisan *et al.*, 2020). In North-east and North-western Nigeria, it plays an important role as subsistence and commercial crop, it contributes significantly to household food supply, livestock feed, and agro-industrial raw materials (FAOSTAT, 2024).

Many in-situ researches on cassava genetic diversity using smaller datasets and low-density genotyping have reported population structure to be different across bitter and sweet Brazilian cassava, owing to high haplotype diversity and environmental heterogeneity of cassava-growing regions (Ogbonna *et al.*, 2021). However, ex-situ germplasm collections have revealed comparable structure and spatial

genetic patterns (Ogbonna *et al.*, 2021). Linking such agro-ecological information to available germplasm is essential in pre-breeding activities such as germplasm characterization and subsequent trait architecture dissection (Dwivedi *et al.*, 2016). This can be achieved by georeferencing germplasm collection sites and integrating passport data with agro-ecological variables such as rainfall, temperature, altitude, soil characteristics, and length of the growing season. Tracking and management of germplasm is often challenged by its management cost, the renaming of germplasm by farmers and breeders and a continuous increase in germplasm exchange globally (Kilian and Graner, 2012). Knowledge of the genetic variability and other useful parameters for application in conventional or molecular breeding are essential for their rational use of the germplasm as well as for optimizing the genetic gains (Ogbonna *et al.*, 2021).

Morphological characterization of cassava accessions provides essential baseline information on the variability and distinctiveness of cassava accessions. By evaluating traits such as leaf colour, colour of apical leaves, colour of leaf vein, leaf retention, colour of stem epidermis, root constriction, root shape, and root taste. Such characterization is crucial for breeding programs, genetic conservation, farmer adoption and food security and income generation.

This research was conducted with the aim to evaluate the genotypic variation among cassava accessions collected from North-west and North-eastern regions of Nigeria based on morphological traits for the purpose of identifying genetic variability, establishing distinctiveness, and supporting breeding and conservation programmes.

MATERIALS AND METHODS

Study Area

Field evaluation was conducted at Central and West African Virus Epidemiology (WAVE)-Abdullahi Fodio University of Science and Technology, Aliero (AFUSTA) phenotyping experimental field. The site is located in the University premises, Aliero (latitude 12° 16' 42" N; longitude 4° 27' 6" E, Altitude 262.1 m above sea level). The cassava accessions evaluated were sourced from farmers' fields in North-west and North-east, Nigeria. North-western Nigeria consists of seven (7) states which are: Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto and Zamfara while, North-eastern Nigeria consists of six (6) states which are: Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe.

North-west and North-east are two of the six political regions in Nigeria.

The climate of the two regions is characterized by alternate wet and dry seasons in response to the changes in pressure patterns; the rainy season in these regions is associated with late onset and earlier cessation (Abdulkadir *et al.*, 2013). The challenges of erratic, recurring rainfall variability have adversely affected moisture quality in the two regions. Agriculture is the most dominant economic activity in the two regions (Abdulkadir *et al.*, 2013).

Source of Cassava Accessions and Sampling

A germplasm survey was conducted during 2021/2022 growing season to collect cassava accessions that farmers are growing across the seven (7) states of North-west and the six (6) states of

North-east, Nigeria. In each state, survey routes follow a road map which allowed sampling of cassava fields in various Local Government Areas (LGAs) of the states. In each state, major motorable roads were followed and cassava fields surveyed were minimum of 10 km apart depending on intensity of cassava production as described by Sseruwagi *et al.* (2004). Sampling of cassava fields was done on major roads and occasionally crossing the feeder roads to ensure adequate coverage of cassava fields in each state. Stem cuttings of 294 accessions were sourced from farmers' fields. While two (2) varieties (NR8718 and TME419) were used as checks. The two (2) varieties were sourced from National Root Crops Research Institute (NRCRI) Umudike, Abia State, Nigeria. This makes the accessions used 296 in total (Table 1).

Table 1: Names of the accessions collected from North-west and North-east, Nigeria

Source (State)	Accessions' local name (number collected)
Adamawa	<i>Yar kasa</i> (2), <i>Dan-calaba</i> (2), <i>Farin-iri</i> (4), <i>Bakin-icce</i> (2), <i>Dan-Jalingo</i> (3), <i>Kukun</i> (3), <i>Dan-aku</i> (4), <i>Dan-arziki</i> (2), <i>Bakin-iri</i> (4), <i>Dan-zugunu</i> (1), <i>Dan-dachi</i> (1), <i>Dongon-itache</i> (2), <i>Jan-rogo</i> (2), <i>Dan-kasa</i> (1), <i>Bantagi</i> (1). Total 34
Bauchi	<i>Arziki</i> (5), <i>Dan-wari</i> (2), <i>Duwala</i> (3), <i>Yar waro</i> (1). Total 11
Borno	<i>Dan-Jalingo</i> (3), <i>Dan-Jigawa</i> (3), <i>Doya</i> (5). Total 11
Gombe	<i>Bakin-icce</i> (2), <i>Bakin-iri</i> (1), <i>Dan-Nasarawa</i> (2), <i>Duwala</i> (2), <i>Jan-itache</i> (1), <i>Jan-rogo</i> (2). Total 10
Jigawa	<i>Bakin-iri</i> (3), <i>Farin-iri</i> (3), <i>Mai dara</i> (2), <i>Mai jansule</i> (3). Total 11
Kaduna	<i>Agric</i> (3), <i>Guntun Jijiya</i> (3), <i>Mai daci</i> (2), <i>Mai zaki</i> (2), <i>Rogo mai danko</i> (3), <i>Rogo na gari</i> (2), <i>Tare yunwa</i> (1), <i>Yar kasa</i> (1). Total 17
Kano	<i>Bakin-iri</i> (3), <i>Dan-daci</i> (3), <i>Dan-gargari</i> (2), <i>Dan lafiya</i> (2), <i>Farin-iri</i> (2), <i>Jan-iri</i> (2), <i>Labusa</i> (1), <i>Mai dara</i> (2), <i>Mai ganyen rini</i> (1), <i>Mai siliya</i> (2), <i>Obasanjo</i> (2), <i>Shonakau</i> (2), <i>Sarkin-fawa</i> (3). Total 20
Katsina	<i>Agric</i> (2), <i>Bakin rogo</i> (3), <i>Dan wari</i> (8), <i>Farin rogo</i> (2), <i>Jan rogo</i> (2). Total 26
Kebbi	<i>Badujali</i> (1), <i>Bakin-icce</i> (4), <i>Bako-bako</i> (3), <i>Bakware</i> (4), <i>Baure</i> (1), <i>Dan-ajafa</i> (2), <i>Dan-Agric</i> (3), <i>Dan-Aliero</i> (3), <i>Dan-Niger</i> (4), <i>Dan-Bashalma</i> (1), <i>Dan-Galaru</i> (4), <i>Dan-Kungiya</i> (1), <i>Dan-Rugu</i> (4), <i>Farin-rogo</i> (4), <i>Jan-rogo</i> (3), <i>Toris</i> (1), <i>Bahaushe</i> (4), <i>Barunje</i> (3), <i>Dan-gwamnati</i> (4), <i>Obasanjo</i> (2), <i>Sarkin-fawa</i> (2). Total 39
Sokoto	<i>Bahaushe</i> (7), <i>Bakin-rogo</i> (1), <i>Barunje</i> (4), <i>Dan-bega</i> (1), <i>Dan-galaru</i> (1), <i>Dan-gwade</i> (2), <i>Dan-Bashalma</i> (1), <i>Dan-ware</i> (4), <i>Dan-yada</i> (1), <i>Farin-rogo</i> (3), <i>Jan-rogo</i> (2), <i>Sagam</i> (4), <i>Shabuda</i> (1), <i>Dan-gwamnati</i> (4), <i>Sarkin-fawa</i> (2). Total 38
Taraba	<i>Bahaushe</i> (4), <i>Bakin-icce</i> (2), <i>Bakin-iri</i> (6), <i>Dan-calaba</i> (7), <i>Dan-gwamnati</i> (4), <i>Dan-Jalingo</i> (3), <i>Farin-rogo</i> (4), <i>Jan-rogo</i> (2), <i>Kukun</i> (1), <i>Munpel</i> (2), <i>Pumel</i> (5), <i>Yafin mata</i> (3), <i>Yar kasa</i> (5). Total 42
Yobe	<i>Arzki</i> (3), <i>Duwala</i> (6), <i>Yar waro</i> (5) Total 14
Zamfara	<i>Bahaushe</i> (3), <i>Bakin-rogo</i> (2), <i>Bazamfare</i> (2), <i>Dan-bulagu</i> (1), <i>Dan-mashi</i> (1), <i>Dan-burmi</i> (1), <i>Dan-Gombe</i> (1), <i>Dan-gwade</i> (1), <i>Dan-ware</i> (2), <i>Farin-rogo</i> (2), <i>Jan-iri</i> (2), <i>Jan-rogo</i> (3). Total 21
National Root Crops Research Institute (NRCRI) Umudike, Abia State	NR8718 (1) and TME419 (1). Total 2
Total	296

In each cassava field sampled and surveyed, all the cassava accessions found in the field were assessed using a mobile phone application called Kobo Collect (version v2021.2.4). Cassava accessions were assessed based on some morphological and quantitative traits. The farmers were asked to provide the name of each cassava accession. Stem cuttings were collected for field experiment.

Stem cuttings of the accessions collected were preserved in jute bags and were transported immediately to experimental site for onward planting. Field coordinates (latitude and longitude) of each field sampled and surveyed were recorded using Kobo Collect application.

Planting, Experimental Design and Layout

Stem cuttings of all the cassava accessions collected during the survey were planted at WAVE-AFUSTA cassava phenotyping experimental field. Before planting, the field was cleared, ploughed, harrowed and ridges were made at a spacing of 1 m apart. A pre-emergence herbicide (Bayer Lagon: Aclonifen + Isoxaflutole) was sprayed to manage weed infestation within 24 hours after planting. Cassava stem cuttings of 25 cm to 30 cm each were planted at a spacing of 1 m x 1 m. The stem cuttings were planted into the soil at an angle of 45°, leaving one-third of each stem cutting above the ground with at least three buds inserted into the soil.

The experimental field size was 500 m². The experiment was laid out using an Augmented Design in Randomized Complete Block with three blocks as previously described by Nokoe (2001). Each block measuring 125 m² with 2 m distance between blocks. Fifteen (15) stem cuttings per accession were planted. The cuttings were planted on 15 m long ridges Field

evaluation was conducted during 2022/2023 growing season.

Management of the Experimental Site

The experimental site was fenced with wire to avoid damage by animals. Regular weeding of the experimental site was carried out to avoid competition. The experimental field was irrigated twice in a week during dry season for proper establishment before the onset of rainy season. NPK fertilizer (15:15:15) was applied at a rate of 200 kg ha⁻¹ in two split applications, at 6 and 16 weeks after planting.

Data Collection

Morphological Traits

Qualitative traits were evaluated using the agromorphological descriptors for cassava developed by Fukuda *et al.* (2010). Data were collected at four time points: 3, 6, 9, and 12 (at harvest) months after planting (MAP) (Table 2).

Data Analysis

Morphological frequency distribution was estimated for each of the characters observed among the accessions. The phenotypic variation among the studied cassava accessions for morphological traits was explored using a multivariate analysis technique. Multivariate analysis of the 296 x 14 qualitative data matrices was subjected to principal component analysis (PCA) using R software version 3.6.1 program (R.C.T., 2019). To classify the accessions based on their qualitative traits similarity, the Aggregative Hierarchical Clustering (AHC) and Analysis of Dynamic Clusters (k-means) was carried out (Kumar *et al.*, 2025).

Table 2: Qualitative data and techniques used for scoring

Trait	Code	Scoring	Sampling time (MAP)
Colour of apical leaves	CAL	3 = Light green; 5 = Dark green; 7 = Purplish green; 9 = Purple	3
Leaf color	LC	3 = Light green; 5 = Dark green; 7 = Purple green; 9 = Purple	6
Pubescence on apical leaves	PAL	0 = Absent; 1 = Presence	3
Colour of leaf vein	CLV	3 = Green; 5 = Reddish-green in less than half of the lob; 7 = Reddish-green in more than half of the lob; 9 = All Red	6
Petiole color	PEC	1 = Yellowish-green; 2 = Green; 3 = Reddish-green; 5 = Greenish-red; 7 = Red; 9 = Purple	6

Table 2: Qualitative data and techniques used for scoring (Contuation.)

Trait	Code	Scoring	Sampling time (MAP)
Colour of stem epidermis	CSTE	1 = Cream; 2 = Light brown; 3 = Dark brown; 4 = Orange	9
Colour of end branches	CEBR	3 = Green; 5 = Green-purple; 7 = Purple	9
Colour of stem cortex	CSC	1 = Orange; 2 = Light green; 3 = Dark green	9
Colour of stem exterior	CSE	3 = Orange; 4 = Greeny-yellowish; 5 = Golden; 6 = Light brown; 7 = Silver; 8 = Gray; 9 = Dark brown.	9
Root constrictions	RCO	1 = Few to none; 2 = Some; 3 = Many	12 at harvest
Colour of root cortex	CRC	1 = White or cream; 2 = Yellow; 3 = Pink; 4 = Purple	12 at harvest
External colour of storage root	ECSR	1 = White or cream; 2 = Yellow; 3 = Light brown; 4 = Dark brown	12 at harvest
Root shape	RS	1 = Conical; 2 = Conical-cylindrical; 3 = Cylindrical; 4 = Irregular	12
Colour of end branches	CEBR	3 = Green; 5 = Green-purple; 7 = Purple	9

Source: Fukuda *et al.* (2010). MAP = months after planting.

RESULTS

Qualitative Traits

Among the evaluated accessions, dark green apical leaf colour was the most prevalent, occurring in 192 accessions, followed by light green (52) and purplish green (48), while only four accessions exhibited a purple apical leaf colour (Fig. 1). Apical leaf pubescence was absent in the majority of the accessions, with 199 accessions showing no

pubescence (Fig. 2). Leaf colour assessment revealed that most accessions (201) possessed dark green leaves, whereas a smaller proportion (95) displayed light green leaves (Fig. 3). Regarding petiole colour, yellowish-green was the most common, recorded in 89 accessions, followed by reddish-green in 82 accessions, while green petioles were observed in only 36 accessions (Fig. 4).

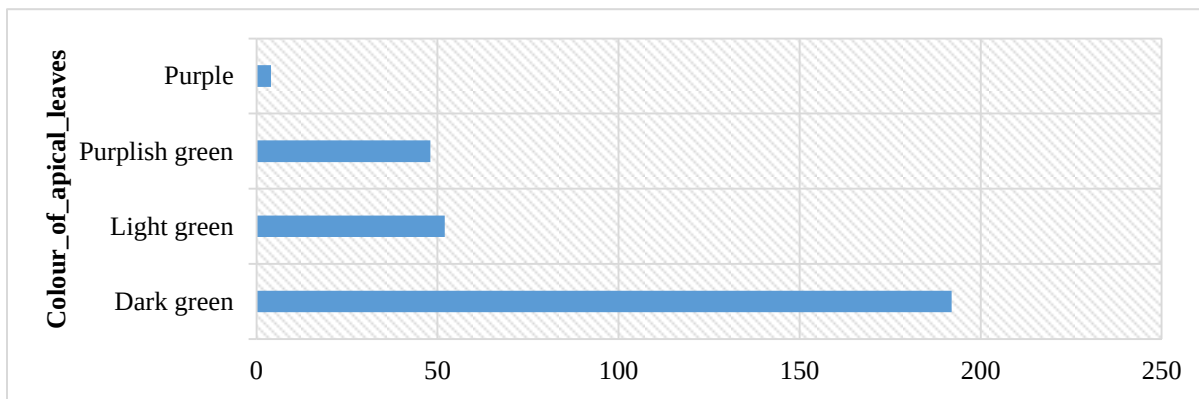


Fig. 1: Distribution of cassava accessions based on colour of the apical leaves.

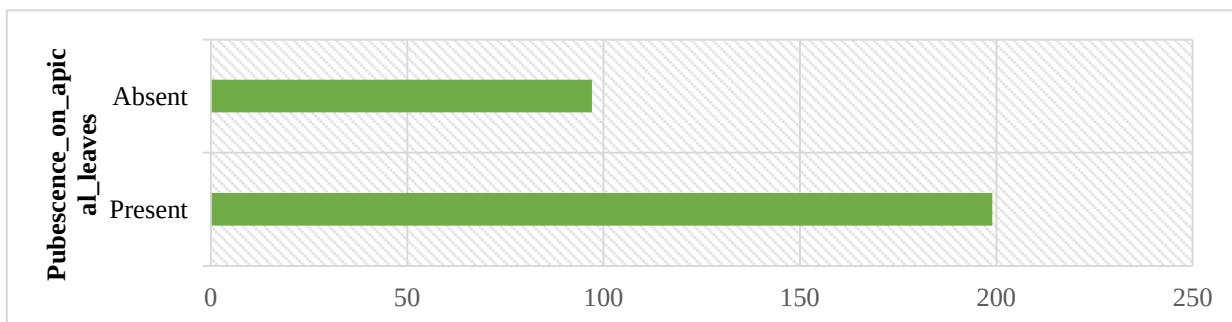


Fig. 2: Distribution of cassava accessions for presence or absence of pubescence on apical leaves

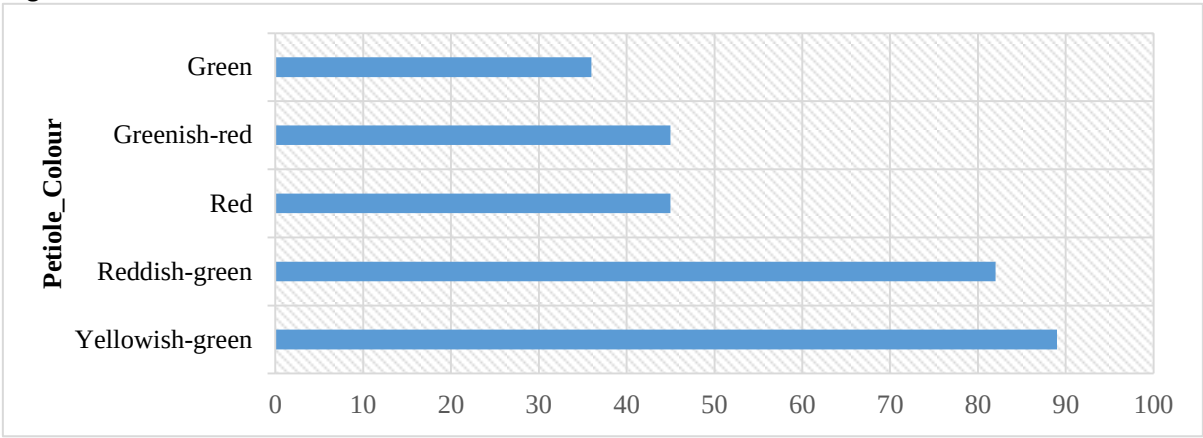


Fig. 4: Distribution of cassava accessions based on petiole colour.

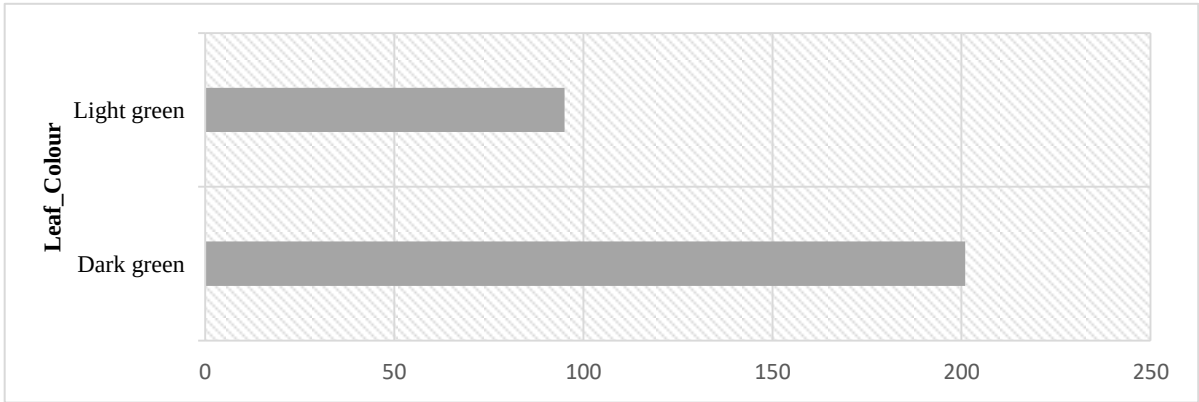


Fig. 3: Distribution of cassava accessions based on leaf colour

Figure 5 shows distribution of accessions based on colour of leaf veins. The results showed that the majority of the accessions (216) exhibited green leaf veins. This was followed by 50 accessions displaying a reddish-green coloration in less than half of the leaf lobe, while 30 accessions showed reddish-green coloration in more than half of the lobe. Regarding the colour of the end branch in adult plants, most accessions (183) had green end branches, followed by 103 accessions with green-purple end branches,

whereas only 10 accessions exhibited purple end branches (Fig. 6). Distribution of accessions based on colour of stem exterior is presented in figure 7. Variation was also observed in stem exterior colour among the accessions. The predominant stem exterior colour was greenish-yellow, recorded in 89 accessions, followed by light-brown in 74 accessions and dark-brown in 52 accessions. A relatively small number of accessions (11) exhibited a golden stem exterior colour.

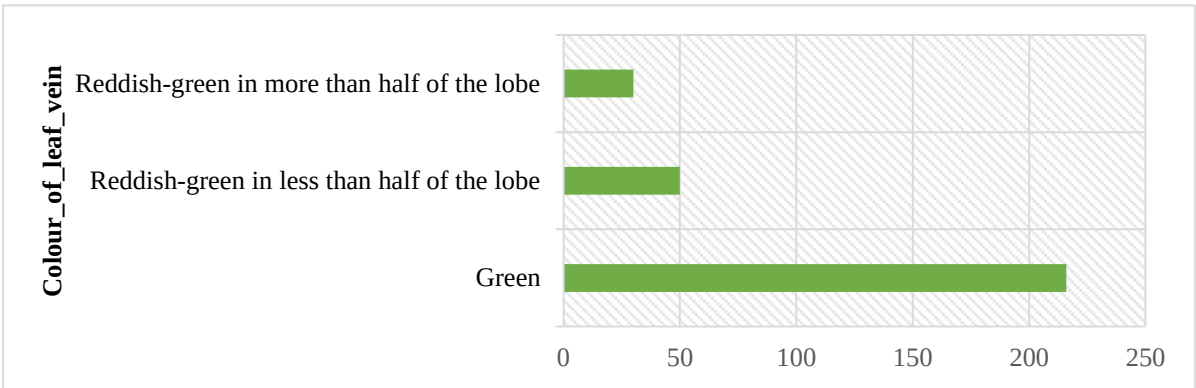


Fig. 5: Distribution of cassava accessions based on colour of leaf veins.

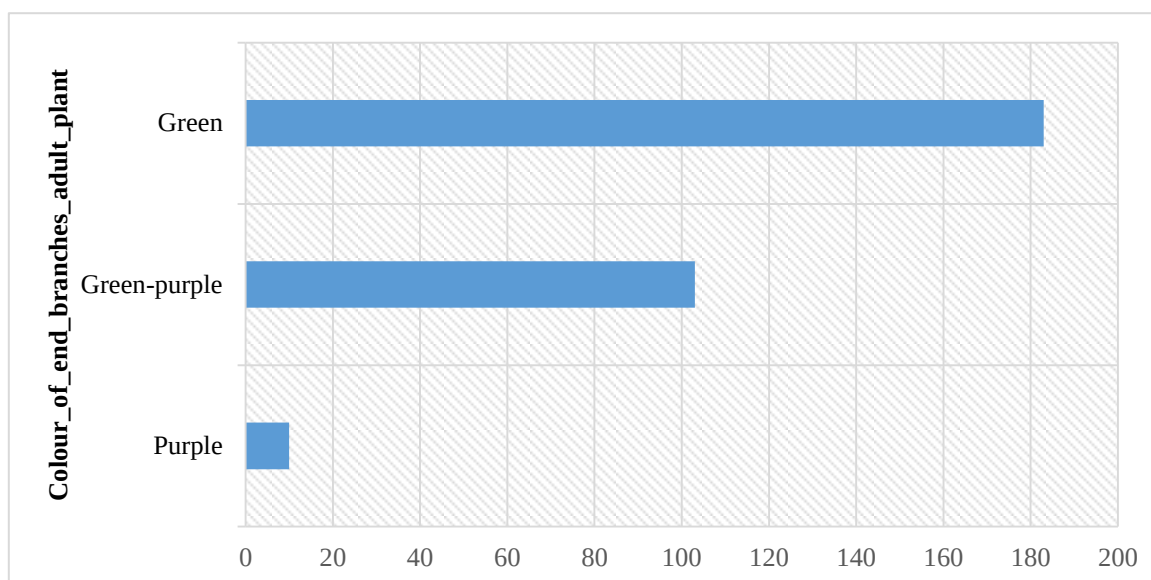


Fig. 6: Distribution of cassava accessions based on colour of end branches of adult plant.

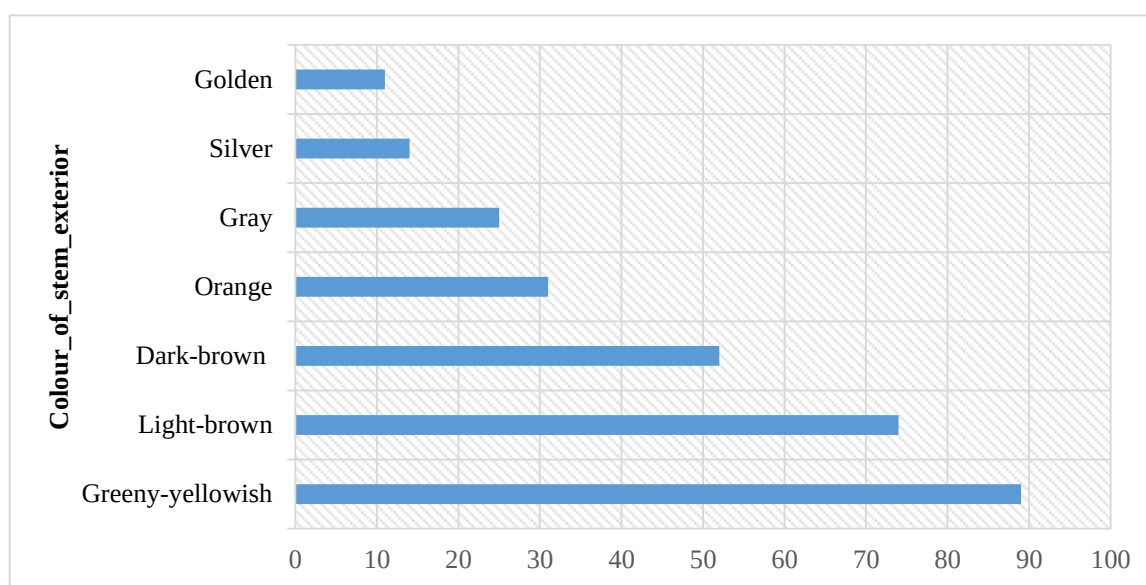


Fig. 7: Distribution of cassava accessions based on colour of stem exterior.

Similarly, stem epidermis colour varied across the evaluated accessions. Light-brown stem epidermis was the most common, occurring in 123 accessions, followed by cream-coloured epidermis in 97 accessions. Orange stem epidermis was the least frequent, being observed in only 27 accessions (Fig.8).

Figure 9 shows results of root shape. Considerable variation was observed among the accessions with respect to root shape. The majority of the accessions

(102) exhibited a cylindrical root shape, followed by 75 accessions with a conical-cylindrical root shape, while 51 accessions displayed a conical root shape. Root constriction also varied among the accessions, with most accessions (146) exhibiting few to no root constrictions. This was followed by 94 accessions showing some root constrictions, whereas 56 accessions recorded many root constrictions (Fig. 10). Furthermore, substantial variation was observed in the external colour of storage roots. The predominant

external colour was light brown, recorded in 122 accessions, followed by dark brown in 85 accessions. Yellow external root colour was the least common, occurring in only 33 accessions (Fig. 11). Similarly, differences were observed in the colour of the root cortex among the evaluated accessions.

White or cream-coloured root cortex was the most prevalent trait, occurring in 164 accessions, followed by pink root cortex in 98 accessions. In contrast, yellow and purple root cortex colours were less frequent, being observed in 22 and 12 accessions, respectively (Fig. 12)

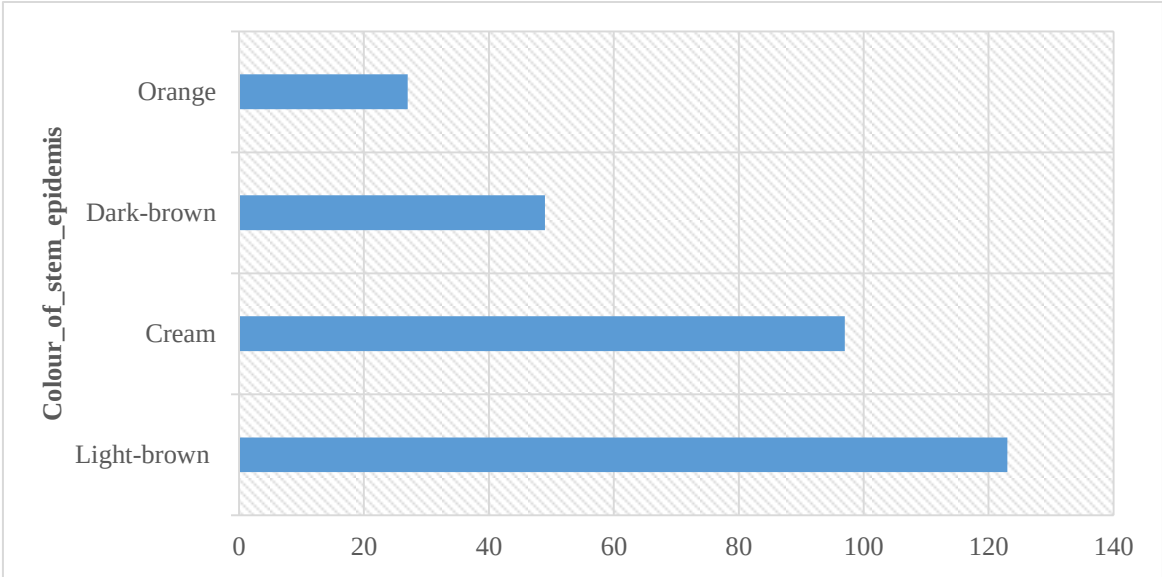


Fig. 8: Distribution of cassava accessions based on colour of stem epidermis.

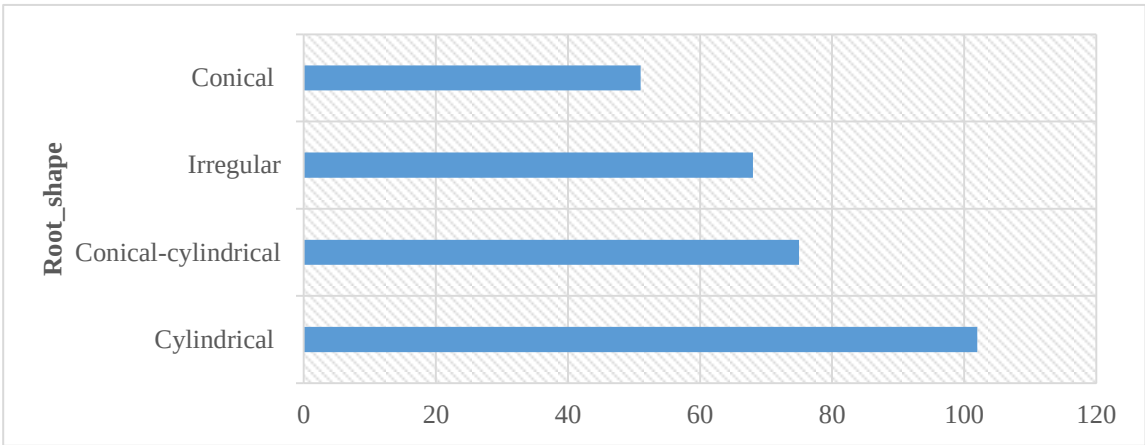


Fig. 9: Distribution of cassava accessions based on root shape.

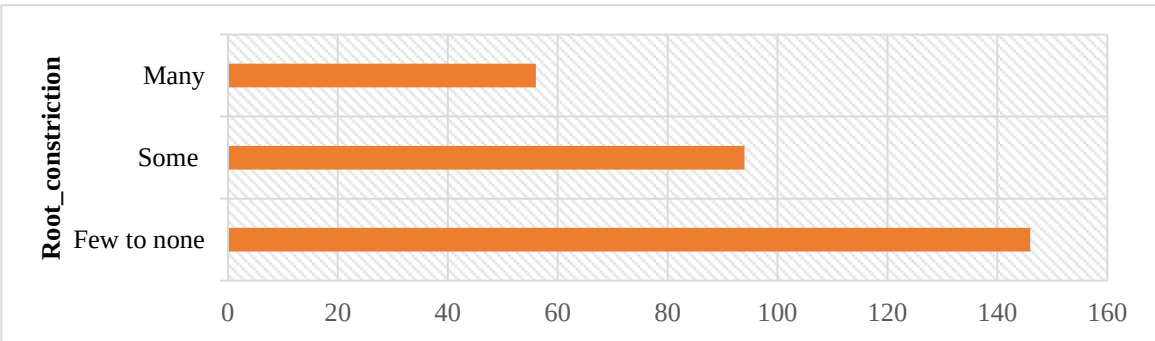


Fig. 10: Distribution of cassava accessions based on root constrictions.

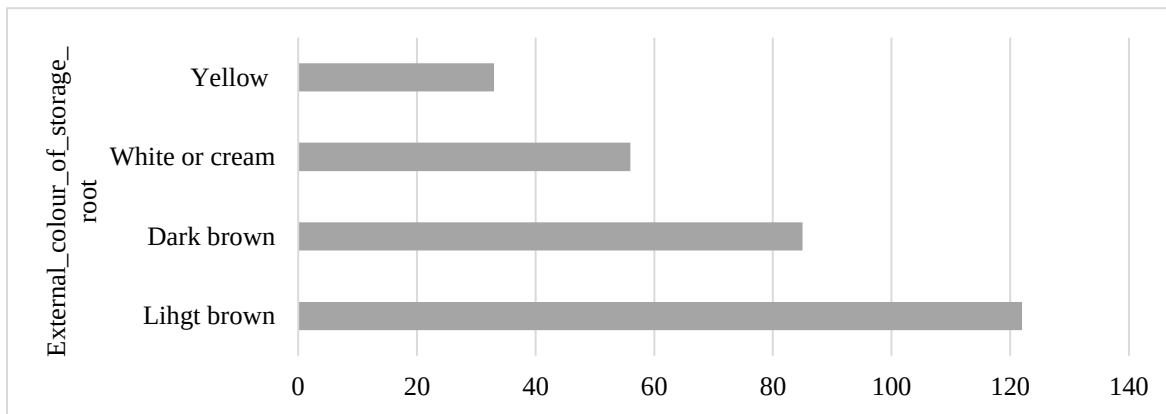


Fig. 11: Distribution of cassava accessions based on external colour of storage roots.

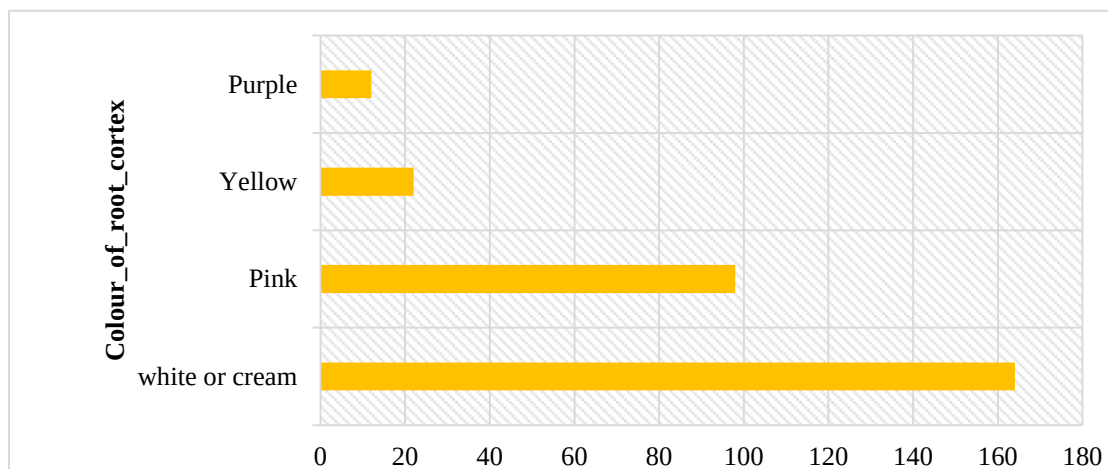


Fig. 12: Distribution of cassava accessions based on colour of root cortex.

Hierarchical Classification of the Accessions based on Qualitative Traits

Hierarchical cluster analysis of the 296 cassava accessions based on 14 qualitative traits classified the accessions into four distinct clusters according to their shared morphological characteristics. Examination of the dendrogram revealed that the clustering pattern was largely independent of the two geopolitical zones from which the accessions were collected, indicating no clear geographical grouping. The genetic similarity

coefficient for the qualitative traits ranged from 0.0 to 0.5, with an average similarity of 0.4. As illustrated in Fig. 13, the distribution of accessions across the clusters was highly uneven, with Cluster I containing 9 accessions, Cluster II comprising a single accession, Cluster III containing 6 accessions, and Cluster IV encompassing the majority of the accessions (280). The first two dimensions of the Factor Analysis of Mixed Data (FAMD) accounted for 10.6% of the total variation among the cassava accessions. Dimension 1

(Dim 1), which explained 6.1% of the variation, was primarily associated with plant architectural traits, including branching habit, branching level, and height to the first branching point. Dimension 2 (Dim 2) accounted for 4.5% of the total variation and was mainly influenced by leaf morphological characteristics such as leaf lobe length, leaf lobe width, and petiole traits. In contrast, root quality traits contributed only moderately or weakly to the variation captured by these two dimensions (Fig. 14).

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DISCUSSION

Considerable variation exists among the cassava accessions evaluated for several qualitative traits

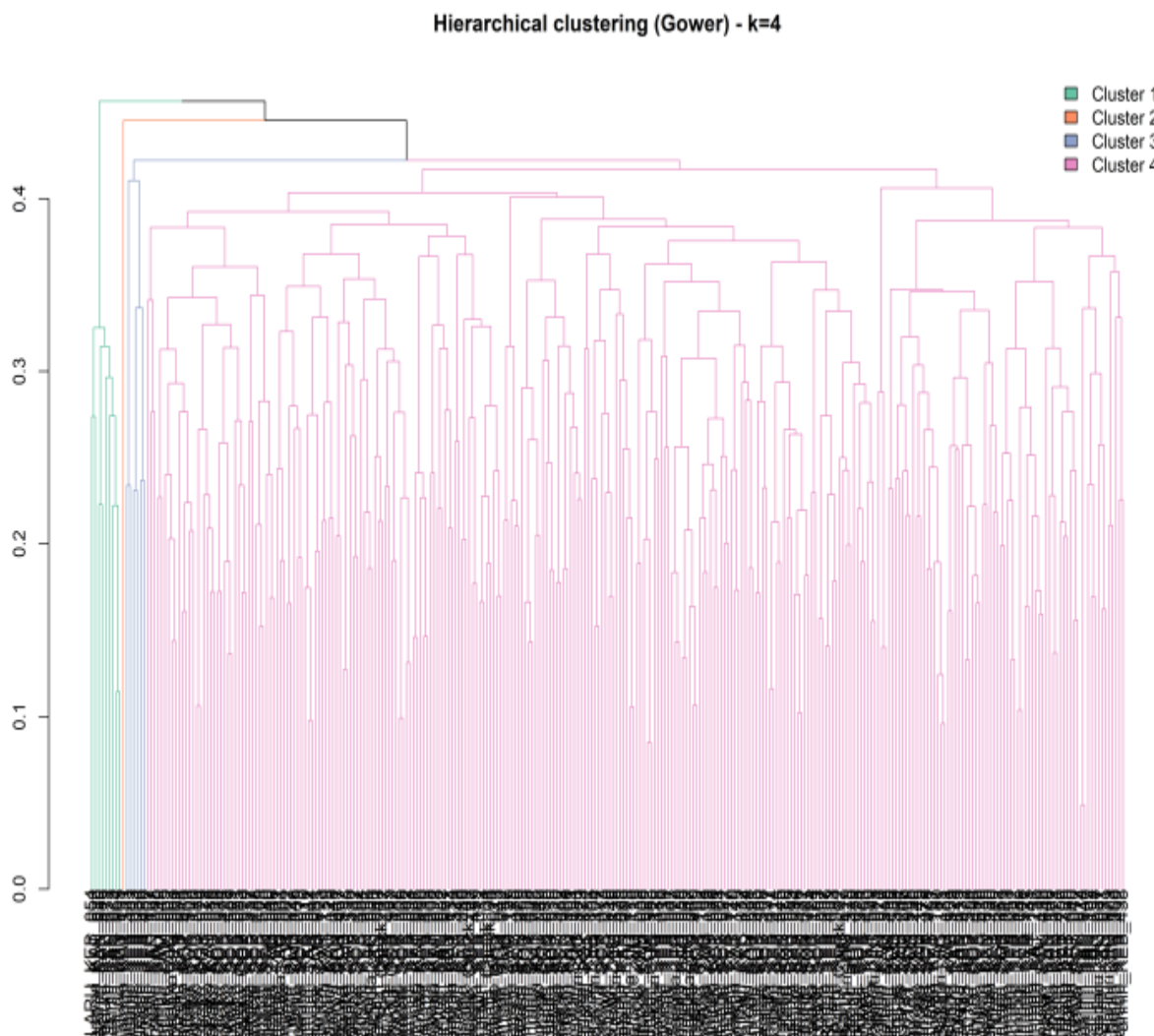


Fig. 13: A dendrogram showing the dissimilarity of 296 accessions by an average distance method of hierarchical clustering patterns using 14 qualitative traits

Variable Contributions

The first two dimensions of the Factor Analysis of Mixed Data (FAMD) accounted for 10.6% of the total variation among the cassava accessions. Dimension 1 (Dim 1), which explained 6.1% of the variation, was primarily associated with plant architectural traits, including branching habit, branching level, and height

associated with plant growth and morphology. These traits included leaf colour, petiole colour, apical leaf colour, leaf vein colour, stem exterior colour, root shape, root cortex colour, and leaf retention, among others. Such qualitative descriptors are valuable for varietal identification, characterization, and selection by farmers. According to Karim *et al.* (2020),

qualitative traits play a significant role in the identification and selection of cassava varieties. Likewise, Agre *et al.* (2016) reported that farmers commonly use leaf and stem colour characteristics to distinguish among cassava varieties. The observed variability among cassava accessions evaluated in the present study is consistent with the findings of Amara *et al.* (2024), Kumar *et al.* (2025) and Bilate-Daemo *et al.* (2023). Earlier, Laila *et al.* (2021) reported that agro-morphological traits have long been recognized as reliable indicators of genetic variability in cassava populations. Bilate *et al.* (2022) emphasized that

cluster analysis is a useful tool for grouping genetically similar cassava varieties while distinguishing them from more divergent genotypes. In the present study, the Aggregative Hierarchical Clustering (AHC) and K-means clustering analyses grouped the 296 cassava accessions into four distinct clusters based on similarities in their qualitative traits. The clustering pattern was independent of the geopolitical zones from which the accessions were collected, indicating a lack of clear geographic structuring among the genotypes.

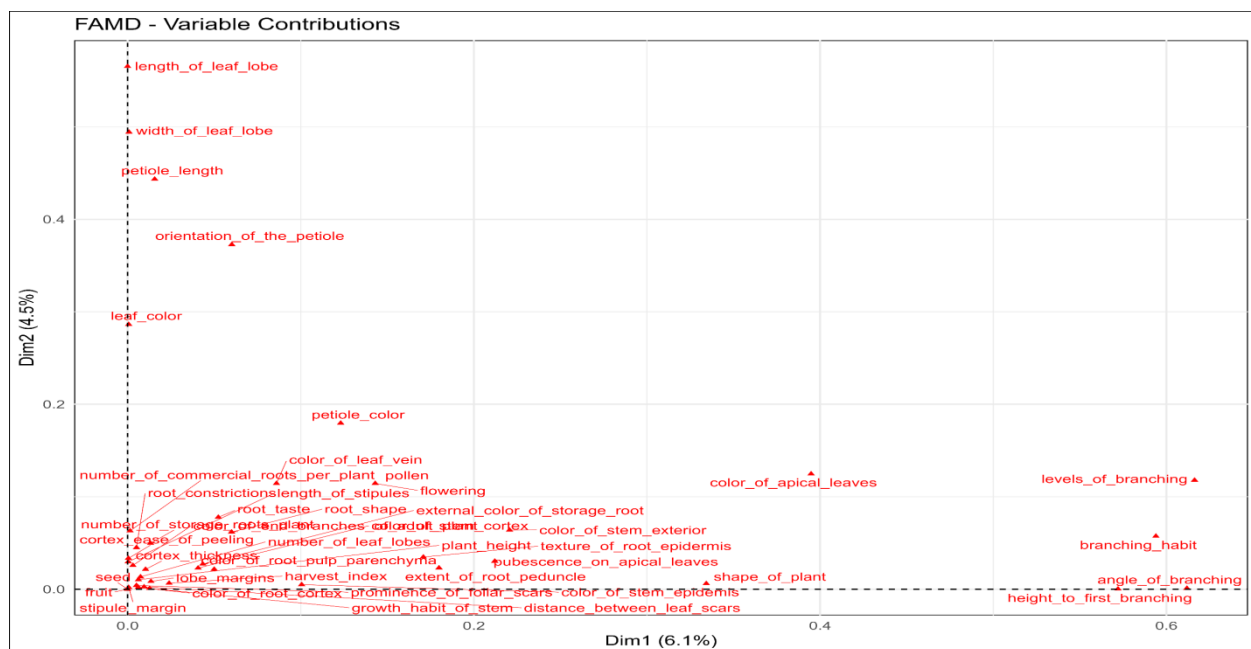


Fig. 14: Contribution of morphological traits to the first two dimensions derived from the Factor Analysis of Mixed Data (FAMD).

Notably, the majority of the accessions were assigned to Cluster IV, suggesting a high degree of similarity among cassava accessions cultivated across North-western and North-eastern Nigeria. This pattern may be attributed to the continuous exchange of planting materials among farmers through the informal cassava seed system. In these regions, farmers commonly obtain stem cuttings from neighbouring farms, nearby communities, or previous harvests, facilitating the widespread dissemination of similar genotypes. Comparable findings were reported by Amara *et al.* (2024), who grouped 103 cassava accessions into three clusters, and by Karim *et al.*

(2020), who classified 102 accessions into five clusters. The clustering pattern observed in this study also agrees with the findings of Afonso *et al.* (2014). Similarly, Abegunde *et al.* (2024) grouped 470 cassava accessions collected from South-western and North-central Nigeria into three clusters based on qualitative traits.

The Factor Analysis of Mixed Data (FAMD) further revealed the traits contributing most to the observed variation among the accessions. Leaf morphological traits, particularly leaf lobe length, leaf lobe width, and petiole characteristics, were the major contributors to Dimension 2, which accounted for

4.5% of the total variation. In contrast, root quality traits exhibited moderate to low contributions to the first two dimensions of the FAMD analysis, suggesting that these traits are only partially associated with canopy architecture and leaf morphology. This relative independence indicates that selection for canopy-related characteristics may not necessarily result in corresponding changes in root quality traits, thereby providing opportunities for independent improvement of both trait groups in cassava breeding programmes.

Conclusion

This research established the existence of substantial genetic variability among cassava accessions cultivated in the North-east and North-west geopolitical zones of Nigeria. This suggests considerable genetic diversity within the cassava germplasm cultivated within the study areas. Cassava accessions were clearly grouped into distinct clusters. This indicated differences and similarities among the cassava accessions cultivated in the study areas. This

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further reveal that farmers do source or transfer cassava seeds among themselves within the study areas.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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