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Morphological diversity of taro genus *Xanthosoma* collected in four geographical areas in Côte d'Ivoire based on qualitative traits

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This study is part of the context of the development and sustainable management of neglected plant genetic resources in Côte d'Ivoire, including taro. The objective is to characterize the morphological diversity within taro accessions of the genus *Xanthosoma* from four geographical areas of Côte d'Ivoire. The study took place in the central, eastern, western and southern geographical areas of Côte d'Ivoire, involving 119 accessions of taro genus *Xanthosoma* comprising four morphotypes (M1, M2, M3 and M7). These accessions have been characterized based on traits related to the plant's habit, leaves, main tuber and secondary tubers, revealing a considerable morphological diversity. The observed traits were highly discriminating, leading to the identification of four homogeneous classes. The morphotypes M1, M2, M3 and M7 played a crucial role in classifying the 119 accessions of the taro genus *Xanthosoma*, with each class exclusively containing one of the four morphotypes. Classes 1 and 2, containing the M2 and M1 morphotypes, respectively, were closely related. These results demonstrate that the majority of taro accessions in Côte d'Ivoire can be characterized by the presence of four morphotypes: M1, M2, M3 and M7. Taro breeding efforts could be directed based on these four *Xanthosoma* morphotypes.

Key words: Diversity, taro, morphotypes, sustainable management, *Xanthosoma.*

INTRODUCTION

Taro holds significant importance as a staple food in numerous African countries, particularly south of the Sahara, contributing to food security as a reserve food source. Cultivated for its tubers and consumed for its leaves, two common taro genera in sub-Saharan Africa are *Colocasia and Xanthosoma* (Onyeka, 2014). Both genera are well-suited to various geographical areas in sub-Saharan Africa and rank among the most widely consumed tuber plants alongside cassava and yam. In West Africa, *Xanthosoma* is recognized as the true taro, serving as the primary edible Araceae (Opara, 2003). In Côte d'Ivoire, tuber crops, including taro, hold a significant place in the dietary habits of the population, alongside cassava and yam, forming the foundation of

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Table 1. Number of taro accessions of the genus *Xanthosoma* collected by morphological type in the center, east, west and south geographical areas, used as plant material.

Morphotype	Number of accessions by geographic area				
	Center	East	West	South	Total
M1	8	16	12	3	39
M2	12	6	32	1	51
M3	0	3	0	4	7
M7	0	22	0	0	22
Total	20	47	44	8	119

the diet in the 1960s (Haeringer, 1972). Despite its nutritional value, taro is relatively less known and valued compared to yam and cassava.

Taro's dry matter primarily consists of 60 to 90% carbohydrates, with starch content ranging between 73 and 80%, including an amylose content between 19 and 30.62% (Jane et al., 1992; Pérez et al., 2005). Notably, taro is richer in amylose compared to cassava (16.89%) or maize (22.4%) (Liu et al., 1997). With a digestibility estimated at 98.8% (Varin and Vernier, 1994), taro tubers are utilized in the production of various food products, including flour (Amon et al., 2011, 2014; Mulyaningsih et al., 2019).Despite its nutritional richness and potential as a food and cash crop, taro is often considered a second-choice food in Africa, particularly in Côte d'Ivoire. Consequently, the cultivation system for taro in Côte d'Ivoire remains underdeveloped, and its agronomic potential is not well-explored. Adequate documentation of local resources, their variability, and distribution is lacking, yet such data is crucial for defining effective management and improvement strategies for taro consumption in Côte d'Ivoire.In a recent study conducted in Côte d'Ivoire, Koffi and Koffi (2021) identified and described seven taro morphotypes (M1, M2, M3, M4, M5, M6 and M7) based on farmers' knowledge. Subsequently, taro accessions containing the seven morphotypes were re-examined by Koffi et al. (2021) to determine the botanical genera of taro cultivated in Côte d'Ivoire. These authors identified two genera of taro in cultivation : *Colocasia and Xanthosoma*, based on qualitative characteristics of the leaves. To formulate an effective strategy for taro improvement in Côte d'Ivoire, understanding the genetic variability of the genera *Colocasia and Xanthosoma* is essential. The objective of the study is to characterize the morphological diversity within taro accessions of the genus *Xanthosoma* from four geographical areas of Côte d'Ivoire.

MATERIALS AND METHODS

Plant material

The plant material utilized in this study comprises 119 taros accessions collected from the central, eastern, western and southern geographical areas of Côte d'Ivoire. These accessions pertain to four of the seven morphotypes (M1, M2, M3 and M7) of taro identified in Côte d'Ivoire by Koffi and Koffi (2021). Subsequently, Koffi et al. (2021) described and identified these morphotypes as belonging to the genus *Xanthosoma* (Table 1).

Study site

The trials to assess the morphological diversity of taro accessions belonging to the genus *Xanthosoma* were conducted from June 2020 to March 2021 in the commune of Soubré. The geographical coordinates of the site are 5° 42' 81″ north latitude and 6° 33′ 12″ west longitude. Soubré experiences a humid equatorial climate with an average temperature of 27°C. The annual variations in precipitation and temperature result in two rainy seasons and two dry seasons. The significant dry season extends from December to March, followed by a rainy season from April to mid-July. Subsequently, there is a dry season from mid-July to mid-September, concluding with a brief rainy season from mid-September to November. Soubré's vegetation is characterized by a dense humid forest, and the soil is predominantly deep ferritic with a sandy-clay texture and a lumpy structure (Yao-Kouamé and Kané, 2008).

Experiment design

The field layout followed a completely randomized design with five replications. The experimental plot measured 26 × 26 m and included 595 plants, representing the 119 accessions. Each accession was represented by 5 plants. The planting distance was set at 1 m between and within rows, with 1 m edges. Manual weeding was performed throughout the plant development phase.

Data collection and analysis

Twelve qualitative traits, selected from standard descriptors for Taro (IPGRI, 1999), were employed to characterize morphological diversity (Table 2). The collected data underwent Multiple Correspondence Analysis (MCA), Hierarchical Ascending Classification (HAC), and Discriminant Factor Analysis (DFA). Multiple Correspondence Analysis (MCA) was utilized to explore relationships between the qualitative traits and further describe morphological variation among accessions. MCA is particularly valuable for describing datasets by combining correlated variables into factors.

Hierarchical Ascending Classification (HAC) was employed to derive homogeneous groups of accessions. Lastly, Discriminant Factor Analysis (DFA) was conducted to identify the most discriminating traits and elucidate the characteristics of the groups obtained through HAC. All these analyses were carried out using the statistical software R version 4.1.0 (R Core Team, 2021).

Table 2. List of 12 qualitative variables observed between five and ten months after planting, on five plants per accession for the analysis of morphological diversity of taro accessions of the genus *Xanthosoma.*

Traits observed	Code	Variant	Codes
Shape of the base of the leaf	ShBL	Sagittate	BLSa
		Hastate	BLHa
Predominant position (shape) of the leaf blade surface	PrPL	Drooping	PLDr
		Horizontal	PLHo
		Cup-Shaped	PLCu
Color of the leaf blade	CoLB	Green-Dark	LBGD
		Green-Pale	LBGP
		Green	LBGr
Color of the main rib	CoMR	Green	MRGr
		Yellowish-Green	MRYG
		Yellow	MRYe
Color of the petiole	CoPe	Green	PeGr
		Green-White	PeGW
		Green-Pale	PeGP
Color of the petiole base	CoPB	Pink	PBPi
		Light-Pink	PBLP
		White	PBWh
		Yellow	PBYe
Color of the outer sheath	CoOS	Purple	OSPu
		Vert-Pâle	OSGP
Color of the interior sheath	CoIS	Brown	ISBr
		Green	ISGr
Rejection formation	ReFo	Yes	FoYe
		No	FoNo
Color of the flesh of the main tuber	CoFM	Pink	FMPi
		Beige	FMBe
		Pink-Beige	FMPB
Buds color	BuCo	Pink	CoPi
		White	Cowh
		Pink-White	CoPW
Color of the flesh of the secondary tuber	CoFS	Pink	FSPi
		White	FSWh
		Beige	FSBe
		Pink-White	FSPW
		White-Pink	FSWP
		Beige-Pink	FSBP
		Yellow	FSYe

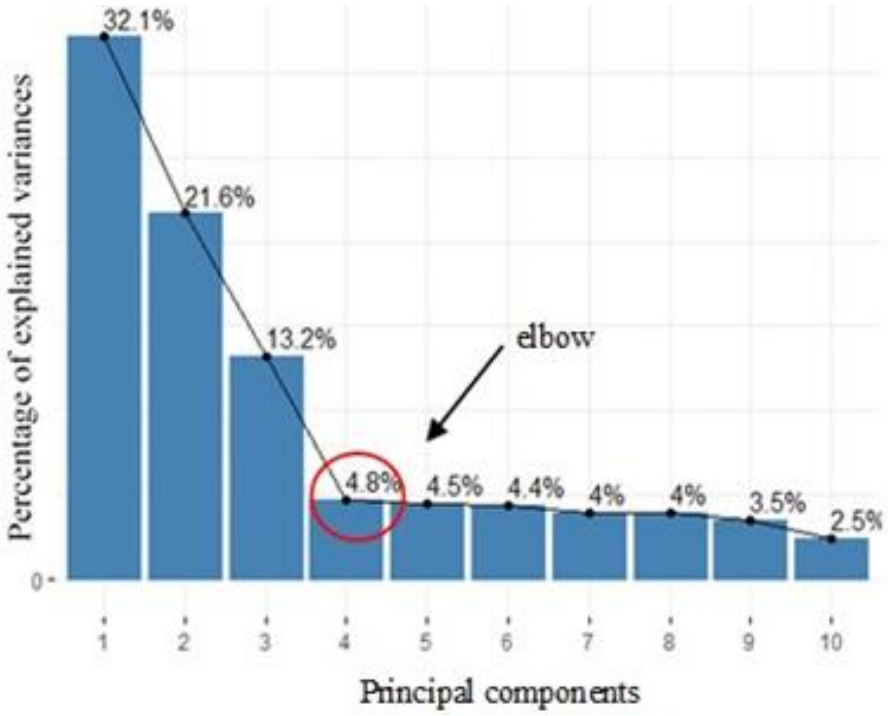

Figure 1. Decay curve of the percentages (%) of variance explained by the principal components of the multiple correspondence analysis.

RESULTS

Morphological variability and diversity structuring of 119 taro accessions of the genus *Xanthosoma*

Following the elbow detection rule, which identifies the breakpoint of the decay curve of the percentages of variance explained by the principal components of the MCA (Cattell and Vogelmann, 1977), the first three principal components located before the elbow were retained for the interpretation of the results (Figure 1). These components collectively explain 66.97% of the total variation.

With the exception of buds color (BuCo), all 12 observed traits were relevant in structuring the diversity of taro accessions belonging to the genus *Xanthosoma*. The shape of the base of the leaf (ShBL), predominant position of the leaf blade surface (PrPL), color of the main rib (CoMR), rejection formation (ReFo), and color of the flesh of the main tuber (CoFM) significantly contributed to the formation of axis 1 ($r2 > 0.7$).

Additionally, color of the outer sheath (CoOS) and color of the inner sheath (CoIS) made a significant contribution to the formation of axis 2 ($r2 > 0.7$), while color of the flesh of the secondary tuber (CoFS) strongly contributed to the formation of axis 3 ($r2 > 0.7$). Blade color (CoLB) and petiole color (CoPe) were more involved in the formation of axes 1 and 2 ($r2 > 0.7$). Moreover, color of the petiole base (CoPB) and color of the flesh of the main tuber (CoFM) had significant impacts on the formation of axes 1 and 3 ($r2 > 0.7$).

Each factorial axis of MCA was named based on the contribution of different variables to its formation (Table 3). Therefore, axis 1 describes leaf structure and characteristics of the shoots and plants, axis 2 describes the coloration of the aerial part, and axis 3 mainly describes the coloration of the tuber flesh.

The projection of taro accessions of the genus *Xanthosoma* in the factorial planes 1 to 2 of MCA took into account axis 1 (32.10%) and axis 2 (21.60%), expressing the greatest variability. It revealed three distinct groups (Figure 2).

In Figure 3, the projection of variants in the factorial plane planes 1 to 2 of MCA revealed that Group 1 was composed of accessions with the following traits: Green-dark leaf blade (LBGD), main rib of yellow color (MRYe), green-white petiole (PeGW), pink-white buds (CoPW), sagittate base leaf (BLSa), sheaths purple on the outside (OSPu), and brown inside (ISBr), pink petiole base (PBPi), main tuber with pink (FMPi) or beige (FMBe) flesh. Some of these accessions had secondary tubers showing yellow (FSYe), pink (FSPi), or white (FSWh) flesh. Other accessions in this group had secondary tubers with a doublé pink and white flesh color, either pink-dominant (FSPW) or white (FSWP).

Group 2 comprised accessions with the leaf blade (LBGP), petiole (PeGP), and the outside sheath (OSGP) of pale green color. The inside of the sheath of these accessions was green (ISGr).

Table 3. Eigenvalues, percentagesof variability explained by the factorial axes and MCA and correlations coefficient between traits and the first three factorial axes.

Variable	PC1	PC2	PC3
Eigenvalues	0.67	0.45	0.27
% of variance	32.09	21.65	13.23
% of cumulative variance	32.09	53.74	66.97
ShBL	0.96*	0.02	0.00
PrPL	0.96*	0.02	0.00
CoLB	0.98*	0.89*	0.08
CoMR	0.82*	0.21	0.03
CoPe	0.98*	0.89*	0.08
CoPB	0.97*	0.45	0.79*
CoOS	0.00	0.89*	0.08
CoIS	0.00	0.89*	0.08
ReFo	0.85*	0.02	0.00
CoFM	0.91*	0.27	0.72*
BuCo	0.22	0.64	0.68
CoFS	0.32	0.23	0.72*

*the strongly correlated traits (r2 > 0.7): ShBL, shape of the base of the leaf; PrPL, predominant position of the leaf blade surface; CoLB, color of the leaf blade; CoMR, color of the main rib; CoPe, color of the petiole; CoPB, color of the petiole base; CoOS, color of the outer sheath; CoIS, color of the inner sheath; ReFo, rejection formation; CoFM, color of the flesh of the main tuber; BuCo, buds color; CoFS, color of the flesh of the secondary tuber.

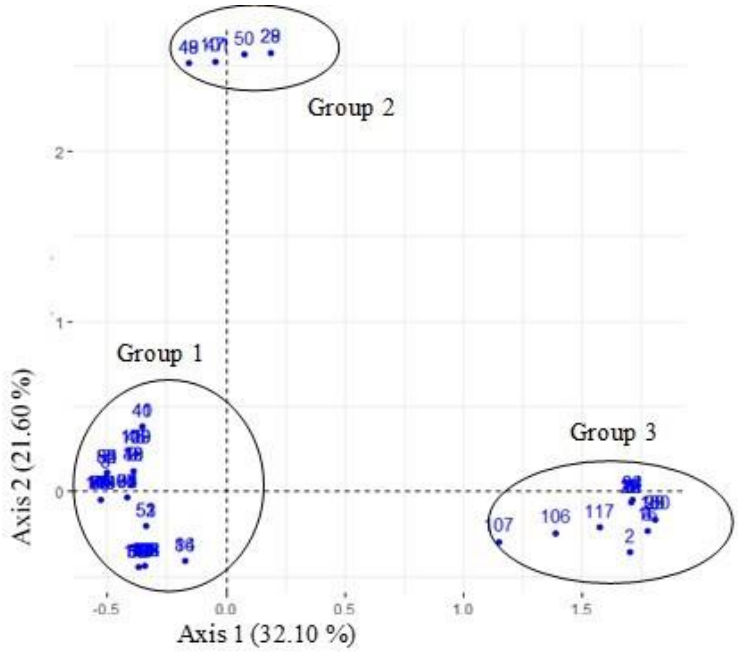

Figure 2. Structuring the diversity of 119 taro accessions of the genus *Xanthosoma* into three distinct groups in the plane formed by the factorial axes 1-2 of MCA.

Group 3 was composed of accessions with rejections (FoYe), main rib either green (MRGr) or yellow-green (MRYG), horizontal leaf blade surface (predominant position) (PLHo), and flesh of the secondary tubers with a doublé beige and pink color, with beige dominance (FSBP).

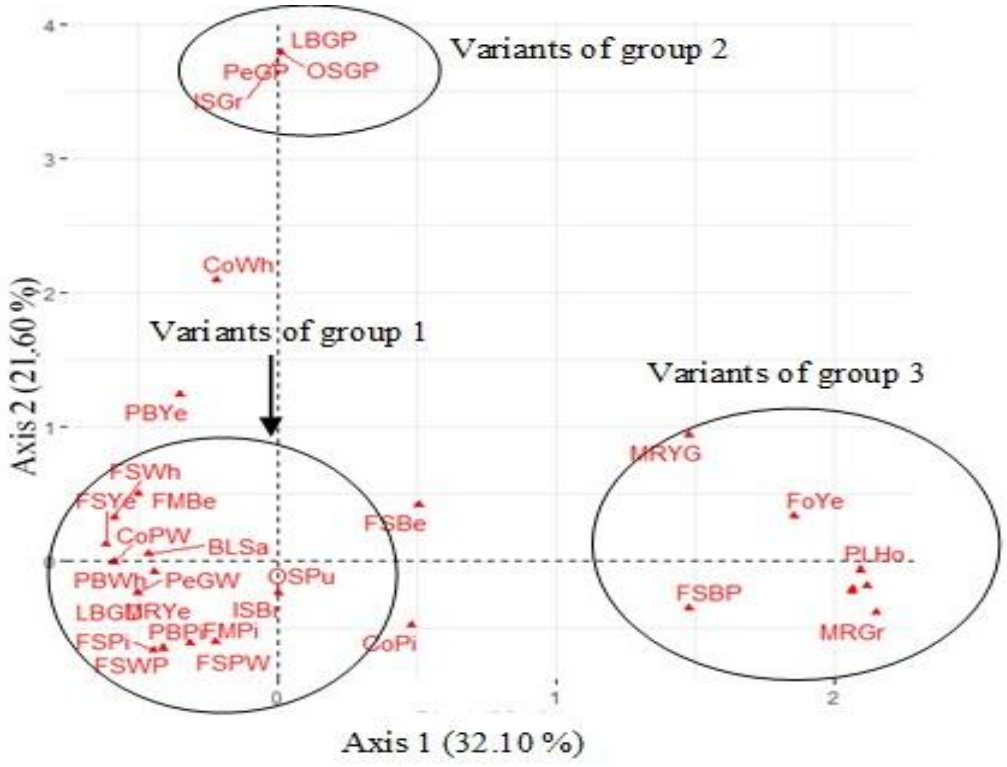

Figure 3. Projection of variants of 119 taro accessions of the genus *Xanthosoma* in MCA factorial plane 1-2. LBGD, green-dark leaf blade; MRYe , main rib of yellow color; PeGW , green-white petiole; CoPW , pink-white buds; BLSa, sagittate base leaf; OSPu, sheaths purple outside; ISBr, sheaths brown inside; PBPi , pink petiole base; FMPi , main tuber pink flesh; FMBe, main tuber beige flesh; FSYe, secondary tubers yellow flesh; FSPi, secondary tubers pink flesh; FSWh, secondary tubers white flesh. FSPW, secondary tubers with pink and white flesh with pink dominance; FSWP , secondary tubers with pink and white flesh with white dominance; LBGP, pale green leaf blade; PeGP, pale green petiole; OSGP, sheath pale green outside; ISGr, sheath green inside; FoYe , rejections presence; MRGr, green main rib; MRYG, yellow-green main rib; PLHo , horizontal leaf blade surface; FSBP, secondary tubers with beige and pink flesh with beige dominance; CoWh, white buds; PBPi, yellow petiole base; FSBe, secondary tubers beige flesh; CoWh, pink buds.

Classification of the 119 taro accessions of the genus *Xanthosoma* into homogeneous classes

Taro accessions of the genus *Xanthosoma* were distributed into four homogeneous classes by the Hierarchical Ascending Classification (Figure 4).

Class 1 comprised only M2 morphotype accessions from the central, eastern, western, and southern areas. Class 2 gathered accessions of morphotype M1 originating from the central, eastern, western and southern areas. Class 3 exclusively contained accessions of morphotype M3 from the eastern and southern areas. Lastly, Class 4 included only accessions of morphotype M7 from the eastern area (Table 4). The area of origin of taro accessions of the genus Xanthosoma does not appear to be a determining factor in their classification. Conversely, the morphological type seems to be the primary factor differentiating these classes.

Although the Multiple Correspondence Analysis structured the 119 accessions of the genus *Xanthosoma* into three groups (Figure 2); the Hierarchical Ascending Classification revealed four homogeneous classes. One of the MCA groups would thus contain two very similar morphotypes with many similarities and few differences.

Discrimination of homogeneous classes of the 119 taro accessions of the genus *Xanthosoma*

The projection of the four classes of taro accessions belonging to the genus *Xanthosoma* into the Discriminant Factorial Analysis factorial plane resulted in a highly distinct structuring (Figure 5). Despite accessions in classes 1 and 2 belonging to different morphotypes, these classes were found to be very close to each other, originating from group 1 obtained by the structuring of the MCA. Conversely, classes 3 and 4 come respectively from groups 2 and 3 of the MCA (Figure 2).

The 12 traits analyzed were found to be very highly

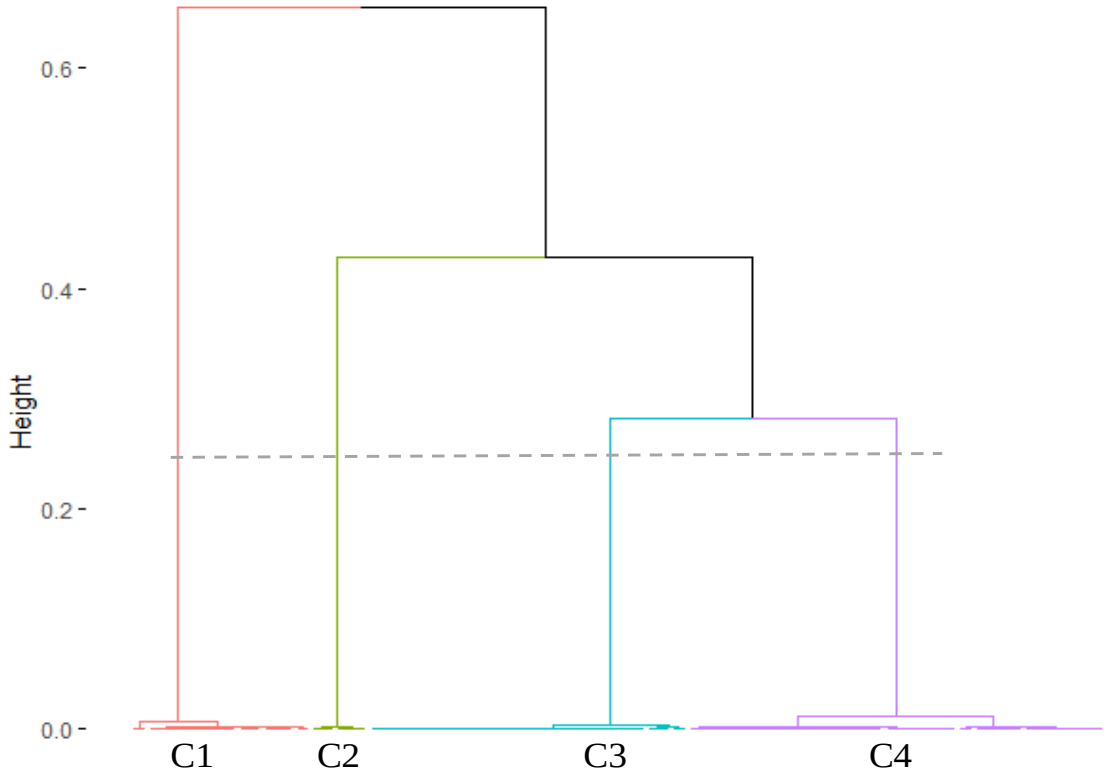

Figure 4. Dendrogram presenting the four homogeneous classes of taro accessions of the genus *Xanthosoma* highlighted by the hierarchical ascending classification.

Table 4. Morphotypes, areas of origin and number of homogeneous classes of taro accessions of the genus *Xanthosoma.*

Class	Morphotype	Areas of origin	Number of accessions
Class 1	M2	Center, east, west, south	51
Class 2	M1	Center, east, west, south	39
Class 3	M3	East, south	7
Class 4	M7	East	22

significant ($P < 0.001$) to discriminate the four classes of accessions. Table 5 presents these traits in descending order of their discriminative power.

Based on the indicators "class/variants," which show the frequency of each variant in each class in relation to the entire set of classes, and "variants/class," which display the frequencies of accessions having the said variants within each class, the characteristics of the four homogeneous classes were highlighted. The "global" indicator presented the frequencies of the variants within the 119 taro accessions of the genus *Xanthosoma*.

Class 1 is composed of accessions with the following traits: Beige flesh of the main tuber (CoFM=Beige), pink-white buds (BuCo=Pink-white), white petiole base (CoPB=White), whitish-green petiole (CoPe=Green-white), yellow main rib (CoMR=Yellow), green-dark leaf blade (CoLB=Green-dark), cup-shaped leaf blade (PrPL=Cup-shaped), sagittate leaves (ShBL=Sagittate), purple leaf sheath on the outside (CoOS=Purple), brown on the inside (CoIS=Brown), and free of rejections (ReFo=No) (Table 6).

Class 2 consists of accessions with pink flesh of the main tuber (CoFM=Pink), pink buds (BuCo=Pink), pink petiole base (CoPB=Pink), secondary tubers with pink (CoFS=Pink) and pink-white flesh (CoFS=Pink-white), whitish green petiole (CoPe=Green-white), yellow main

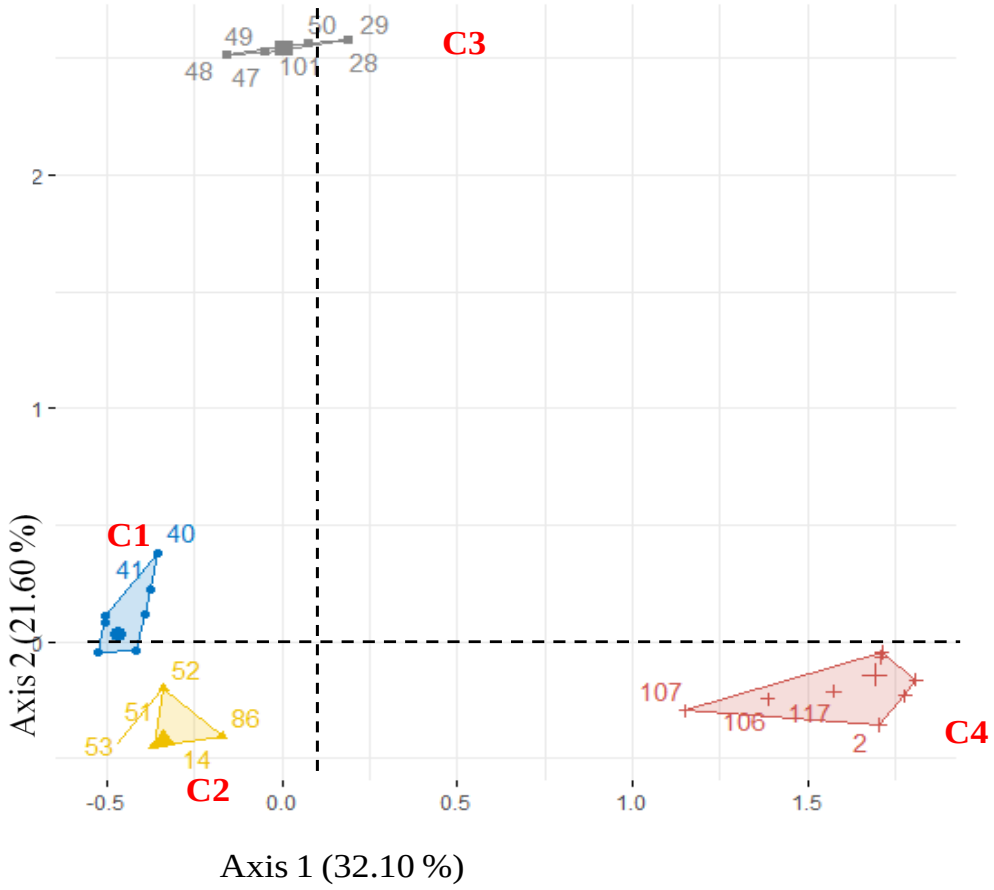

Figure 5. Projection of the homogeneous classes of taro accessions of the genus *Xanthosoma* obtained by HCA in the factorial plane 1-2 of the discriminant factorial analysis.

Table 5. Traits observed discriminating the four classes of taro accessions of the genus Xanthosoma highlighted by the discriminant factorial analysis.

Traits observed	*P*	df
CoPB	< 0.001	9
CoLB	< 0.001	6
CoPe	< 0.001	6
CoFM	< 0.001	6
BuCo	< 0.001	6
ShBL	< 0.001	3
CoOS	< 0.001	3
CoIS	< 0.001	3
CoMR	< 0.001	6
PrPL	< 0.001	6
ReFo	< 0.001	3
CoFS	< 0.001	18

ShBL, shape of the base of the leaf; PrPL, predominant position of the leaf blade surface; CoLB, color of the leaf blade; CoMR, color of the main rib; CoPe, color of the petiole; CoPB, color of the petiole base; CoOS, color of the outer sheath; CoIS, color of the inner sheath; ReFo, rejection formation; CoFM, color of the flesh of the main tuber; BuCo, buds color; CoFS, color of the flesh of the secondary tuber.

Table 6. Variants of characteristic traits of taro accessions of the genus *Xanthosoma* of class 1 identified by AFD the discriminant factorial analysis.

Variants	Class/variant	Variant/class	Global	p.Value
CoFM=Beige	87.93	100	48.74	< 0.001
BuCo=Pink-white	100	86.27	36.98	< 0.001
CoPB=White	100	74.51	31.93	< 0.001
CoFS=White	90.63	56.86	26.89	< 0.001
CoPe=Green-white	56.67	100	75.63	< 0.001
CoMR=Yellow	56.67	100	75.63	< 0.001
CoLB=Green-dark	56.67	100	75.63	< 0.001
ReFo=No	53.13	100	80.67	< 0.001
PrPL=Cup-shaped	52.58	100	81.51	< 0.001
ShBL=Sagittate	52.58	100	81.51	< 0.001
CoIS=Brown	45.54	100	94.12	< 0.05
CoOS=Purple	45.54	100	94.12	< 0.05

ShBL, shape of the base of the leaf; PrPL, predominant position of the leaf blade surface; CoLB, color of the leaf blade; CoMR, color of the main rib; CoPe, color of the petiole; CoPB, color of the petiole base; CoOS, color of the outer sheath; CoIS, color of the inner sheath; ReFo, rejection formation; CoFM, color of the flesh of the main tuber; BuCo, buds color; CoFS, color of the flesh of the secondary tuber.

Table 7. Variants of characteristic traits of taro accessions of the genus *Xanthosoma* of class 2 identified by AFD the discriminant factorial analysis.

Variants	Class/variant	Variants/class	Global	p. Value
CoFM=Pink	95.12	100	34.45	< 0.001
CoPB=Pink	100	92.31	30.25	< 0.001
CoFS=Pink-white	90.91	76.92	27.73	< 0.001
BuCo=Pink	63.93	100	51.26	< 0.001
CoPe=Green-white	43.33	100	75.63	< 0.001
CoMR=Yellow	43.33	100	75.63	< 0.001
CoLB=Green-dark	43.33	100	75.63	< 0.001
ReFo=No	40.63	100	80.67	< 0.001
PrPL=Cup-shaped	40.21	100	81.51	< 0.001
ShBL=Sagittate	40.21	100	81.51	< 0.001
CoFS=Pink	100	15.39	5.04	< 0.001
CoPB=PBYe	13.04	7.69	19.32	< 0.05

ShBL, shape of the base of the leaf; PrPL, predominant position of the leaf blade surface; CoLB, color of the leaf blade; CoMR, color of the main rib; CoPe, color of the petiole; CoPB, color of the petiole base; CoOS, color of the outer sheath; CoIS, color of the inner sheath; ReFo, rejection formation; CoFM, color of the flesh of the main tuber; BuCo, buds color; CoFS, color of the flesh of the secondary tuber.

rib (CoMR=Yellow), green-dark leaf blade (CoLB=Green-dark), cup-shaped leaf blade (PrPL=Cup-shaped), sagittate leaves (ShBL=Sagittate), purple leaf sheath on the outside (CoOS=Purple) and brown on the inside (CoIS=Brown), and free of rejections (Table 7).

Class 3 grouped accessions with the green sheath inside (CoIS=Green) and green-pale outside (CoOS= Green-pale), green-pale petiole (CoPe=Green-pale), green-pale leaf blade (CoLB=Green-pale), white buds (BuCo=white), yellow petiole base (CoPB=Yellow), yellow-green main rib (CoMR=Yellow-green) and beige flesh of the main tuber (CoFM=beige) (Table 8).

Class 4 gathered accessions with light-pink petiole base (CoBP=Light-pink), green petiole (CoPe=Green), green leaf blade (CoLB=Green), hastate leaves (ShBL= Hastate), pink-beige flesh of the main tuber (CoFM=Pink-beige), drooping leaf blade (PrPL=Drooping), rejection formation (ReFo=Yes), yellow-green and green main rib (CoMR=Yellow-green, CoMR=Green) and pink buds (BuCo=Pink) (Table 9). Figure 6 shows images of the characteristic variants discriminating the four classes of taro accessions of the genus *Xanthosoma*.

Table 8. Variants of characteristic traits of taro accessions of the genus *Xanthosoma* of class 3 identified by AFD the discriminant factorial analysis.

Variants	Class/variant	Variants/class	Global	p. Value
CoIS=Green	100	100	5.88	< 0.001
CoOS=Green-pale	100	100	5.88	< 0.001
CoPe=Green-pale	100	100	5.88	< 0.001
CoLB=Green-pale	100	100	5.88	< 0.001
BuCo=White	50	100	11.77	< 0.001
CoPB=Yellow	30.44	100	19.33	< 0.001
CoMR=Yellow-green	28	100	21.01	< 0.001
CoFM=Beige	12.07	100	48.74	< 0.01

CoLB, color of the leaf blade; CoMR, color of the main rib; CoPe, color of the petiole; CoPB, color of the petiole base; CoOS, color of the outer sheath; CoIS, color of the inner sheath; CoFM, color of the flesh of the main tuber; BuCo, buds color.

Table 9. Variants of characteristic traits of taro accessions of the genus *Xanthosoma* of class 4 identified by AFD the discriminant factorial analysis.

Variants	Class/variants	Variants/class	Global	p. Value
CoPB=Light-pink	100	100	18.49	< 0.001
CoPe=Green	100	100	18.49	< 0.001
CoLB=Green	100	100	18.49	< 0.001
ShBL=Hastate	100	100	18.49	< 0.001
CoFM=Pink-beige	100	90.91	16.81	< 0.001
PrPL=Drooping	100	90.91	16.81	< 0.001
ReFo=Yes	86.96	90.91	19.33	< 0.001
CoMR=Yellow-green	72	81.82	21.01	< 0.001
BuCo=Pink	36.07	100	51.26	< 0.001
CoMR=Green	100	18.18	3.36	< 0.001
CoFS=Beige	35.90	63.64	32.77	< 0.001
CoFS=Beige-pink	71.43	22.72	5.88	< 0.01
PrPL=Horizontal	100	9.10	1.68	< 0.01

ShBL, shape of the base of the leaf; PrPL, predominant position of the leaf blade surface; CoLB, color of the leaf blade; CoMR, color of the main rib; CoPe, color of the petiole; CoPB, color of the petiole base; CoOS, color of the outer sheath; CoIS, color of the inner sheath; ReFo, rejection formation; CoFM, color of the flesh of the main tuber; BuCo, buds color; CoFS, color of the flesh of the secondary tuber.

Traits observed	Variants			
Color of the petiole base (CoPB)	 Pink (C2 : 100%)	 Light-pink (C4 : 100%)	 Yellow (C2 : 13.04% ; C3 : 30.43%)	 White (C1 : 100%)

Color of the leaf blade (CoLB)	 Green-dark (C1 : 56.67% ; C2 : 43.33%)	 Green (C4 : 100%)	 Green-pale (C3 : 100%)
Color of the petiole (CoPe)	 Whitish-green (C1 : 56.67% ; C2 : 43.33%)	 Green (C4 : 100%)	 Green-pale (C3 : 100%)
Color of the flesh of the main tuber (CoFM)	 Pink (C2 : 95.12% ; C4 : 4.88%)	 Pink-beige (C4 : 100%)	 Beige (C1 : 87.93% ; C3 : 12.07%)
Buds color (BuCo)	 Pink (C2 : 63.93% ; C4 : 37.07%)	 Pink-white (C1 : 100%)	 White (C3 : 50%)

Traits observed	Variants		
Shape of the base of the leaf (ShBL)	 Sagittate (C1 : 52.58% ; C2 : 40.21%)	 Hastate (C4 : 100%)	
Color of the outer sheath (CoOS)	 Purple (C1 : 45.54%)	 Green-pale (C3 : 100%)	
Color of the interior sheath (CoIS)	 Brown (C1 : 45.54%)	 Green (C3 : 100%)	
Predominant position (shape) of the leaf blade surface (PrPL)	 Cup-shaped (C1 : 52.58%. C2 : 40.21%)	 Drooping (C4 : 100%)	 Horizontal (C4 : 100%)
Color of the main rib (CoMR)	 Yellow (C1 : 56.67% ; C2 : 43.33%)	 Yellow-green (C3 : 29.17% ; C4 : 70.83%)	 Green (C4 : 100%)

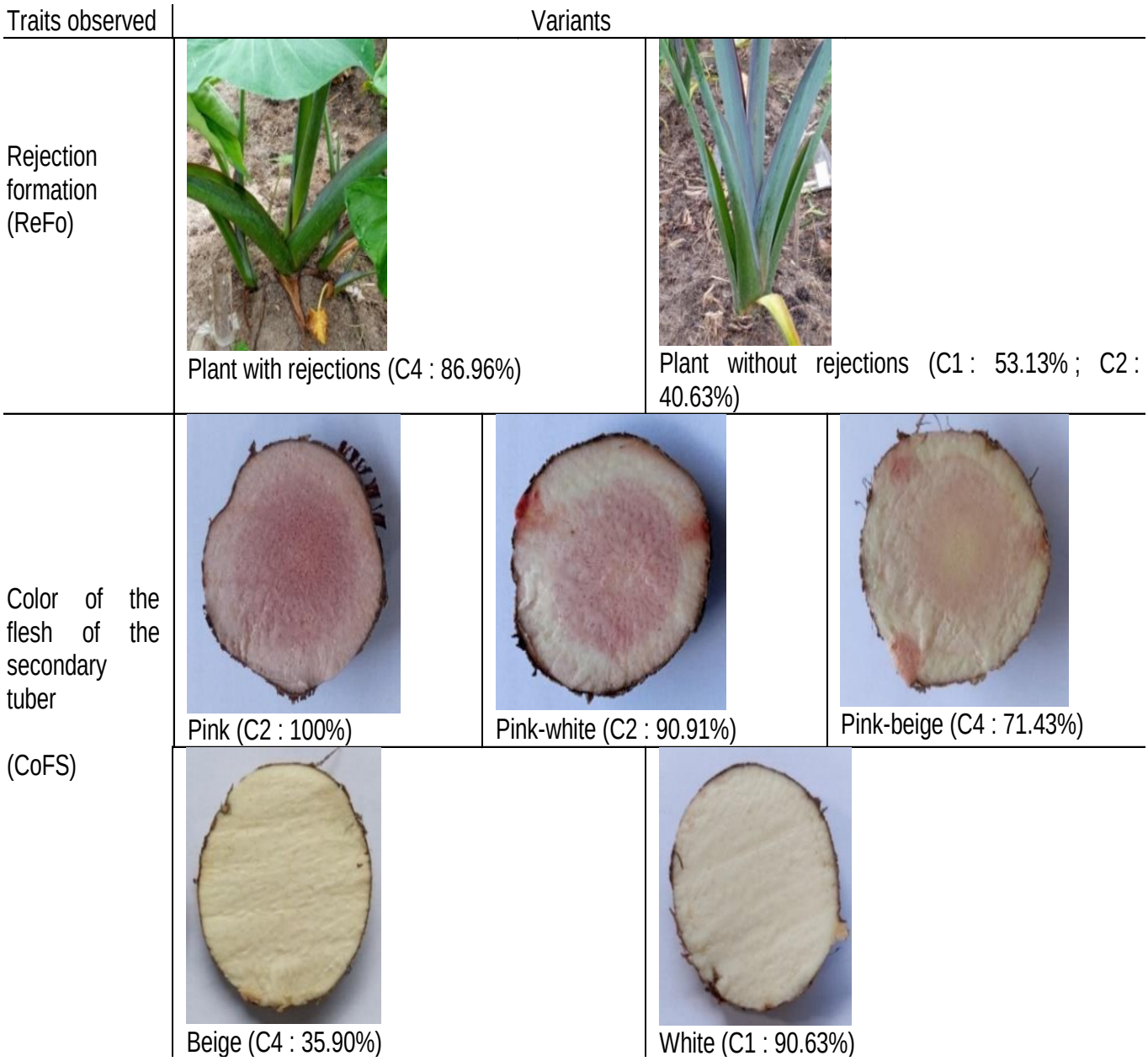

Figure 6. Variants of characteristic traits discriminating the four classes of taro accessions of the genus *Xanthosoma*.

DISCUSSION

The analysis of morphological variability in 119 taros Accessions of the genus *Xanthosoma* collected across the central, east, west and south areas of Côte d'Ivoire revealed significant diversity. Characteristics related to the plant's habit, leaves, main tuber and secondary tubers proved to be highly discriminating in this study.

These traits strongly contributed to the formation of the first three axes in the Multiple Correspondence Analysis, highlighting distinct morphological groups.

Taro accessions of the genus *Xanthosoma* were initially separated into three groups in the factorial planes 1 to 2 of the MCA. Group 1 accessions exhibited green-dark leaf blades, whitish-green petioles, a main tuber with pink or beige flesh, and secondary tubers with pink, white, and beige flesh. Some of these secondary tubers displayed a doublé coloration of pink-white flesh, either predominantly pink or predominantly white. Group 2 accessions were primarily characterized by the pale-green coloration of the leaf blades and petioles. They also had a main tuber with beige flesh and secondary tubers with white and beige flesh. Group 3 comprised accessions with green leaf blades and petioles, a main

tuber, and secondary tubers with flesh of double beige-pink color, predominantly pink.

These distinctive traits specific to each group confirm the existence of three main types of plants within the taro accessions of the genus *Xanthosoma* in Côte d'Ivoire. The initial grouping of the 119 accessions into three groups was further refined into four homogeneous classes. Group 1 was subdivided into two classes, resulting in classes 1 and 2. Groups 2 and 3 gaves rise to classes 3 and 4, respectively. These results underscore the substantial agromorphological diversity of taro accessions within the genus *Xanthosoma* in Côte d'Ivoire. Similar findings were reported by Wada et al. (2021) and Villavicencio et al. (2021) in their studies on the taro species *Xanthosoma sagittifolium* (L.) Shott. These authors also identified four agromorphological classes within collections of taro accessions belonging to the species *Xanthosoma sagittifolium*. Wada et al. (2021) and Villavicencio et al. (2021) observed phenotypes with characteristic traits similar to those highlighted in this study, including the shape of the base of the leaf, leaf blade color, petiole color and color of the flesh tuber.

The similarities between the classes of taro accessions belonging to the species *X. sagittifolium* revealed by Wada et al. (2021) and Villavicencio et al. (2021), and the classes of taro accessions of the genus Xanthosoma observed in our study, suggest that the taro accessions collected in Côte d'Ivoire may contain accessions of the species *X. sagittifolium*.

However, the rejections formation in the accessions of class 4, a distinguishing feature in this study, was not mentioned by Wada et al. (2021) and Villavicencio et al. (2021). Additionally, accessions of class 4 are atypical, being the only ones that produce a consumable main tuber among the 119 taro accessions of the genus *Xanthosoma* collected in Côte d'Ivoire. This suggests that the taro accessions considered in this study may encompass accessions of two botanical varieties within the species *X. sagittifolium* or possibly accessions of a second species within the same genus in addition to *X. sagittifolium*.

The morphological types M1, M2, M3 and M7 played a crucial role in the classification of the 119 taro accessions within the genus Xanthosoma. Each class exclusively grouped accessions of a single morphotype, irrespective of their geographical areas of origin. Class 1, for instance, consisted of accessions of morphotype M2 from the central, east, west and south areas. Class 2 gathered only accessions of morphotype M1 from the same regions. Class 3 included accessions of morphotype M3 from the east and south areas, while class 4 contained accessions of morphotype M7 from the east.

Classes 1 and 2, representing M2 and M1 morphotypes, respectively, were closely positioned. These two classes, and by extension, these two morphotypes, exhibited many similarities and very few differences. Farmers often found it challenging to differentiate between morphotypes M1 and M2 based on the identical aerial part of the plants, which comprised long petioles and leaf blades. Farmers typically relied on the flesh color of the tuber for distinction, with morphotype M1 producing tubers with generally pink flesh, while morphotype M2 gave tubers with white and beige flesh. Additionally, the coloration of the petiole base below the collar could also be used for differentiation, as morphotype M1 had a pink petiole base, whereas morphotype M2 had a white petiole base.

The results strongly suggest that the taro genus *Xanthosoma* in Côte d'Ivoire exhibits significant morphological diversity. The 119 accessions considered in the study likely belong to the species *X. sagittifolium* (L.) Schott, as described by Wada et al. (2021) and Villavicencio et al. (2021). The observed polymorphism in the species *X. sagittifolium* in Côte d'Ivoire could be explained by the fact that *X. sagittifolium* is a species complex containing more than one species, according to various authors and botanists, including Snowdon (1991).

Conclusion

Taro accessions within the genus *Xanthosoma* collected in the central, east, west and south regions of Côte d'Ivoire exhibited significant morphological diversity. The characteristics related to the plant's habit, leaves, main tuber and secondary tubers were highly discriminating, leading to the identification of four homogeneous classes. The morphological types M1, M2, M3 and M7 played a crucial role in classifying the 119 taro accessions within the genus Xanthosoma. Each class exclusively contained accessions of a single morphotype, with classes 1 and 2 representing the M2 and M1 morphotypes, respectively, being very closely positioned.

Conducting a diversity study using molecular markers would offer a more comprehensive understanding of the diversity among taro accessions within the genus *Xanthosoma* cultivated in Côte d'Ivoire. Additionally, such an analysis could help determine the precise genetic makeup and classification of the atypical accessions found in class 4.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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