Scientific Research Publishing

Open Journal of Applied Sciences, 2025, 15(6), 1661-1677
https://www.scirp.org/journal/ojapps
ISSN Online: 2165-3925
ISSN Print: 2165-3917

Endogenous Knowledge and Morphological Characterization of Cassava (*Manihot esculenta* Crantz) Accessions Found in Some Agricultural Areas of Gabon

Gino Boussiengui-Boussiengui*, René Noël Poligui, Christie Yaëlle Massounga, Henri Nzandi, Pherla Ichida Oyanadigui Odjoueri, Armel Mouketou Mouketou, Denis Assey, Antoine Mitte Mbeang Beyeme, Christian Moupela

Département de Phytotechnologie, Institut National Supérieur d'Agronomie et de Biotechnologies, Université des Sciences et Techniques de Masuku, Franceville, Gabon
Email: *gbouss@gmail.com

How to cite this paper: Boussiengui-Boussiengui, G., Poligui, R.N., Massounga, C.Y., Nzandi, H., Oyanadigui Odjoueri, P.I., Mouketou Mouketou, A., Assey, D., Mbeang Beyeme, A.M. and Moupela, C. (2025) Endogenous Knowledge and Morphological Characterization of Cassava (*Manihot esculenta* Crantz) Accessions Found in Some Agricultural Areas of Gabon. *Open Journal of Applied Sciences*, **15**, 1661-1677.
https://doi.org/10.4236/ojapps.2025.156114

Received: May 11, 2025
Accepted: June 22, 2025
Published: June 25, 2025

Abstract

Cassava is a food crop that contributes to food security and is well established in Gabon. Taking into account endogenous knowledge and the dynamics of accessions agrobiodiversity at national level is necessary to undertake conservation strategies to reduce genetic erosion. Based on a participatory survey approach with field visits and data collection, 43 villages spread over seven (7) departments comprising 13 socio-cultural groups were surveyed. In the villages surveyed, 82.75% of cassava cultivation is carried out by women and 54.55% by farmers under 55 years of age. Of the 110 farms visited, 93.64% are individual farms and 6.36% are cooperatives found exclusively in the provinces of Woleu Ntem and Nyanga. The areas under individual use are less than 1 ha, compared with 5 - 22 ha for cooperatives. The harvest is done from 6 months for early accessions and 12 months for late ones. As for the cuttings, it is done in old plantations aged 8 to 12 months. A main component analysis (PCA) although low (22.50%) confirms morphological variability. In addition to the major descriptors (color of the apical leaf, color of the main rib, color of the petiole and sometimes color of the terminal branch), endogenous knowledge of cassava accessions is based on the phenotypic characteristics, the place of origin or on the introducer of the accession in the locality. The Hierarchical Ascending Classification (AHC) has allowed the structure of these accessions in 3 groups of morphological diversity. Group 1 consists of accessions with a small first branching height (<1 m) and a large branching angle (>90˚). Group 2 comprises individuals with a larger first branching height (>1.35 m) and a low branching angle (<90˚). In the third group, accessions are mainly characterized by the absence of branching. The identification of these different groups offers a great opportunity for the creation of improved cassava varieties in Gabon.

Keywords

Cassava, Accessions, Gabon, AHC, PCA

1. Introduction

Cassava (*Manihot esculenta* Crantz) originates from Latin America and is increasingly grown in tropical and subtropical regions. In the tropics, it is the primary source of calories [1] (Dixon *et al.*, 2002) and the source of income for small farmers. It is considered one of the main sources of carbohydrates, being a staple food mainly for people in Latin America and Africa [2] (Alvarez *et al.* 2007), which use both tuberosilic roots as a rich source of starch and, the leaves as source of protein, minerals and vitamins [3] (Ceballos, 2012). The crops were introduced in Gabon after the first world war by cultivars returning from Congo [4] (Raponda-Walker and Sillans, 1961).

Due to its easy cultivation, year-round availability, and tolerance to extreme ecological and biotic stress conditions, a wide variety of cassava genotypes can be found in the growing areas [5] (Lozano, 1985), [6] (Nweke *et al.*,1994), [1] (Dixon *et al.*, 2002). The diversity is due to the fact that genotypes respond differently to different climatic and biotic factors, while also the constant exchange of genetic material among cassava farmers [7] (Maroya, 1997). Some of these characters can be relevant for varietal improvement and breeding programs. Indeed, [8] (Fukuda and Guevara, 1998) indicated that the evaluation of the existing genetic variability is necessary and must be based on appropriate and recognized descriptors.

According to [9] (Hahn, 1979), the movement of cassava plant material between producers not only preserves and protects varietal diversity, but also provides indications of the preferences of farmers for cassava in a country or agro-ecological zone.

To better express these preferences, producers distinguish the different cassava genotypes by local names that are generally descriptive of the physical characteristics of the plants, such as the color of certain organs, size and type of foliage, yield potential and production cycle etc. These names may also describe the original source of the genotype or indicate an event that coincides with the introduction of the genotype [7] (Maroya, 1997). Despite their significance, these names are of little use in a botanical classification of different varieties because the same variety can have several names from one village to another or from one ethnical group to another.

To our knowledge, few studies on the analysis of endogenous knowledge and phenotypic characterization of cassava varieties have been done in Gabon except for some unpublished works by the Ministry of Agriculture describing some varieties in a non-exhaustive way.

The aim of this study is to identify the morphological characteristics of cassava accessions encountered in agricultural areas of Gabon. Specifically, this work aims to inventory cassava accessions present in the areas surveyed, identify key criteria for recognition of accessions, and analyze morphological variability within the cassava accessions encountered.

2. Materials and Methods

2.1. Site Selection Criteria and Data Collection Methodology

The study was carried out between 2018 and 2020 in some agricultural areas of the provinces of Woleu Ntem, Ngounié, Ogooué-lolo, Moyen Ogooué, Nyanga and Haut-Ogooué in Gabon including seven (7) departments (**Figure 1**). The choice of locations and farmers was made not only on the basis of accessibility, but also their ability to identify different accessions in local languages.

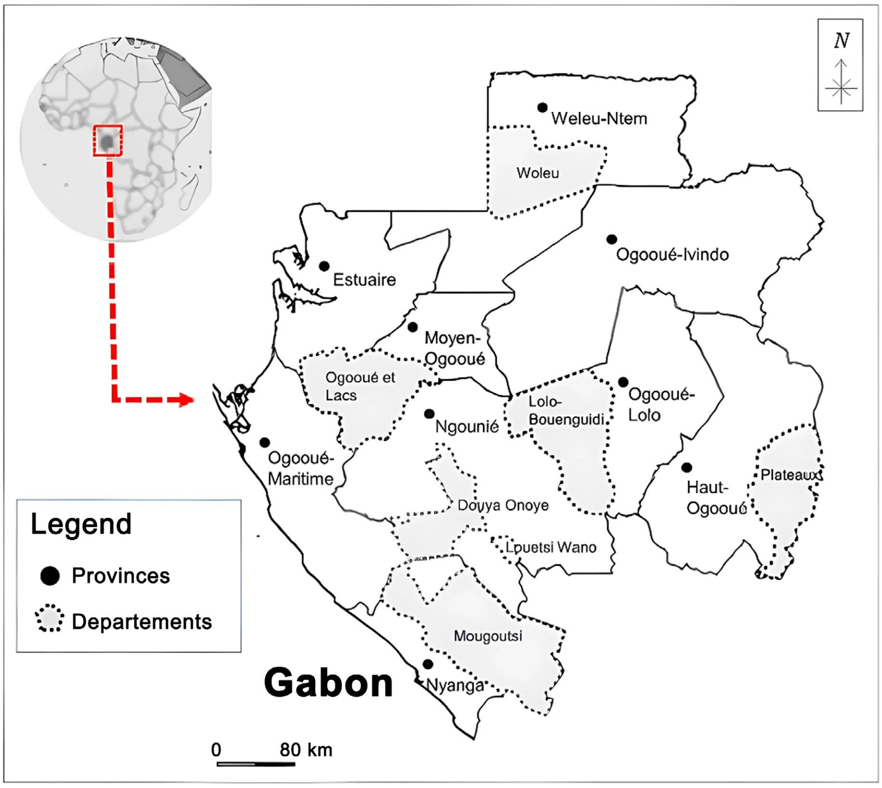

Figure 1. Location of prospected sites for the study.

Data were collected during expeditions from the different sites through the application of participatory research appraisal tools and techniques, such as direct observation, group discussions, individual interviews, and field visits using a questionnaire following [10] (Adjatin *et al.*, 2012), [11] (Kombo *et al.*, 2012). In each village, interviews were conducted with the help of a local translator and groups surveyed were made of 5 to 10 farmers of both sexes and of different ages identified and assembled with the assistance of the local farmers' associations and the chief of the village involved in the study to facilitate the organization of the meetings and the collection of data according to [11] (Kombo *et al.*, 2012).

2.2. Measured Parameters

Seventeen variables were determined, including 12 qualitative and 06 quantitative. Three plants/accessions were measured and observed. All of its measurements and observations were made according to the criteria defined by [12] (Fukuda *et al.*, 2010). Qualitative variables are essentially the color of the apical leaves (CAL), the shape of the central leaflet (SCL), the color of the leaf vein (CLV), the petiole color (CP), the color of the stem cortex (CSC), color of mature leaf (CML), the color of stem epidermis (CSE), color of end branches (CEB), external color of the root (ECR), the color of root cortex (CRC) and the color of root pulp (CRP). For quantitative variables, the number of lobes (NL), length of petiole (LP), distance between leafs scars (DLS), height of first branch (HFB), diameter at the neck of the main stem (DNS) and angle of first branch (AFB).

2.3. Statistical Analysis of Data

The matrix of data composed of the means of quantitative variables and the different modalities of qualitative variables was used to carry out a Principal Component Analysis (PCA). The variables that contribute most to axis formation were defined as active variables and the rest as additional variables. An Ascending Hierarchical Classification (AHC) then allowed to classify accessions into homogeneous groups according to the Ward method using a similarity index of the Euclidean distance. These multivariate analyses were performed using the XLSTAT 2022 software.

3. Results and Discussion

3.1. Characteristics of the Prospected Area

The data related to the villages and socio-cultural groups, characteristics of the farms, age distribution and gender approach are respectively presented in **Tables 1-3**.

Table 1. List of prospected villages and socio-cultural groups.

Number	Villages	Departements	Provinces	Socio-cultural groups
1	Makongola	Lolo-Bouenguidi	Ogooué Lolo	Nzebi
2	Mayang	Lolo-Bouenguidi		Nzebi
3	Aéroport	Lolo-Bouenguidi		Massango
4	Ngoungui	Lolo-Bouenguidi		Pouvi
5	Camp militaire	Lolo-Bouenguidi		Massango
6	Mabimbi	Lolo-Bouenguidi		Akélé

Continued

7	Ikembelé	Lolo-Bouenguidi		Akélé, Massango, Nzébi
8	Makongola	Lolo-Bouenguidi		Nzébi
9	Kounadémbé	Lolo-Bouenguidi		Massango
10	Mokabo	Douya Onoye		Mitsogo
11	Moukidi	Douya Onoye		Punu
12	Mouila	Douya Onoye	Ngounié	Punu, Nzébi
13	Mouyamba	Louetsi Wano		Massango
14	Lebamba	Louetsi Wano		Nzébi
15	Adzabikat	Woleu		
16	Elop	Woleu		
17	Abang-Medoumou	Woleu	Woleu Ntem	Fang
18	Essong Medzome	Woleu		
19	Mbam Assengma	Woleu		
20	Nzela Bola	Ogooué et Lacs		Nzébi/Woumbou
21	Koungoule	Ogooué et Lacs		Echira/Fang
22	Lobi-Mbigou	Ogooué et Lacs		Massango
23	Mbolet	Ogooué et Lacs	Moyen Ogooué	Akélé/Nzébi
24	Issala II	Ogooué et Lacs		Massango
25	Mitoné	Ogooué et Lacs		Miènè/Fang
26	Massika	Ogooué et Lacs		Punu/Mitsogo
27	Mouroumbi	Mougoutsi		Punu
28	Mabotsa	Mougoutsi		Loumbou
29	Manfila	Mougoutsi		Loumbou
30	Moumbatsi	Mougoutsi		Punu
31	Payilou	Mougoutsi	Nyanga	Punu
32	Mouhanzi	Mougoutsi		Loumbou
33	Bidembe	Mougoutsi		Punu
34	Gorde	Mougoutsi		Punu
35	Ilama	Mougoutsi		Punu
36	Midjongou	Mougoutsi		Punu
37	Ossolé	Plateaux		
38	Odjouma	Plateaux		
39	Ampou	Plateaux		
40	Akou	Plateaux	Haut-Ogooué	Téké
41	Souba	Plateaux		
42	Abouyi	Plateaux		
43	Eau clair	Plateaux		

Table 2. Characteristics of the farms found in agricultural areas.

No	Province	Departement	Exploitation	Total	Area (ha)	Harvest (month)	Cutting (month)
1	Haut Ogooué	Plateaux	Cooperative	0	-	≥8	≥8
			Personal	31	≤1		
2	Moyen Ogooué	Ogooué et Lacs	Cooperative	0	-	≥12	12
			Personal	15	≤1		
3	Woleu Ntem	Woleu	Cooperative	4	≥5	≥6	≥8
			Personal	2	≤1		
4	Nyanga	Mougoutsi	Cooperative	3	≥10	≥8	≥8
			Personal	19	≤1		
5	Ogooué Lolo	Lolo Bouéguidi	Cooperative	0	-	≥8	≥8
			Personal	20	≤1		
6	Ngounié	Doya/Louétsi wano	Cooperative	0	-	≥12	≥8
			Personal	16	≤1		
Total	**6**	**8**		**110**			
			Cooperative	**7** (6.36%)	**[5 - 22]**	**[6 - 12[**	**[8 - 12]**
			Personal	**103** (93.64)	**≤1**		

Table 3. Age distribution of respondents and gender approach.

	Characteristics		
Ages	**Total**	**Women**	**Men**
[30 - 55[	60 (**54.55%**)	50 (**54.95%**)	10 (**52.63%**)
[55 - 77]	50 (**45.45%**)	41 (**45.05%**)	9 (**47.37%**)
Total	110 (**100%**)	91 (**82.73%**)	19 (**19.27%**)

Except Haut Ogooué (Plateaux Department) and Woleu Ntem (Woleu Department) where only one dominant socio-cultural group is found, the rest of the prospected area is composed of farmers from two (2) to nine (9) socio-cultural groups (**Table 1**). This can be explained by the fact that those two departments are populated by only one ethnic group (Fang for Woleu Department and Téké for Plateaux Department), which is not the case for the other prospected area, where the highest socio cultural group diversity was found in the Department of Ogooué and lacs.

Out of the six (6) provinces and the seven (7) departments surveyed, 93.64% are personal farms (planting area ≤ 1 ha) against 6.36% of cooperatives (planting area between 5 and 22 ha) found only in Nyanga and Woleu Ntem provinces (**Table 2**). Similar results were observed by [13] (Amadi *et al.*, 2020) where farms use less than 1ha and 80% - 82% did not belong to a cooperative society in Imo state of Nigeria. In this study, the presence of cooperatives is justified by the implementation of the PDAR ("Projet de Développement Agricole et Rural"), with the help of IFAD (International Fund for Agricultural Development). The project plans on developing nurseries for peanuts, plantains and cassava, and promoting the creation and organization of local farming cooperatives, while providing the facilities for the transformation and commercialization of farm products.

Regarding age and gender approach, 54.55% of farmers are under 55 years old and 45.45% are aging between 55 and 77 years old, with women representing 82.73% of active farmers (**Table 3**). Similar results suggest that cassava farming is practiced more by women than men [14] (Nwaobiala *et al.*, 2019), [15] (Claudette and Roger, 2022). Also, the average age of cassava farmers across Cameroon regions is 42.2 years [15] (Claudette and Roger, 2022), lower than the average of 53.5 years observed in agricultural areas of Gabon and confirmed by [16] (Mouketou *et al.*, 2023).

3.2. Endogenous Knowledge: Key Criteria for Recognition of Cassava Accessions by Farmers

Group discussions, individual interviews with cassava producers, and field visits using a questionnaire were done to determine the recognition criteria. The major criteria are presented in **Figure 2**.

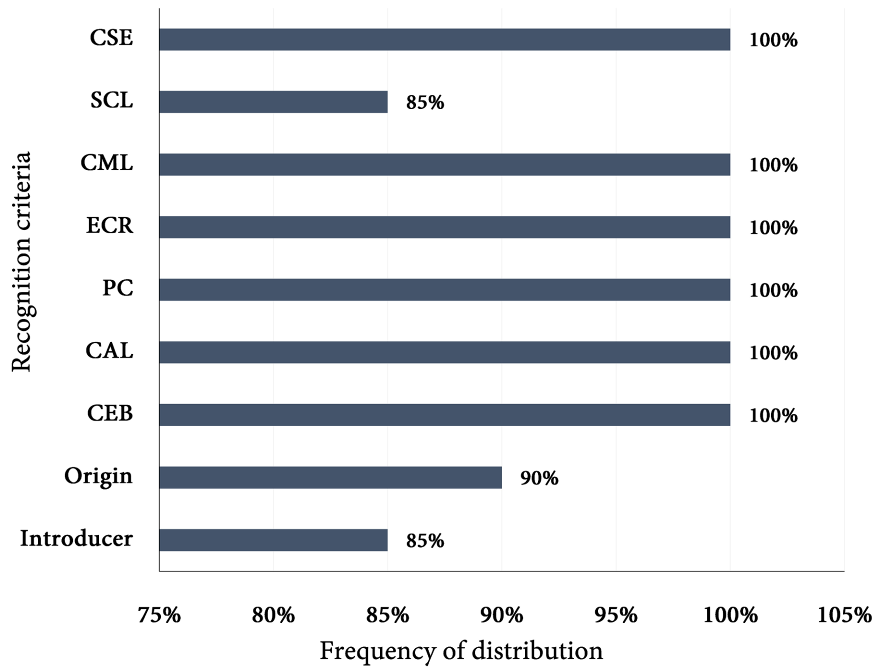

Figure 2. Major criteria for recognition of cassava accessions by producers. **CSE**: color of the stem exterior, **CEB**: color of end branches, **CML**: color of mature leaf, **ECR**: External color of the storage root, **PC**: petiole color, **CAL**: color of apical leaves, **SCL**: shape of central leaflet.

In Gabon, more than 85% of farmers distinguish different cassava accessions based on the morphological characteristics, origin and introducer (**Figure 2**). The seven (7) morphological characteristics are the color of the stem exterior (CSE), the color of end branches (CEB), the color of mature leaf (CML), the external color of the storage root (ECR), the petiole color (PC), the color of apical leaves (CAL) and the shape of central leaflet (SCL). The analysis of morphological characteristics in various organs showed variations within the studied accessions. Color appears to be the most representative and similar results were obtained by [17] (Asare *et al.*, 2011), [18] (Doussouh *et al.*, 2016), [19] (Nadjiam *et al.*, 2016), [20] (Djaha *et al.*, 2017). In addition, [21] (Agre *et al.*, 2016) have reported that farmers use the colors of the leaves and stems to identify the cassava cultivars. Also, the inter-ethnic union through filiate links or by purchasing cuttings would have favored this exchange of accessions. Hence, the presence of cultivars bearing names of their origins (Ongali, Akiéni) or people (Nzaou, Pauline) who would have introduced them into a locality. According to [22] (Delêtre, 2010) and [20] (Djaha *et al.*, 2017), this designation often leads to confusion since the same accession may have different names depending on the area of cultivation but also the language.

3.3. Variability of Diversity in the Prospected Provinces

In total, 211 accessions were recorded in the six (6) provinces prospected, where the highest number of 51 accessions were found in Haut Ogooué, 44 in Ogooué Lolo, 42 in Moyen Ogooué and 39 in Nyanga (**Table 4**). Except for Haut Ogooué, where 86.27% of the accessions are bitter, the rest of the provinces cultivate more than 56% of sweet accessions.

Table 4. Variability of the number of local cassava accessions by provinces.

No	Provinces	Total accessions	Sweet accessions (%)	Bitter accessions (%)
1	Haut Ogooué	51	7 (**13.73%**)	44 (**86.27%**)
2	Moyen Ogooué	42	31 (**73.80%**)	12 (**26.19%**)
3	Woleu Ntem	14	8 (**57.14%**)	6 (**42.86%**)
4	Nyanga	39	30 (**76.92%**)	9 (**23.08%**)
5	Ogooué Lolo	44	25 (**56.82%**)	19 (**43.18%**)
6	Ngounié	21	14 (**66.67%**)	7 (**33.33%**)
Total	**6**	**211**	**115 (54.50%)**	**97 (45.50%)**

High levels of accession diversity, however, do not necessarily imply high levels of genetic diversity since out of the 211 recorded accessions, only 98 were different to each other. The distinctness can arise from a combination of environmental and recognition factors. Different collection sites may have resulted in capturing unique genotypes or phenotypes, contributing to the distinct count. Variability in environmental conditions (e.g., soil type, climate) where accessions were collected can lead to phenotypic differences, even among genetically similar plants. The initial sample size may have included duplicates or closely related accessions that were not genetically distinct, leading to a higher number and less distinct accessions when duplicates are removed.

There are several mechanisms through which diversity can be increased locally, the most important of which is the dissemination of accessions alongside the flow of people. This was confirmed by [22] (Delêtre, 2010) in its works on manioc diversity in Gabon. Exchanges of cuttings between farmers were extremely frequent in the prospected areas and represented the principal medium for farmers to acquire new accessions. But repeated and independent introductions of the same accession in a village, or the simple deformation of the original name while the accession passes down the generations and circulates among farmers, can generate synonymies, thereby artificially increasing diversity. This was also confirmed by [22] (Delêtre, 2010).

The observed higher level of bitter accessions in Haut Ogooué province compare to the other provinces can be explained by the dietary habits. In fact, in Plateaux Department, cassava sticks and fufu are staple foods, and adequate preparation before eating are therefore crucial steps for reducing the natural hydrocyanic acid [23] (Montagnac *et al.*, 2009). In the other provinces, in addition to above mentioned staple food, cooked cassava tuber is used which may justify the presence of 56% to 77% of sweet accessions.

3.4. Principal Component Analysis (PCA)

Multivariate analyses are statistical methods used in diversity analysis. In this study, multivariate analyses were used to elucidate the nature and degree of divergence of cassava accessions collected in different agro-ecological zones of Gabon. The PCA, applied to the 98 accessions on the basis of 17 morphological variables (11 qualitative and 6 quantitative), results in a low variability (25.12%) within the accessions analyzed and revealed by the first two axes. The data might have low inherent variability, suggesting that the traits do not change much across observations. It suggests that many qualitative characters are correlated or redundant, they may not contribute significantly to overall variance and the PCA may capture only a small amount of the total variability. This variability is lower than that observed by [24] (Ephrem *et al.*, 2014) in the Central African Republic and [21] (Djaha *et al.*, 2017) in Côte d'Ivoire. Indeed, these authors obtained variabilities of 55% and 63.84%, respectively.

The lower variability observed in this work can be explained by not only the higher exchange rate of accessions between farmers, but also similarities observed within accessions bearing different names from one agricultural zone to another. Duplicates in cassava were often highlighted by several authors in numerous collections throughout the world [17] (Asare *et al.*, 2011), [25] (N'Zue *et al.*, 2014), and different accessions can have the same name or several names can be assigned to one accession [26] (Elias *et al.*, 2011). Exchanges of cuttings between farmers were extremely frequent in the prospected areas, and represented the principal medium for farmers to acquire new accessions [22] (Delêtre, 2010). But, repeated and independent introductions of the same accession in a village, or the simple deformation of the original name while the accession passes down the generations and circulates among farmers, can generate synonymies, thereby artificially increasing diversity [22] (Delêtre, 2010) (**Figure 3**).

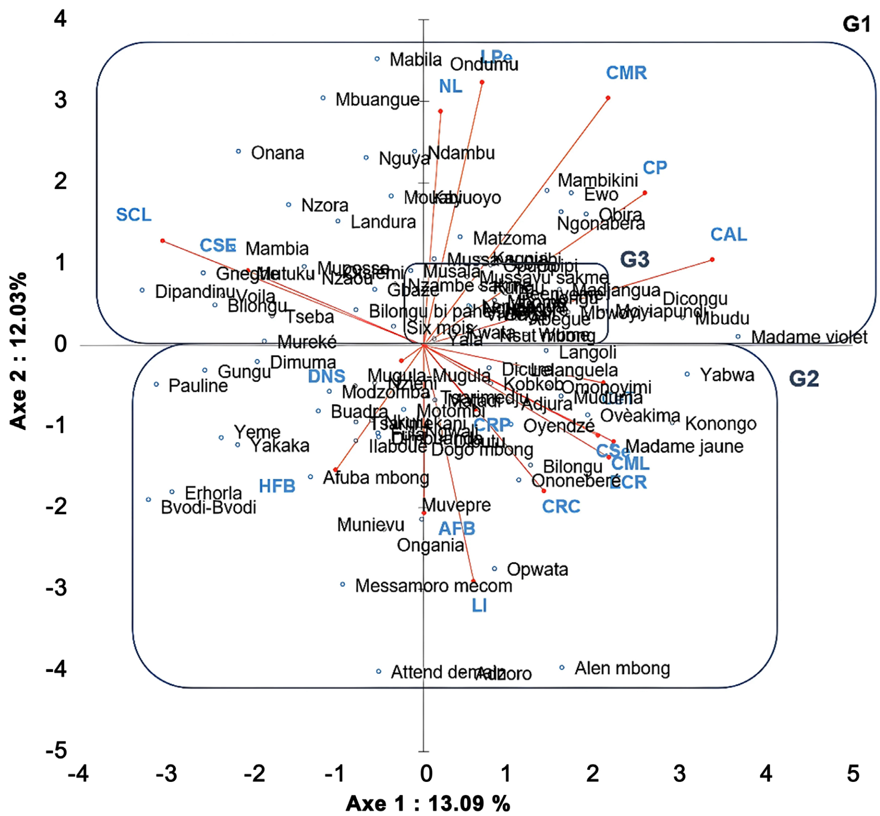

Figure 3. Distribution of variables and accessions in plan 1 - 2 revealed from the PCA for the 98 cassava accessions.

3.5. Ascending Hierarchical Classification (AHC)

The ascending hierarchical classification of the 98 accessions based on qualitative (11) and quantitative (6) traits classified into three groups with similar characteristics as a function of the variable (**Figure 4**). The genetic similarity for the 17 traits ranged from zero to three hundred, with a mean similarity of 300. The cassava accessions were grouped into three distinct clusters with similarities of 54.59. Similar results were observed by [20] (Djaha *et al.*, 2017) and [25] (N'Zue *et al.*, 2014). Nevertheless, in their work on cassava accessions, [27] (Ampong-Mensah, 2000) in Ghana and [28] (Bolamba *et al.*, 2024) in RD Congo obtained four homogeneous groups.

The main Characteristic of the three groups where based on the height of the first branching (HFB), the angle of the first branching (AFB), the length of the petiole (LP), the distance between leafs scars (DLS), and the diameter at the neck of the main stem (DNS) (**Table 5**) and on qualitative traits (**Table 6**). Group I and 2 contain 45 accessions each and Group 3 contains 8 accessions. The AHC shows a strong phenotypic organization based essentially on the five (05) quantitative variables mentioned above. Similar results were reported by [20] (Djaha *et al.*, 2017). However, [17] (Asare *et al.*, 2011) found that the length of the central lobe and the color of the petiole are the most relevant variables for distinguishing cassava accessions in Ghana. This contradiction could be explained by the difference between the two places of collection and the environmental conditions.

Branching can influence the number of tuber produced and breeding for optimal branching can enhance yield potential. Accessions with specific branching habits may have better air circulation and reducing disease incidence. Understanding branching can help in developing appropriate agronomic practices for different environments. Utilizing the genetic variability within the accession groups helps in selecting diverse parental lines, which can enhance the potential for heterosis (hybrid vigor). Hybridization between different accession groups can

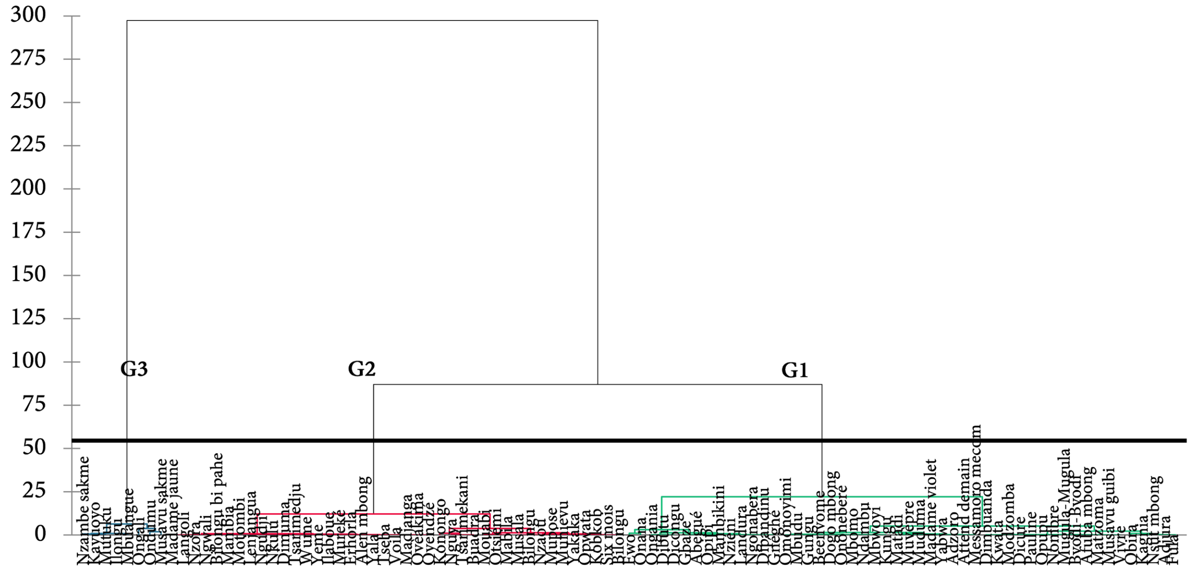

Figure 4. Ascending hierarchical classification of the 99 accessions found in the agricultural zones of Gabon.

Table 5. Characteristic of groups from the Ascending Hierarchical Classification.

Variables	Group 1	Group 2	Group 3
N	45	45	8
HFB	78.62 ± 10.24b	136.63 ± 27.10a	0c
AFB	115.13 ± 11.59a	85.83 ± 9.92b	0c
PL	20.38 ± 3.19a	15.07 ± 3.34b	21.13 ± 3.34b
DLS	4.07 ± 1.79a	3.39 ± 1.15b	2.75 ± 1.25b
DNS	2.82 ± 0.69a	2.57 ± 0.67a	2.38 ± 0.46a

On the lines, the averages followed by the same letter are statistically identical to the threshold $\alpha = 5\%$; Mean error type. **N**: number of accessions, **HFB**: height of first branching, **AFB**: angle of first branching, **PL**: petiole length, **DLS**: distance between leafs scars, **DNS**: diameter at the neck of the main stem.

Table 6. Classification of cassava accessions by group from the ascending hierarchical classification.

Group	Accessions	CAL	SCL	CLV	PC	CML	CSE	CCS	CEB	ECR	CRC	CRP
Group 1	Adzoro	Dark green	Lanceolate	Reddish-green L	Red	Dark green	Dark brown	Dark green	Green	Dark brown	White	White
	Abegué	Dark green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Green	Dark brown	Pink	White
	Adjura	Purplish green	Elliptic-lanceolate	Green	Yellowish-green	Dark green	Dark brown	Dark green	Green-purple	Dark brown	Pink	White
	Afuba mbong	Purplish green	Other	Reddish-green M	Red	Dark green	Cream	Dark green	Green-purple	Dark brown	Pink	White
	Attend demain	Dark green	Elliptic-lanceolate	Green	Yellowish-green	Dark green	Light brown	Dark green	Green	Light brown	Pink	White
	Beenvome	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Green	Light brown	White	White
	Dibutu	Purplish green	Elliptic-lanceolate	Green	Reddish-green	Dark green	Dark brown	Dark green	Purple	Light brown	White	White
	Dicongu	Purple	Elliptic-lanceolate	Reddish-green L	Purple	Purple green	Light brown	Dark green	Purple	Light brown	Pink	White
	Dicure	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Green	Light brown	White	White
	Dimbuanda	Purplish green	Elliptic-lanceolate	Green	Red	Dark green	Light brown	Orange	Green-purple	Dark brown	White	White
	Dipandinu	Light green	Lanceolate	Green	Red	Light green	Light brown	Light green	Green	Light brown	White	White
	Dogo mbong	Purplish green	Elliptic-lanceolate	Green	Reddish-green	Dark green	Light brown	Dark green	Green	Light brown	White	White
	Ewo	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Green-purple	Dark brown	White	White
	Fula	Dark green	Elliptic-lanceolate	Green	Yellowish-green	Dark green	Light brown	Dark green	Green	Dark brown	White	White
	Gbaze	Purplish green	Elliptic-lanceolate	Green	Reddish-green	Dark green	Light brown	Dark green	Green	Light brown	White	White
	Gnéghé	Light green	Lanceolate	Green	Red	Dark green	Light brown	Light green	Green	Light brown	White	White
	Gungu	Light green	Lanceolate	Green	Yellowish-green	Dark green	Dark brown	Dark green	Green	Light brown	White	White
	Kagnia	Dark green	Elliptic-lanceolate	Reddish-green M	Red	Dark green	Dark brown	Dark green	Green	Dark brown	White	White
	Kungu	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Green-purple	Dark brown	White	White
	Kwata	Purplish green	Lanceolate	Reddish-green L	Greenish-red	Dark green	Light brown	Dark green	Green	Dark brown	White	White
	Landura	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Green-purple	Cream	White	White
	Madame violet	Purple	Lanceolate	Reddish-green M	Purple	Purple	Dark brown	Dark green	Purple	Dark brown	Pink	White
	Mambikini	Purple	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Light green	Green	Dark brown	White	White
	Matadi	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Green	Light brown	White	White
	Mbomo	Dark green	Elliptic-lanceolate	Reddish-green M	Red	Dark green	Light brown	Dark green	Green	Dark brown	White	White
	Mbudu	Purple	Elliptic-lanceolate	Reddish-green L	Purple	Purple green	Light brown	Dark green	Purple	Dark brown	Pink	White
	Mbwoyi	Purple	Lanceolate	Reddish-green M	Red	Dark green	Light brown	Light green	Green-purple	Dark brown	Pink	White
	Messamoro mecom	Dark green	Elliptic-lanceolate	Reddish-green L	Greenish-red	Dark green	Light brown	Dark green	Green	Dark brown	White	White
	Modzomba	Purplish green	Elliptic-lanceolate	Green	Yellowish-green	Dark green	Light brown	Dark green	Green	Light brown	White	White
	Muduma	Purple	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Purple	Dark brown	White	White
	Muvèpre	Purplish green	Elliptic-lanceolate	Green	Reddish-green	Dark green	Light brown	Dark green	Green	Dark brown	Pink	White
	Ndambu	Dark green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Dark brown	Dark green	Green-purple	Light brown	White	White
	Ngonabera	Purple	Elliptic-lanceolate	Reddish-green L	Purple	Dark green	Light brown	Dark green	Green-purple	Dark brown	White	White

Continued

	Nombre	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Purple green	Light brown	Light green	Green-purple	Dark brown	White	White
	Nsut mbong	Purple	Elliptic-lanceolate	Reddish-green M	Red	Dark green	Light brown	Dark green	Green-purple	Dark brown	Pink	White
	Nziéni	Purplish green	Elliptic-lanceolate	Green	Yellowish-green	Dark green	Light brown	Light green	Green-purple	Dark brown	White	White
	Obira	Purplish green	Elliptic-lanceolate	Reddish-green M	Red	Dark green	Dark brown	Light green	Green	Dark brown	White	White
	Omonoyimi	Purplish green	Elliptic-lanceolate	Reddish-green M	Red	Dark green	Dark brown	Light green	Purple	Dark brown	Pink	White
	Onana	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Light green	Light brown	Light green	Green-purple	Light brown	White	White
	Ongania	Purplish green	Elliptic-lanceolate	Green	Green	Dark green	Light brown	Light green	Green	Light brown	Pink	White
	Ononeberé	Purplish green	Elliptic-lanceolate	Green	Reddish-green	Dark green	Dark brown	Dark green	Green	Dark brown	White	White
	Opipi	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Green	Dark brown	White	White
	Opupu	Purplish green	Elliptic-lanceolate	Reddish-green M	Red	Dark green	Light brown	Dark green	Green	Light brown	White	White
	Pauline	Light green	Lanceolate	Reddish-green L	Red	Dark green	Light brown	Light green	Green	Dark brown	White	White
	Yabwa	Purple	Elliptic-lanceolate	Reddish-green M	Purple	Purple green	Light brown	Dark green	Green-purple	Dark brown	Pink	White
Group 2	Alen mbong	Dark green	Elliptic-lanceolate	Reddish-green M	Purple	Dark green	Dark brown	Dark green	Green	Dark brown	Pink	White
	Bilongu	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Purple	Dark brown	Pink	White
	Bilongu bi pahe	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Orange	Green	Light brown	Cream	White
	Buadra	Purplish green	Lanceolate	Green	Greenish-red	Dark green	Dark brown	Light green	Green	Light brown	Pink	White
	Bvodi-Bvodi	Dark green	Lanceolate	Green	Greenish-red	Dark green	Cream	Light green	Green	Light brown	Pink	White
	Dimuma	Dark green	Lanceolate	Green	Greenish-red	Dark green	Cream	Light green	Green	Dark brown	Pink	White
	Erhorla	Light green	Lanceolate	Green	Greenish-red	Dark green	Light brown	Light green	Green	Dark brown	Pink	White
	Ilaboue	Purplish green	Elliptic-lanceolate	Green	Greenish-red	Dark green	Light brown	Dark green	Green	Light brown	Cream	White
	Kobkob	Purplish green	Ovoid	Green	Red	Dark green	Dark brown	Light green	Green	Dark brown	Cream	White
	Konongo	Purple	Elliptic-lanceolate	Reddish-green L	Greenish-red	Purple green	Dark brown	Dark green	Purple	Dark brown	Pink	White
	Langoli	Purplish green	Lanceolate	Reddish-green L	Red	Dark green	Dark brown	Dark green	Green	Dark brown	Cream	White
	Lenjangua	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Light green	Dark brown	Light green	Green	Light brown	Pink	White
	Mabila	Purplish green	Lanceolate	Reddish-green M	Red	Dark green	Light brown	Light green	Green-purple	Light brown	Cream	White
	Madame jaune	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Light green	Orange	Light green	Green-purple	Dark brown	Yellow	Yellow
	Madjanga	Purple	Elliptic-lanceolate	Reddish-green M	Red	Dark green	Light brown	Light green	Green-purple	Dark brown	Cream	White
	Mambia	Light green	Obovate-lanceolate	Reddish-green L	Red	Dark green	Cream	Light green	Green-purple	Light brown	Cream	White
	Matzoma	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Light green	Light brown	Dark green	Green-purple	Dark brown	Cream	White
	Motombi	Light green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Green-purple	Dark brown	Cream	White
	Mouabi	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Light green	Light brown	Light green	Green	Light brown	Cream	White
	Mugula-Mugula	Purplish green	Lanceolate	Reddish-green L	Reddish-green	Dark green	Dark brown	Light green	Green	Light brown	Cream	White
	Munievu	Purplish green	Elliptic-lanceolate	Green	Greenish-red	Dark green	Light brown	Dark green	Green	Dark brown	Cream	White

Continued

	Mupose	Purplish green	Lanceolate	Reddish-green L	Red	Dark green	Light brown	Light green	Green	Light brown	Cream	White
	Mureké	Light green	Lanceolate	Reddish-green L	Greenish-red	Dark green	Light brown	Light green	Green	Dark brown	Pink	White
	Musala	Purplish green	Elliptic-lanceolate	Reddish-green M	Red	Light green	Light brown	Light green	Green	Dark brown	Cream	White
	Musavu guibi	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Green-purple	Dark brown	Cream	White
	Ngudji	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Light green	Green-purple	Dark brown	Cream	White
	Nguya	Purple	Lanceolate	Reddish-green L	Red	Light green	Light brown	Dark green	Green	Light brown	Cream	White
	Ngwali	Purplish green	Obovate-lanceolate	Reddish-green L	Red	Dark green	Light brown	Light green	Green	Light brown	Cream	White
	Nkulu	Dark green	Elliptic-lanceolate	Green	Green	Dark green	Dark brown	Light green	Green	Dark brown	Cream	White
	Nzaou	Purplish green	Lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Green-purple	Cream	Cream	White
	Nzora	Purplish green	Lanceolate	Reddish-green L	Red	Dark green	Light brown	Light green	Purple	Cream	Cream	White
	Opwata	Purplish green	Lanceolate	Reddish-green L	Red	Dark green	Dark brown	Light green	Green-purple	Dark brown	Cream	White
	Otsiémi	Purplish green	Lanceolate	Green	Red	Dark green	Light brown	Light green	Green	Dark brown	Cream	White
	Ovèakima	Purplish green	Lanceolate	Reddish-green M	Red	Dark green	Dark brown	Dark green	Green	Dark brown	Pink	White
	Oyendzé	Purplish green	Lanceolate	Green	Red	Dark green	Dark brown	Dark green	Green	Dark brown	Cream	White
	Six mois	Purplish green	Obovate-lanceolate	Reddish-green L	Red	Dark green	Light brown	Light green	Green	Dark brown	Cream	White
	Tsarimedju	Dark green	Elliptic-lanceolate	Green	Green	Dark green	Light brown	Dark green	Green	Dark brown	Cream	White
	Tsarimekani	Dark green	Lanceolate	Reddish-green L	Greenish-red	Dark green	Light brown	Dark green	Green	Dark brown	Cream	White
	Tseba	Purplish green	Lanceolate	Reddish-green L	Red	Light green	Light brown	Light green	Green	Light brown	Cream	White
	Vivre	Purplish green	Elliptic-lanceolate	Reddish-green L	Greenish-red	Dark green	Dark brown	Light green	Green	Light brown	Cream	White
	Voila	Purplish green	Lanceolate	Green	Red	Light green	Cream	Light green	Green	Dark brown	Cream	White
	Wume	Purplish green	Elliptic-lanceolate	Reddish-green L	Reddish-green	Purple green	Light brown	Dark green	Green-purple	Dark brown	Cream	White
	Yakaka	Purplish green	Lanceolate	Green	Greenish-red	Dark green	Light brown	Light green	Green	Light brown	Cream	White
	Yala	Purplish green	Lanceolate	Reddish-green L	Red	Dark green	Light brown	Light green	Green	Dark brown	Pink	White
	Yeme	Purplish green	Elliptic-lanceolate	Green	Greenish-red	Dark green	Cream	Dark green	Green	Light brown	Cream	White
Group 3	Kayuoyo	Purplish green	Lanceolate	Green	Yellowish-green	Dark green	Light brown	Light green	Green	Dark brown	Cream	White
	Ilongu	Purplish green	Elliptic-lanceolate	Reddish-green L	Reddish-green	Dark green	Light brown	Dark green	Green	Dark brown	Pink	White
	Mbuangue	Purplish green	Lanceolate	Reddish-green M	Yellowish-green	Light green	Light brown	Light green	Green	Light brown	Cream	White
	Musavu sakme	Purplish green	Elliptic-lanceolate	Reddish-green L	Red	Dark green	Light brown	Dark green	Green-purple	Light brown	Cream	White
	Mutuku	Purplish green	Lanceolate	Green	Yellowish-green	Light green	Light brown	Dark green	Green	Light brown	Cream	White
	Nzambe sakme	Purplish green	Elliptic-lanceolate	Green	Yellowish-green	Dark green	Light brown	Dark green	Green-purple	Dark brown	Cream	White
	Ondumu	Purplish green	Oblang-lanceolate	Reddish-green L	Red	Dark green	Orange	Light green	Green	Light brown	Cream	White
	Ongali	Purple	Elliptic-lanceolate	Green	Red	Dark green	Light brown	Dark green	Green	Light brown	Cream	White

CAL: color of apical leaves, **SCL**: shape of central leaflet, **PC**: petiole color, **CML**: color of mature leaf, **CLV**: color of leaf vein, **CSE**: color of stem epidermis, **CCS**: color of cortex stem, **CEB**: color of end branches, **ECR**: External color of the storage root, **CRC**: color of the root cortex, **CRP**: color of root pulp.

create new varieties with improved traits. This is particularly useful in developing cassava that is resilient to environmental stresses. Understanding the genetic makeup of the accession groups can aid in mapping traits of interest and developing targeted breeding strategies. Maintaining a diverse gene pool through these accession groups ensures the conservation of genetic resources, which is vital for long-term breeding success.

The analysis of qualitative characteristics in various organs showed variations within the studied accessions. Color appears to be the most representative and distinctive trait [17] (Asare *et al.*, 2011) and [21] (Agre *et al.*, 2016).

4. Conclusion

The study of the agro-morphological diversity of the 211 cassava accessions found in the prospected area in Gabon and their structuring on the basis of 17 descriptors showed variability with only 98 accessions clearly identified, indicating a high number of duplicates. This diversity was structured in 3 groups characterized by the height of the first branching, the angle of the first branching, the length of the petiole, the distance between leafs scars and the diameter at the neck of the main stem. This observed genetic variability between accessions is important for varietal breeding work. Breeding programs can effectively utilize the identified cassava accession groups to develop improved varieties that meet agricultural demands and environmental challenges.

Acknowledgements

Mr. Jonathan MBOULOU ELLA, Regional Director of Agriculture Woleu-Ntem and Ogooué-Ivindo, Mr. Serge ABESSOLO MBA, Director of Project PDAR/FIDA and the personnel, Mr. Edouard MASSALA, Regional Director of Agriculture Ngounié-Nyanga, Mr. BOUNGUILI Etienne, Provincial Director of Agriculture Ogooué-Lolo, Mr. Sévérin Arnaud BIBANG, Provincial Director of Agriculture Nyanga, Mr. Marius NZAOU, Provincial Director of Agriculture Moyen-Ogooué and Ms. Prisca IKOUELE IKOUETE, Agricultural Sector Plateaux. All of them for facilities and logistics.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Dixon, A.G., Ngeve, J.M. and Nukenine, E.N. (2002) Response of Cassava Genotypes to Four Biotic Constraints in Three Agro-Ecologies of Nigeria. *African Crop Science Journal*, **10**, 11-21. https://doi.org/10.4314/acsj.v10i1.27553

[2] Alvarez, E., Mejia, J.F., Llano, G.A. and Loke, J.B. (2007) Detection, and Characterization of a Phytoplasma Associated with Frog SK in Disease in Cassava. *Bulletin of Insectology*, **60**, 273-274.

[3] Ceballos, H. (2012) Cassava in Colombia, and the World: New Perspectives for a Millennial Crop. In: Ospina, B. and Ceballos, H., Eds., *Cassava in the Third Millennium*,

California Institute of Applied Technology, 1-13.

[4] Raponda-Walker, A. and Sillans, R. (1961) Les Plantes Utiles Du Gabon. *Quarterly Journal of Crude Drug Research*, **1**, Article 27.

[5] Lozano, C. (1985) Comprehensive Breeding Approach to Pest and Disease Problems of Cassava. In: Cock, J.H. and Reyes, J.A., Eds., *Cassava*: *Research*, *Production and Utilization*, Centro International de Agricultura Tropical, 562-574.

[6] Nweke, F.I., Dixon, A.G.O., Asiedu, R. and Folayan, S.A. (1994) Cassava Varietal Needs of Farmers and the Potential for Production Growth in Africa. Collaborative Study of Cassava in Africa. Working Paper No. 10.

[7] Maroya, N.K. (1997) Caractérisation morphologique des clones de manioc cultivés en Afrique de l'ouest et du centre (Bénin, Cameroun, Ghana et Nigéria).

[8] Fukuda, W.M.G. and Guevara, C.L. (1998) Descritores morfológicos e agronômicos para a caracterização de mandioca (*Manihot esculenta* Crantz). Embrapa-CNPMF, Documentos.

[9] Hahn, S.K., Terry, E.R., Leuschner, K., Akobundu, I.O., Okali, C. and Lal, R. (1979) Cassava Improvement in Africa. *Field Crops Research*, **2**, 193-226. https://doi.org/10.1016/0378-4290(79)90024-8

[10] Adjatin, A., Dansi, A., Eze, C.S., Assogba, P., Dossou-Aminon, I., Akpagana, K., *et al.* (2012) Ethnobotanical Investigation and Diversity of Gbolo (*Crassocephalum rubens* (juss. Ex Jacq.) S. Moore and *Crassocephalum crepidioides* (Benth.) S. Moore), a Traditional Leafy Vegetable under Domestication in Benin. *Genetic Resources and Crop Evolution*, **59**, 1867-1881. https://doi.org/10.1007/s10722-012-9901-z

[11] Kombo, G.R., Dansi, A., Loko, L.Y., Orkwor, G.C., Vodouhè, R., Assogba, P., *et al.* (2012) Diversity of Cassava (*Manihot esculenta* Crantz) Cultivars and Its Management in the Department of Bouenza in the Republic of Congo. *Genetic Resources and Crop Evolution*, **59**, 1789-1803. https://doi.org/10.1007/s10722-012-9803-0

[12] Fukuda, W.M.G., Guevara, C.L., Kawuki, R. and Ferguson, M.E. (2010) Selected Morphological and Agronomic Descriptors for the Characterization of Cassava. International Institute of Tropical Agriculture.

[13] Amadi, G., Uwandu, Q.C. and Uzuegbu, J.O. (2020) An Analysis of Gender Participation in Cassava Production by Small-Scale Farmers in Imo State, Nigeria. *Journal of Agriculture and Food Environment*, **7**, 58-67.

[14] Nwaobiala, C.U., Alozie, E.N. and Anusiem, C.N. (2019) Gender Differentials in Farmers' Involvement in Cassava Production Activities in Abia State, Nigeria. *Agrosearch*, **19**, 72-86. https://doi.org/10.4314/agrosh.v19i1.6

[15] Claudette, D.V. and Roger, T.I. (2022) Sociodemographic Characterization of Cassava Farmers in Cameroon. *Journal of Scientific Agriculture*, **6**, 51-65. https://doi.org/10.25081/jsa.2022.v6.9072

[16] Mouketou, A., Ndiade Bourobou, D., Koumba, A.A, *et al.* (2023) Occurrence, Distribution and Farmers Perceptions of Cassava Diseases in Gabon, Central Africa. *Asian Research Journal of Agriculture*, **16**, 49-63.

[17] Asare, P.A., Galyuon, I.K.A., Sarfo, J.K. and Tetteh, J.P. (2011) Morphological and Molecular Based Diversity Studies of Some Cassava (*Manihot esculenta* Crantz) Germplasm in Ghana. *African Journal of Biotechnology*, **10**, 13900-13908. http://dx.doi.org/10.5897/AJB11.929

[18] Doussoh, A.M., Dangou, J.S., Houedjissin, S.S., Assogba, A.K. and Ahanhanzo, C. (2017) Analyse des connaissances endogènes et des déterminants de la production de la patate douce [*Ipomoea batatas* (L.)], une culture à haute valeur socioculturelle et

économique au Bénin. *International Journal of Biological and Chemical Sciences*, **10**, 2596-2616. https://doi.org/10.4314/ijbcs.v10i6.16

[19] Nadjiam, D., Sarr, P.S., Naïtormbaïdé, M., Mbaïlao Mbaïguinam, J.M. and Guisse, A. (2016) Agro-Morphological Characterization of Cassava (*Manihot esculenta* Crantz) Cultivars from Chad. *Agricultural Sciences*, **7**, 479-492. https://doi.org/10.4236/as.2016.77049

[20] Delêtre, M. (2010) The Ins and Outs of Manioc Diversity in Gabon, Central Africa. A Pluridisciplinary Approach to the Dynamics of Genetic Diversity of *Manihot esculenta* Crantz (Euphorbiaceae). PhD Thesis, Botany Department School of Natural Sciences University of Dublin.

[21] Djaha, K.E., Abo, K., Bonny, B.S., Kone, T., Amouakon, W.J.L., Kone, D., *et al.* (2017) Caractérisation agromorphologique de 44 accessions de manioc (*Manihot esculenta* Crantz) cultivés en Côte d'Ivoire. *International Journal of Biological and Chemical Sciences*, **11**, 174-184. https://doi.org/10.4314/ijbcs.v11i1.14

[22] Agre, A.P., Badara, G., Adjatin, A., Dansi, A., Bathacharjee, R., Rabbi, I.Y., Dansi, M. and Gedil, M. (2016) Folk Taxonomy and Traditional Management of Cassava (*Manihot esculenta* Crantz) Diversity in Southern and Central Benin. *International Journal of Innovation and Scientific Research*, **20**, 500-515.

[23] Montagnac, J.A., Davis, C.R. and Tanumihardjo, S.A. (2008) Processing Techniques to Reduce Toxicity and Antinutrients of Cassava for Use as a Staple Food. *Comprehensive Reviews in Food Science and Food Safety*, **8**, 17-27. https://doi.org/10.1111/j.1541-4337.2008.00064.x

[24] Ephrem, K.K., Akpavi, S., *et al.* (2014) Preliminary Characterization of Cassava Germplasm. https://www.eujournal.org/index.php/esj/article/viewFile/2635/2496

[25] Boni, N., Pamelas, O.M., Michel, K.A., Dibi, K.E.B., Zohouri, G.P., Essis, B.S., *et al.* (2014) Morphological Characterization of Cassava (*Manihot esculenta* Crantz) Accessions Collected in the Centre-West, South-West and West of Côte d'Ivoire. *Greener Journal of Agricultural Sciences*, **4**, 220-231. https://doi.org/10.15580/gjas.2014.6.050614224

[26] Elias, M., McKey, D., Panaud, O., Anstett, M.C. and Robert, T. (2001) Traditional Management of Cassava Morphological and Genetic Diversity by the Makushi Amerindians (Guyana, South America): Perspectives for On-Farm Conservation of Crop Genetic Resources. *Euphytica*, **120**, 143-157. http://dx.doi.org/10.1023/A:1017501017031

[27] Ampong-Mensah, G. (2000) Preliminary Characterization of Cassava Germplasm from South-Western Ecozone (Central and Western Region) of Ghana. University Of Cape Coast (UCC).

[28] Bolamba, F., Mukandama, J.P., Looli, L. and Nzawele, D.B. (2024) Caractérisation morpho-quantitative des cultivars locaux de manioc (*Manihot esculenta* Crantz) collectes dans la province de la Tshopo (RD. Congo). *Agronomie Africaine*, **36**, 99-111.