Assessment of agromorphological diversity of cassava accessions grown in the South Comoe region (South-East) of Côte d'Ivoire

Abstract

Cassava is an important foodstuff for the Ivorian population. Côte d'Ivoire's South Comoe region (South-East), known as the country's cassava introduction zone, breeds several varieties of cassava from all sources, whose cuttings are continually exchanged with producers in other production zones. Knowledge of the agromorphological diversity of accessions in this region will enable them to be better exploited to boost national production. An agromorphological characterization was carried out on a collection of 45 accessions collected from growers in the region, using ten quantitative variables. Analysis of variance (ANOVA) showed significant phenotypic differences for all the traits studied. Principal component analysis (PCA) confirmed this polymorphism at 74.47% for the first two axes. Accessions were structured into 4 groups of morphological variability following Hierarchical Ascending Classification (HAC). These groups are distinguished by plant height, first branch height, number of lobes, central lobe width, central lobe length, ratio length/width lobe, petiole length, tuber weight per plant and total yield. The first three groups have varieties with yields in excess of 20 t/ha and constitute the best genetic resources for increasing cassava production in Côte d'Ivoire.

Keywords : Cassava, agromorphological diversity, South Comoe, Côte d'Ivoire.

Introduction

Cassava (*Manihot esculenta Crantz*), is one of the most widely grown and consumed food crops in many parts of the world (**Kouakou *et al.,* 2015**). It is a very important crop in several tropical and subtropical regions of the world, including countries in Africa (56%), Asia (30%) and Latin America (14%) (**Zhou *et al.,* 2017**). In Côte d'Ivoire, cassava is the second most important food crop after yam, and plays a key role in the food system. It is used to produce various processed products such as attieke, placali and its production is estimated at over 6 to 7 million tonnes for a consumption of 100-110 kg/year per inhabitant living in urban areas (**Faostat, 2022**). Despite this socio-economic importance, production remains low (< 10 tons/ha compared with 20 to 30 tons) on research stations to cover the population's food needs, due to the use of low-yield, disease and pest susceptible varieties (**Thiemele et al., 2024a**). Côte d'Ivoire's South Comoe (South-East) region, known as the country's cassava introduction zone, breeds several varieties of cassava from all sources, whose cuttings are continually exchanged with producers in other production zones. The genetic diversity of cassava remains unknown, and knowledge of the agromorphological variability of accessions from this region will enable better knowledge and selection of high-yielding varieties to increase production in the region and in other production zones. Thus, the aim of this study is to analyze the agromorphological diversity of cassava accessions from the South Comoe zone of Côte d'Ivoire, with a view to effectively exploiting these genetic resources to increase national production.

Material and Methods

Study site

The study took place at the experimental site of Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS, Côte d'Ivoire) at Bringakro in Belier region. The experimental site is located between latitude (6°25'0" N) and longitude (5°4'60'' W) in central Côte d'Ivoire, in the town of Toumodi. The study area is a transition zone between forest and savannah. The region's soils are ferralitic and hydromorphic. The climate is humid, with average annual rainfall of 1,200 mm, spread over 5 to 8 months, and temperatures ranging from 24° to 28°C.

Plant Material

The plant material consisted of 45 accessions of Manihot esculenta (Crantz) collected from farmers in the South Comoe region of Côte d'Ivoire. These accessions were collected in a participatory manner with the growers on the basis of their vernacular names.

Experimental Design

The experiment was based on a completely randomized design. Each accession was represented by 5 plants. A planting density of 10,000 plants/ha with a spacing of 1 m (rows) x 1 m (plants) was adopted. Planting material consisted of mature stem cuttings around 20 cm long, containing between 6 and 8 nodes and planted horizontally on ploughed soil, at a depth of less than 10 cm.

Data Collection

Data were mainly collected using the descriptors proposed by **Fukuda *et al.* (2010)** at 3, 6, 9 and 12 months after planting. Tuberous roots were analyzed at harvest, at 12 months after planting. Ten (10) quantitative variables were observed, taking into account stem, leaves and tuberous roots. The variables were observed on all plants of each accession (**Table 1**).

Table 1 : Agromorphological characteristics measured during experimentation

Traits observed	**Unit**	**Code**	**Techniques of measurement**
1- Number of tuber per plant	Unit	NTP	Record the number of tuber per plant
2- Height to first branching	cm	HRAM1	Measure vertical height from ground to first primary branch
3- Plant height	cm	HPL	Measured vertically from the ground to the top of the canopy
4- Central lobe width	cm	LARLOC	Measured from the widest part of the middle lobe
5- Central lobe length	cm	LONLOC	Measure the distance between the point of insertion of the lobes and the upper tip of the central lobe.
6- Ratio length/width lobe		RATIO L/W	Calculate the ratio between length and width
7- Number of leaf lobes		NDLO	Counted the leaves per plant with consideration of the predominant number of lobes (5 leaves/plant)
8- Weight of fresh tuber per plant	Kg	PTP	Total tuber shaving length greater than 20 cm are weighted
9- Petiole length	cm	LPE	Measured on three leaves per plant
10- Tuber yield	t/ha	RDT	Calculate using the formula : RDT= (Weight of fresh root/plant (kg) / (Plot area (m^2)) * (10 000 m^2 / 1 000)

Data Analysis

A descriptive analysis (mean, minimum, maximum, standard deviation, coefficient of variation) was carried out for each descriptor. These analyses enabled us to assess the variability of the characters measured in the accessions. The Coefficient of Variation (CV) was considered high when it exceeded 20%. A Pearson correlation analysis was used to assess relationships between variables. Multivariate analyses (Principal Component Analysis (PCA), Hierarchical Ascending Classification (HAC)) were performed to structure cassava accessions. An analysis of variance (ANOVA) was used to compare group means and determine significant differences at the 5% level, using the Newman-Keuls test. These statistical analyses were carried out using XLSTAT 2019 version 2.2 software.

Results

Variability in agromorphological characteristics of cassava varieties

Descriptive analysis of characters measured on accessions shows variability within the cassava collection. Most variables have a high coefficient of variation (CV), ranging from 18.7 to 68.3%. Characteristics such as plant height (HPL), height of first branching (HRAM1), central lobe width (LARLOC), ratio length/width lobe (RATIO L/W), number of tuber per plant (NTP), weight of fresh tuber per plant (PTP) and tuber yield (RDT) were more variable between accessions, with coefficients of variation greater than 20%. On the other hand, characters such as number of lobes (NDLO), central lobe length (LONLOC) and petiole length (LPE) showed little variation. The height of the first branch (HRAM1) showed the greatest variability (CV = 68.3%), with values ranging from 24 to 331 cm and an average of 112.199 ± 76.65 cm. The results of the analysis of variance show a significant difference ($p < 0.001$) between varieties for all variables measured.

Table 2 : Descriptive statistics for the quantitative characteristics considered in this study

Traits	Minimum	Maximum	Means ± Standard Deviation	CV (%)	F
HPL (cm)	100	347	236.674 ± 49.416	20.9	***

HRAM1 (cm)	24	331.333	112.199 ± 76.65	68.3	***

Traits	HPL	HRAM1	NDLO	LARLOC	LONLOC	RATIO L/W	LPE	NTP	PTP	RDT

NDLO	4	10	7.137 ± 1.403	19.7	***
LARLOC (cm)	1.8	6	3.826 ± 1.241	32.4	***
LONLOC (cm)	8	20	13.828 ± 2.585	18.7	***
RATIO L/W	1.624	7.51	4.016 ± 1.479	36.8	***
LPE (cm)	11.667	29	18.811 ± 3.521	18.7	***
NTP	1	10	6.614 ± 2.058	31.1	***
PTP (Kg)	0.1	4	2.038 ± 0.886	43.5	***
RDT (Kg/ha)	1	40	20.380 ± 8.863	43.5	***

HPL : Plant height; HRAM1: Height to first branching; NDLO: Number of leaf lobes; LARLOC: Central lobe width; LONLOC: Central lobe length; RATIO L/W: Ratio length/width lobe; LPE: Petiole length; NTP: Number of tuber per plant; PTP: Weight of fresh tuber per plant; RDT: Tuber yield; CV: Coefficient of Variation; F: Fisher's coefficient; *** = significant at P < 0.001.

Analysis of correlations between measured quantitative characteristics

Analysis of correlations between characteristics (**Table 3**) revealed positive relationships between certain traits. Number of lobes (NDLO) was significantly and positively correlated with number of tuber per plant (NTP, r = 0.827), weight of fresh tuber per plant (PTP, r = 0.752) and tuber yield (r = 0.752). Plant height (HPL) was also significantly and positively correlated with first branch height (HRAM1, r = 0.539) and central lobe length (LONLOC, r = 0.543). The correlation between number of tuber per plant (NTP), weight of fresh tuber per plant (PTP) and tuber yield was 0.763 and 0.763 respectively. Also, central lobe length (LONLOC) was significantly and positively correlated with petiole length (LPE, r = 0.586), plant height (r = 0.543) and first branch height (r = 0.596). Finally, first branch height (HRAM1) was significantly and positively correlated with plant height (r = 0.539) and petiole length (r = 0.556) (**Table 3**).

Table 3 : Correlation matrix between measured variables

HPL	1									
HRAM1	**0.539**	1								
NDLO	0.407	0.397	1							
LARLOC	0.013	0.141	0.41	1						
LONLOC	**0.543**	**0.596**	0.154	0.107	1					
RATIO L/W	0.18	0.091	-0.355	-0.825	0.404	1				
LPE	0.389	**0.556**	0.47	0.197	**0.586**	0.046	1			
NTP	0.309	0.231	**0.827**	0.374	-0.034	-0.439	0.277	1		
PTP	0.328	0.204	**0.752**	0.415	0.007	-0.424	0.384	**0.763**	1	
RDT	0.328	0.204	**0.752**	0.415	0.007	-0.424	0.384	**0.763**		1

HPL : Plant height; HRAM1: Height to first branching; NDLO: Number of leaf lobes; LARLOC: Central lobe width; LONLOC: Central lobe length; RATIO L/W: Ratio length/width lobe; LPE: Petiole length; NTP: Number of tuber per plant; PTP: Weight of fresh tuber per plant; RDT: Tuber yield;

Structuring agromorphological variability

Principal Component Analysis (PCA)

The agromorphological variability between cassava accessions was assessed using Principal Component Analysis (PCA) based on the traits measured. This analysis revealed that the first two axes had eigenvalues greater than 1, expressing 74.47% of total variability (**Table 4**). Axis 1, which expresses 47.74% of total variability, is mainly correlated with the number of lobes (NDLO), the number of tuber per plant (NTP), the weight of tuber per plant (PTP) and tuber yield (RDT). This axis mainly captures traits related to tuber quantity and weight. Axis 2, which expresses 26.72% of total variability, is correlated with plant height (HPL), first branch height (HRAM1), central lobe length (LONLOC), ratio length/width lobe (RATIO L/W) and petiole length (LPE). This axis mainly reflects traits related to plant appearance and leaf development.

Table 4 : Principal component (PC) analysis of the qualitative traits showing their contributions to the total variation among 45 cassava accessions

Main components	**Axis 1**	**Axis 2**
Eigen value	4.774	2.673
Variation expressed (%)	47.743	26.726
Cumulative variation expressed (%)	47.743	74.470
HPL	0.235	**0.376***
HRAM1	0.227	**0.402****

NDLO	**0.421****	-0.012
LARLOC	0.271	-0.234
LONLOC	0.119	**0.521****
RATIO L/W	-0.221	**0.456****
LPE	0.273	**0.331***
NTP	**0.393***	-0.138
PTP	**0.419****	-0.129
RDT	**0.419****	-0.129

HPL : Plant height; HRAM1: Height to first branching; NDLO: Number of leaf lobes; LARLOC: Central lobe width; LONLOC: Central lobe length; RATIO L/W: Ratio length/width lobe; LPE: Petiole length; NTP: Number of tuber per plant; PTP: Weight of fresh tuber per plant; RDT: Tuber yield; Values in bold are correlations significant at the 1 and 5% threshold: ** : Significant at 1 % level of probability and, *: Significant at 5 % level of probability.

Hierarchical Ascending Classification (HAC)

The Hierarchical Ascending Classification (HAC) performed on the basis of the averages of the quantitative variables reveals four agromorphological groups (**Figure 1**). The mean characteristics of the different classes obtained are summarized in **Table 5**, and all the variables analyzed show significant variations between classes. Group 1 comprises 12 accessions of average height (HPL = 228.049 cm) and average height of first branching (HRAM1= 187.44 cm), with good productivity of tubers per plant (7.52) and good yield (RDT = 24.65 t/ha). Group 2 comprises 17 accessions of moderate size (HPL = 268.21 cm) with a first branch height of (HRAM1 = 95.46 cm), medium petiole length (LPE = 19.84 cm), good tuber productivity per plant (7.84) and high yield (RDT = 26.09 t/ha). Group 3 consists of 7 accessions with very large height (HPL = 342.91 cm), high first branch height (HRAM1 = 327.20 cm), moderate petiole length (LPE = 21.00 cm), good tuber productivity per plant (NTP = 7.31) and average yield (RDT = 20.89 t/ha). Group 4 is made up of 9 accessions with small height (HPL = 187.80 cm), small first branch height (HRAM1 = 64.21 cm), small petiole length (LPE = 14.88), low tuber productivity per plant (NTP = 5.02) and low yield (NTP = 10.80 t/ha).

Table 5 : Characteristics of 4 cassava cultivars groups from ascending hierarchical clustering

Groups

Traits	1	2	3	4	P-Value
HPL	228.049 c	268.210 b	342.914 a	187.800 d	< 0.0001
HRAM1	187.444 b	95.460 c	327.205 a	64.213 d	< 0.0001
NDLO	8.277 a	8.076 a	7.914 a	5.901 b	< 0.0001
LARLOC	4.615 a	4.463 a	3.310 b	3.267 b	0.002
LONLOC	14.845 b	14.457 b	18.576 a	11.836 c	< 0.0001
RATIO L/W	3.288 b	3.374 b	5.664 a	4.136 b	< 0.0001
LPE	24.659 a	19.849 b	21.007 b	14.882 c	< 0.0001
NTP	7.528 a	7.840 a	7.318 a	5.021 b	0.001
PTP	2.465 a	2.610 a	2.089 a	1.080 b	< 0.0001
RDT	24.650 a	26.098 a	20.893 a	10.802 b	< 0.0001

HPL : Plant height; HRAM1: Height to first branching; NDLO: Number of leaf lobes; LARLOC: Central lobe width; LONLOC: Central lobe length; RATIO L/W: Ratio length/width lobe; LPE: Petiole length; NTP: Number of tuber per plant; PTP: Weight of fresh tuber per plant; RDT: Tuber yield; Values in bold are correlations significant at the 1 and 5% threshold: ** : Significant at 1 % level of probability and, *: Significant at 5 % level of probability. Means followed by the same letters within rows are not significantly different at the 5% threshold according to the Newman-Keuls test.

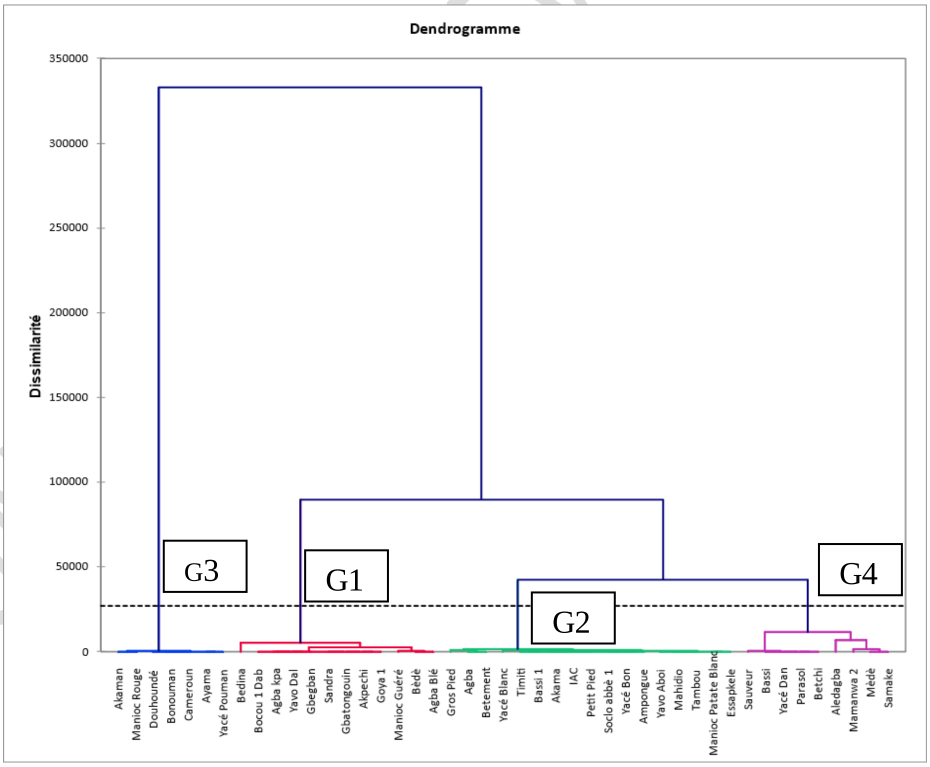

Figure 1 : Agromorphological structuring of 45 cassava cultivars using the HAC method

Discussion

A study of the agromorphological evaluation of Manihot esculenta accessions grown in the South Comoe region of Côte d'Ivoire revealed high variability via the traits studied. Principal component analysis (PCA) confirmed this variability at 74.47%. This variability is higher than that of **Kouakou *et al*. (2023)** and **Thiemele *et al.* (2024a).** These authors studied the agromorphological diversity of cassava accessions collected in Côte d'Ivoire, obtaining variabilities of 71.01% and 57.45% respectively. The variability obtained in our study is also higher than that of **Vandi *et al.* (2024)** in Sierra Leone and **Nadjiam *et al.* (2016)** in Chad, who obtained variabilities of 67.27% and 47.54% respectively. This varietal diversity could be explained by the high heterozygosity within cassava varieties. These results are in line with the research of **Soro *et al.* (2024),** when they studied the genetic diversity of cassava accessions using microsatellite markers.

Positive and significant correlations were found between the traits studied in this study. In particular, the link between the number of lobes and production characteristics (Number of tuber per plant, weight of tuber per plant and tuber yield). These results are similar to those obtained on cassava **by Ntawuruhunga and Dixon (2010), Kouakou *et al.* (2023)** and **Thiemele et al. (2024b).**

The hierarchical ascending classification carried out highlighted four morphological groups (G1, G2, G3 and G4) in the South Comoe region of Côte d'Ivoire. The number of groups obtained in this study is higher than those obtained by **N'zué *et al.* (2014)**, **Djaha *et al.* (2017), Kouakou *et al.* (2023)** and **Thiemele *et al.* (2024a).** Indeed, these authors, having studied the agromorphological diversity of cassava accessions collected in Côte d'Ivoire, have shown that varieties cluster into three genetic groups. This high diversity in the area could be explained by the regular introductions of cassava varieties from Côte d'Ivoire's neighboring countries such as Ghana, Togo, Benin and Nigeria (**Ferguson *et al.*, 2019**). Indeed, the South Comoe region of Côte d'Ivoire is the main area for the introduction of cassava varieties into the country. Growers cultivate several varieties in the same field, and this practice results in high diversity in the area as a result of gene flow between varieties (**Lekha et al., 2011** ; **Thiémélé *et al.*, 2024c**).

Accessions in groups 1, 2 and 3 had yields in excess of 20 t/ha, which are similar to the yields of improved varieties (**N'zué et al., 2004** ; **Bakayoko et al., (2012**). These accessions are potential candidates for increasing national cassava production.

Conclusion

Study of the agromorphological variability of cassava accessions collected in the South Comoe region of Côte d'Ivoire revealed a high degree of variability between accessions, highlighting potential candidates for increasing production in the country and satisfying the needs of the population. The 45 accessions were structured into 4 diversity groups (G1, G2, G3 and G4) on the basis of the variables studied. Varieties in groups 1, 2 and 3 had yields in excess of 20 t/ha. These varieties represent a real asset for farmers, and potential breeding genitors for a breeding program for high-yielding varieties in Côte d'Ivoire.

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