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Morphological traits variation of cowpea (*Vigna unguiculata* L. Walp) grown in Côte d'Ivoire

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The genetic diversity of a genetic resource is an indicator of its richness and offers many possibilities for improvement. Cowpea is an important source of nutrients for humans and animals. This study aimed at assessing genetic diversity and relationships present among 135 accessions in the Centre National de Recherches Agronomiques (CNRA) collection, using qualitative traits. Traits analysis revealed significant genetic variation between the studied accessions through high Shannon diversity index. Estimated for 15 morphological characters with 0.80 mean value, H' ranged from 0.55 to 1. Seed traits generally expressed mean high diversity index (0.70-0.89). Between 15 parameters assessed, 12 exhibited the most discriminating variability of collection. The three MCA factorial axes explained 19.085% of phenotypic variability. The trait seed colour being correlated to these axes could be used as a selection criterion for local cowpeas improvement. Based on MCA and HAC methods, these accessions were classified into three distinct groups. Containing most accessions, subgroup Ia includes all seeds, pod, and flower colours. Almost all accessions of subgroup Ib possessed cream-coloured, smooth and globose seeds. All cluster II accessions have a creeping habit. The CNRA collection being very diversified, it constitutes a useful resource for future cowpea improvement studies in Côte d'Ivoire.

Key words: Cowpea, accessions, genetic diversity, trait qualitative.

INTRODUCTION

The best selection strategies begin from the genetic diversity available in genetic resources. Techniques for assessing genetic diversity through phenotypic and genotypic variations are essential for improving the effectiveness of breeding programmes (Costa et al., 2017). Knowing trait variation can provide more complete understanding of the germplasm resources diversity among breeding materials (Guo et al., 2022). Indeed, assessment of genetic variability based on morphological markers is useful for early characterisation and selection in the field (Raina et al., 2020). Moreover, morphological data is also valuable for assessing and comparing patterns of diversity within and between populations (Veasey et al., 2008) as well as morphological and phenological performances are essential for high-potential agronomic result (Esan et al., 2023). A large

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number of studies (Egbadzor et al., 2014; Toyin, 2019; Barik et al., 2023) using phenotypic markers to understand cowpea (*Vigna unguiculata* (L.) Walp.) genetic diversity.

Native of Africa, cowpea is an important legume (Kouam et al., 2012) and where it constitutes the second most important crop, after groundnuts (*Arachis hypogea*) (Mateva et al., 2023). Among the world, Africa accounts for over 96% of total production, Nigeria, Niger and Burkina Faso being the three main producers (FAO, 2023). Cowpea has significant nutritional potential with high protein, carbohydrate and low fat content (Jayathilake et al., 2018). Its seeds, the most widely consumed, are used in a variety of food preparations. Fresh, young cowpea leaves are also used and ranked among the top four vegetables used in 24 African and seven Asian countries (Mohammed et al., 2021). It should be noted that the leaves (27 to 43%) contain a higher proportion of protein than the dried seeds (21 to 33%) (Anago et al., 2023). Cowpea also ensures the sustainability of production systems, thanks to its rapid soil cover. It protects the soil from erosion and weed invasion, and restores its fertility (Alemu et al., 2016; Das et al., 2018; Adu et al., 2021). It is also climate-resistant and helps to maintain sustainable agriculture. Cowpeas have multiple functions that help maintain good health (Frota et al., 2008; Dinore et al., 2022). Both wild and cultivated forms of this crop make it a well-diversified source conserved in many gene banks around the world: in Africa (International Institute of Tropical Agriculture (IITA), Nigeria), the United States (University of California, Riverside (UCR), State of California) and India (National Plant Genetic Resources Office (NBPGR), New Delhi).

In Côte d'Ivoire, known as the "haricot", cowpea is a highly prized crop for its seeds and leaves (Gore Bi et al., 2020). However, cowpea remains under-utilised crop and grown in rural areas on small-scale, low-income farmers and there are no national agricultural statistics on its yields. Moreover, very little information is available about the diversity of its genetic material. The various studies carried out are inadequate and do not allow us to explore its real potential. The local cowpea available today requires a good knowledge of all its characteristics. Information on the extent of genetic diversity will provide useful information for its improvement. Cowpea cultivation development could therefore contribute to food security and the Ivorian livelihoods improvement. Characterisation and evaluation of cowpea germplasm are essential for effective selection and conservation. Cowpea cultivation development could therefore contribute to food security and the Ivorian livelihoods improvement. Although quantitative traits enable the target traits exploration (Khan et al., 2022), qualitative traits affect the market value of genetic material (Adjimoti et al., 2017). These traits help at understanding plant intraspecific variations.

This study globally aimed at assessing genetic diversity of cowpea accessions grown in Côte d'Ivoire for their improvement in genetic programmes following qualitative traits. Specifically, this study aimed at assessing the Centre National de Recherche Agronomique (CNRA) cowpea accessions phenotypic diversity to determine the most discriminating qualitative traits and establish their genetic link. These results will provide a useful basis for selecting cowpeas.

MATERIALS AND METHODS

Plant

It consisted of *V. unguiculata* seeds of 135 accessions grown in Côte d'Ivoire. These accessions, from diverse agroecological zones, were provided by the CNRA.

Experimental site

Study was carried out on an experimental field in Bédiala (west-central Côte d'Ivoire), between latitude 7°09' 60.00" N and longitude 6°17' 60.00". Located in the Haut-Sassandra zone, this area enjoys a transitional humid tropical climate (Eblin et al., 2020). Its soils are ferrallitic and characterised by a thin humic horizon rich in organic matter, slightly acidic and well structured (Adjiri et al., 2019). Dry and wet seasons also alternate, with mean temperatures ranging from 24.65°C to 27.75°C (Konan et al., 2022). Bédiala is characterised by four seasons, two rainy seasons and two dry seasons (Tonessia et al., 2018). The average annual temperature is 25.6°C (Adjiri et al., 2019).

Experimental design

The field experiments were conducted over two years (2020 to 2021) using a randomised complete block design with two replications. Each replication consisted of 135 rows 4.5 m long, with 0.5 m spacing between rows. Each row contained 10 seed wholes each spaced by 0.5 m. Blocs were spaced by 2 m. The experimental plot total size was 73 m × 14 m, where contained 1350 plants, replicates were 1 m each spaced. Trials were regularly monitored during the growing season.

Traits measurement

Morphological characterisation was assessed following 15 qualitative traits selected from cowpea descriptor developed by the International Board for Plant Genetic Resources (IBPGR). The traits were recorded visually at different stages of plant growth in the field and after harvesting in the laboratory. The data were divided into three categories: (1) vegetative stage, (2) pod stage, and (3) seed stage (Table 1).

Statistical analysis

All the data collected from morphological traits of cowpea accessions were subjected to descriptive statistical analysis (phenotypic frequency distribution and Shannon-Weaver diversity index). Frequency distributions were used to calculate the Shannon-Weaver diversity index (H') for each trait in order to assess their diversity level according to the following formulae (Hennink and Zeven, 1990):

Table 1. Qualitative trait and phenotypic classes for 135-cowpea accessions evaluation.

Qualitative traits		Phenotypes
Vegetative stage	Terminal leaflet colour (Lco)	1: pale green, 2: intermediate, and 3: dark green
	Terminal leaflet shape (Lsh)	1: globose, 2: hastate, 3: oval, 4: rhomboid, and 5: sub-hastate
	Leaf texture (Pte)	1: membranous, 2: intermediate, and 3: coriaceous
	Growth habit (Gha)	1: climbing, 2: climbing erect, 3: creeping, 4: erect, 5: prostrate, 6: semi-erect, and 7: semi creeping
	Leaf hairiness (Pha)	1: glabrescent 2: short appressed hairs, 3: pubescent to hirsut
	Stem pigment (Spi)	1: pale green, 2: intermediate green, 3: dark green, 4: pale red, 5: red, 6: vtr (green with red trace)
	Flower colour (Fco)	1: cream, 2: dark purple, 3: mauve purple, 4: pale pink, 5: pink, 6: purple, 7: purple white, 8: white, 9: white purple, 10: white with purple spot
Pod stage	Pod colour (Pco)	1: brown, 2: chestnut brown, 3: chocolate, 4: khaki, 5: pale khaki, 6: pink, 7: pink khaki, 8: purple, 9: purple khaki, 10: yellow chocolate, 11: yellow khaki, 12: yellow purple
	Pod curvature (Pcu)	1: straight, 2: Slightly curved, 3: Curved, 4: arched
	Raceme position (Rpo)	1: Mostly above canopy, 2: In upper canopy, 3: Throughout canopy
Seed stage	Seed colour (Sco)	1: black, 2: brown argil, 3: brown olive, 4: brown orange, 5: brown red, 6: caramel, 7: cream, 8: orange, 9: red, 10: red-white, 11: terra brown, 12: white
	Seed eye colour (Eco)	1; absent, 2: black, 3: chestnut brown
	Seed hile colour (Hco)	1: brown, 2: chestnut brown, 3: grey, 4: orange, 5: yellow
	Seed texture (Ste)	1: smooth, 2: smooth to rough, 3: rough, 4: rough to wrinkled, 5: wrinkled
	Seed shape (Ssh)	1: globose, 2: ovoid, 3: crowder, 4: kidney, 5: rhomboid

$$H' = -\sum_{i=1}^{n} P_i \, Ln \, P_i / Ln(n)$$

where H'= Shannon-Weaver diversity index, Pi is the proportion of total entries number belonging to the class, n = genera number, and Pi= ni/N as the proportion of type I (ni = total number of individuals of the microbe in type i, N= total number of all individuals in type n).

Multiple correspondence analysis (MCA), carried out to determine the genetic variability level in the collection, detect differences between and within accessions and the most discriminating characters.

Based on the most discriminating characters from the MCA, a hierarchical cluster analysis (HCA) was assessed to establish relationships between accessions. Euclidean distances were estimated and a dendrogram was constructed using the ward D2 method. All analyses were performed using R software version 4.2.2.

RESULTS

Variability in morphological traits of 135 cowpea accessions

During plant growth, 15 qualitative traits were recorded at different stages (vegetative and maturity). Qualitative analysis revealed significant variation between accessions for all the traits analysed (Table 2).

Vegetative stage

At vegetative stage, leaf colour, shape, hairiness and texture, stem pigmentation, plant grown habit and flower colour were the studied traits.

The plant collection terminal leaflets colour ranged between pale green, intermediate green, and dark green. Most accessions (77) possess dark green leaves (57.04%), followed by 30 accessions with intermediate green leaves (22.22%) and 28 accessions carrying pale green leaves (20.74%). Leaf shape characteristics significantly varied among the 135 accessions. Thus, 65 accessions had rhomboid leaflets (48.15%), 32 accessions had sub-hastate leaflets (23.7%), 21 accessions with oval leaflets (15.56%), 13 accessions with hastate leaflets (9.63%), and only 4 accessions carrying globose leaflets (2.96%). This study shows that 48 accessions were characterized by cariceous-textured leaves (35.56%), 48 accessions by intermediate-textured leaves (35.56%) and only 39 accessions with membranous-textured

Table 2. Frequency distribution and Shannon-weaver diversity index for the 15 morphological traits of cowpea in collection.

Morphological description			Accessions frequency	Percentage contribution	Shannon's diversity index (H')
	Leaf Texture	Coriceous	48	35.56	1.00
		Intermediate	48	35.56	
		Membranous	39	28.89	
	Leaf shape	Globose	4	2.90	0.82
		Hastate	13	9.63	
		Oval	21	15.60	
		Rhomboid	65	48.15	
		Sub-hastate	32	23.70	
	Leaf colour	Dark green	77	57.04	0.89
		Intermediate green	30	22.22	
		Pale green	28	20.74	
	Stem pigment	Dark green	57	42.22	0.75
		Intermediate green	20	14.81	
		Pale green	41	30.37	
		Pale red	1	0.74	
		Red	2	1.48	
		Vtr	14	10.37	
Vegetative stage	Grown habit	Climbing	3	2.22	0.56
		Climbing erect	4	2.96	
		Creeping	37	27.41	
		Erect	82	60.74	
		Prostrate	1	0.74	
		Semi-creeping	5	3.70	
		Semi-erect	3	2.22	
	Flower colour	Cream	1	0.74	0.71
		Dark purple	20	14.81	
		Mauve pink	23	17.04	
		Pale pink	3	2.22	
		Pale purple	2	1.48	
		Pink	9	6.67	
		Purple	30	22.22	
		Purple white	1	0.74	
		White	40	29.63	
		White purple	4	2.96	
		White with purple spot	2	1.48	
	Plant hairiness	Glabrescent	34	25.19	0.99
		Pubescent to hirsut	49	36.30	
		Short appressed hairs	52	38.52	
Pod stage	Pod curtuve	Arched	12	8.89	0.89
		Curved	34	25.19	
		Slightly curved	64	47.41	
		Straight	25	18.52	

Table 2. Contd.

	Raceme position	In upper canopy	56		41.48	0.97
		Mostly above canopy		29	21.48	
		Throughout canopy		50	37.04	
	Pod colour	Brown		5	3.70	0.55
		Chestnut brown		3	2.22	
		Chocolate		1	0.74	
		Khaki		80	59.26	
		Pale khaki		1	0.74	
		Pink		1	0.74	
		Pink khaki		2	1.48	
		Purple		2	1.48	
		Purple khaki		1	0.74	
		Yellow chocolate		25	18.52	
		Yellow khaki		12	8.89	
		Yellow purple		2	1.48	
	Seed shape	Crowder		4	2.96	0.81
		Globose		30	22.22	
		Kidney		18	13.33	
		Ovoid		15	11.11	
		Rhomboid		68	50.37	
	Seed texture	Rough		6	4.44	0.73
		Smooth to rough		24	17.78	
		Rough to wrinkled		9	6.67	
		Smooth		81	60.00	
		Wrinkled		15	11.11	
	Eye colour	Absent		86	63.70	0.82
		Black		21	15.56	
		Chestnut brown		28	20.74	
Seed stage	Hile colour	Brown		9	6.67	0.70
		Chestnut brown		38	28.15	
		Grey		12	8.89	
		Orange		1	0.74	
		Yellow		75	55.56	
	Seed colour	Brown olive		12	8.89	0.86
		Brown orange		20	14.81	
		Black		1	0.74	
		Brown argile		5	3.70	
		Brown red		15	11.11	
		Caramel		4	2.96	
		Cream		27	20.00	
		Orange		4	2.96	
		Red		26	19.26	
		Red-white		1	0.74	
		Terra brown		2	1.48	
		White		18	13.33	
Overall mean						0.80

leaves (28.88%). About plant growth habit, most accessions (82) were erect (60.74%), 37 creeping (27.41%), 5 semi-creeping (3.7%), 4 climbing erect (2.96%), 3 semi erect (2.22%), 3 climbing erect (2.22%), and only one was prostrate (0.74%). Stem pigmentation expressed through six different colours: 57 accessions possess dark green stem (42.22%), 41 pale green (30.37%), 20 intermediate green (14.81%), 14 vtr (10.37%), 2 pink (1.48%) and one pale pink (0.74%). All the 135 accessions leaf hairiness expressed through three phenotypes: short and oppressed hairs for 52 accessions (38.52%), pubescent to hirsute hairs for 49 accessions (36.3%), and glabrescent for 34 accessions (25.19%). At blooming, the studied accessions produced flowers of different colours, mainly purple for 30 accessions (22.22%), followed by 20 accessions (14.81%) with dark purple flowers, 2 with pale purple (1.48%) and one producing purple white flower (0.74%). Nearly 40 accessions were white (29.63%), 23 accessions (17.04%) were mauve pink, 9 accessions (6.67%) were pink, 4 accessions (2.96%) were white purple, 3 accessions (2.22%) were pale pink, one accession (0.74%) were cream, and 2 accessions (1.48%) were white with purple spots.

Characteristics of cowpea pods and seed maturity

In cowpea, accessions maturity was accessed through pods and seeds characteristics. Pods maturity was characterized by their colour, curve, and raceme position. Seed shape, colour and texture, eye and hile colours characterized seed maturity.

Pod maturity characteristics

Pods racemes expressed through three phenotypes: on the canopy tip with 56 accessions (41.48%), throughout canopy with 50 accessions (37.04%), and above canopy with 29 accessions (21.48%). In terms of pod curvature, most accessions (64) carried slightly curved pods (47.41%) when some of them (34 accessions) disposed curved pods (25.19%), 25 accessions with straight pods (18.52%) and the other 12 accessions had arched pods (8.89%). There was a predominance of 79 accessions with khaki-coloured pods (58.52%), followed by chocolate yellow 25 (18.52%), khaki yellow 12 (8.89%), brown 5 (3.7%), chestnut brown 3 (2.22%), khaki pink 3 (2.22%), purple 2 (1.48%), purple yellow 2 (1.48%), one chocolate (0.74%), one pale khaki (0.74%), one pink (0.74%), and one khaki purple (0.74%).

Seed characteristics

About seed shape, most accessions (68) studied developed rhomboid seeds (50.37%), 30 containing globose seeds (22.22%), others carrying kidney seeds 18 (13.33%), ovoid seeds 15 (11.11%) and crowder seeds 4 (2.96%). Seed eye colour slightly variate among the studied accessions. More than 86 accessions (63.7%) had no seed eye colour, while 21 accessions (15.56%) were black and 28 accessions were chestnut-brown (20.74%).

Seeds hile colour trait showed that 75 accessions had a yellow colour, 37 were chestnut-brown, 13 grey, 9 brown and one orange. Globally, seeds appeared under 13 colours: cream for 27 accessions, red for 26, 20 brown orange, 18 white, 15 brown red, 12 brown olive, brown argil 5, 4 caramel, 4 orange, 2 terra brown, one black and one red-white. Seed texture varied from smooth to wrinkled. There were 81 accessions (60%) containing smooth seeds, followed by 24 smooths to rough (17.78%), 15 wrinkled (11.11%), 9 rough to wrinkled (6.67%), and 6 rough (4.44%).

Assessing the phenotypic diversity for each of 15 morphological trait, the Shannon's weaver diversity indices (H') varied from 0.55 to 1 with a mean value of 0.80. Among all the analysed traits, leaf texture expressed the higher (H'= 1), moderately high (0.70-0.89) for most of seed traits, while minimum for pod colour (H'= 0.55). The high index (H'= 0.80) indicated a high diversity level in the cowpea collection.

Multiple correspondence analysis (MCA) of cowpea morphological traits

Multiple correspondence analysis (MCA) of all the phenotypic traits showed that the first 3 components accounted for 19.17% of the total variability. From the 87 phenotypic classes identified, 26 derived from 12 traits contributing essentially to this axis formation. Accounting up to 10.74% of total phenotypic variation and defined by the 10 selected traits, axis 1 constituted the most important (Table 3). These traits were seed colour (white), pod colour (khaki, yellow chocolate), flower colour (white), eye colour (absent, chestnut brown), seed texture (rough to wrinkled, smooth, wrinkled), pod curvature (curved, slightly curved), raceme position (canopy tip, throughout canopy), grown habit (creeping, erect), plant hairiness (glabrescent, pubescent to hirsut), and stem pigment (pale green, vtr). Associated with four traits, seed colour (cream), seed shape (globose), raceme position (mostly above canopy), and growth habit (semi-creeping) axis 2 explained 4.45% of total variability. Defined by seed colors characters, colour (brown olive), eye (black) and hile (grey), axis 3 represented 3.98% of total variability. Figure 1 presents the 135 individual projections in plane 1-2. Based on axis 1, these accessions were classified into three groups.

Morphological cluster analysis

Based on the MCA 12 identified characters, the

Table 3. Matrix of Multiple correspondence analysis (MCA) explaining importance of phenotypic traits in squared cosine for the first three axis.

Variable	Axis 1	Axis 2	Axis 3
Variance	0.515	0.211	0.19
% of variance	10.723	4.404	3.958
Cumulative % of variance	10.723	15.127	19.085
Sco_ brown olive	0.04	0.01	**0.24**
Sco_cream	0.22	**0.35**	0.04
Sco_white	**0.43**	0.07	0.01
Pco_khaki	**0.23**	0.07	0.07
Pco_yellow chocolate	**0.60**	0.02	0.01
Fco_white	**0.58**	0.12	0.00
Ssh_globose	0.02	**0.40**	0.04
Eco_absent	**0.67**	0.08	0.07
Eco_black	0.17	0.00	**0.25**
Eco_chestnut brown	**0.36**	0.12	0.01
Hco_grey	0.04	0.01	**0.27**
Ste_rough to wrinkled	**0.21**	0.00	0.03
Ste_smooth	**0.26**	0.17	0.00
Ste_wrinkled	**0.31**	0.02	0.03
Pcu_curved	**0.79**	0.03	0.00
Pcu_slightly curved	**0.25**	0.00	0.20
Rp_in upper canopy	**0.35**	0.04	0.01
Rp_mostly above canopy	0.03	**0.24**	0.00
Rp_throughout canopy	**0.55**	0.05	0.01
Gha_creeping	**0.83**	0.04	0.00
Gha_erect	**0.55**	0.02	0.00
Gha_semi-creeping	0.00	**0.34**	0.00
Pha_glabrescent	**0.62**	0.05	0.01
Pha_pubescent to hirsut	**0.22**	0.01	0.00
Spi_pale green	**0.24**	0.05	0.09
Spi_vtr	**0.34**	0.02	0.02

hierarchical component analysis (HCA) was carried out. Based on Euclidean distances, dendrogram (Figure 2) allowed classification of 135 accessions from the CNRA cowpea collection into two main clusters. Cluster I was subdivided into two subgroups: Ia (red) and Ib (green) containing, respectively 97 and 10 accessions, while subgroup Ib was composed of accessions. Cluster II (purple) comprised 28 accessions.

Containing most accessions, subgroup Ia includes all seed, pod and flower colours. About 92.78% of the accessions are hairy, while over 68.04% have smooth seeds. Moreover, seed forms were 54.64% of accessions for rhomboid form, 7.22% for kidney, 15.46% for ovoid seeds, 19.59% for globose and 3.09% for crowder seeds. Over 80.41% of accessions were coriceous and 78.35%, no coloured eye. Raceme position varied: 57.73% accessions had pods on canopy tip, 21.65% above canopy and 20.62% throughout the canopy. Most accessions, 59.79%, produced slightly curved pods, 20.62% straight, 11.34% arched, and 8.25% curved. Within the group, 41.24% of accessions had pale green, 40.21% dark green, and 18.56%, intermediate green stem.

The subgroup Ib consisted of khaki-coloured pods, white flowers and smooth seeds on hairiness plants. From 10 accessions, 9 (90%) had globose, cream-coloured seeds with brown eyes and hile. Futhermore, 70% carried pods mainly on canopy tip and dark green leaves, whereas 50% were semi-creeping with straight and slightly curved pods.

Cluster II contained creeping accessions with curved pods. About 92% of the accessions were hairless while most (96%) had them in canopy. In addition, 60% of the accessions had chocolate-yellow pods. From these accessions, 50% produced rhomboid seeds, 39.29% kidney and 10.71% globose seeds. On the other hand, 50% produced white seeds, 46.43% cream and 3.57% caramel ones. Seed eye colour was mainly yellow for 78% of the accessions while only one accession produced uncoloured eye. In this group, 50% of

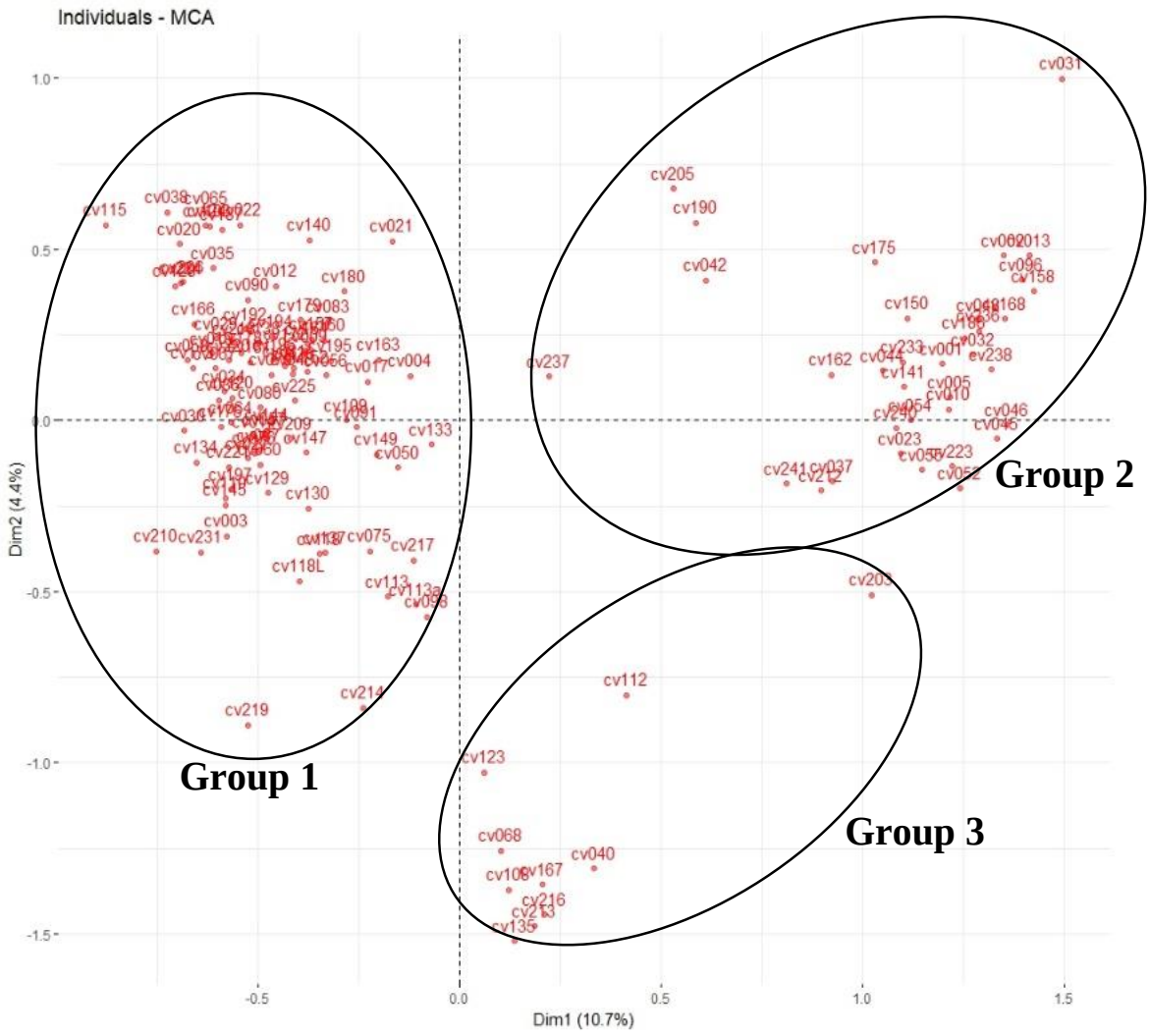

Figure 1. Factorial representation of the 135 accessions analysed from the CNRA cowpea collection.

accessions had vtr-coloured stem pigments, compared with 39.29% dark green and 10.71% red.

DISCUSSION

Genetic diversity is the basis for successful crop improvement and can be assessed using a variety of methods (Fufa et al., 2005). Germplasm phenotypic evaluation enables genetic material characterisation and conservation. This method was the way followed to explore an eventual genetic variability of Côte d'Ivoire cowpea germplasm at different stages of plant development. The present study revealed a high level of genetic diversity for the 135 accessions studied. Phenotypic classes corresponding to the 15 qualitative traits ranged from 3 to 12. This result indicates a high level of phenotypic variability, suggesting presence of genetically distinct accessions of this collection. Barik et al. (2023) already reported significant variation among all the 10 qualitative traits they studied. Moreover, relative frequencies of each trait phenotypic characteristics showed they were irregularly distributed, with predominance of certain phenotypic characteristics. This predominance could indicate the presence of dominant phenotypes. According to Terzić et al. (2020), qualitative traits play an important role in cultivar development process, depending on the desired phenotype as the ultimate breeding goal. Allelic richness, measured by the Shannon-Weaver diversity index, showed variability in each studied trait. Among 15 qualitative traits examined, leaf texture (H'= 1.00) and plant hairiness (H'= 0.99) were the most variable, while pod colour (H'= 0.55) and growth habit (H'= 0.56) showed the least variation. High variability was provided by cowpea leaf texture and accessions were classified into 3 categories, groups 1

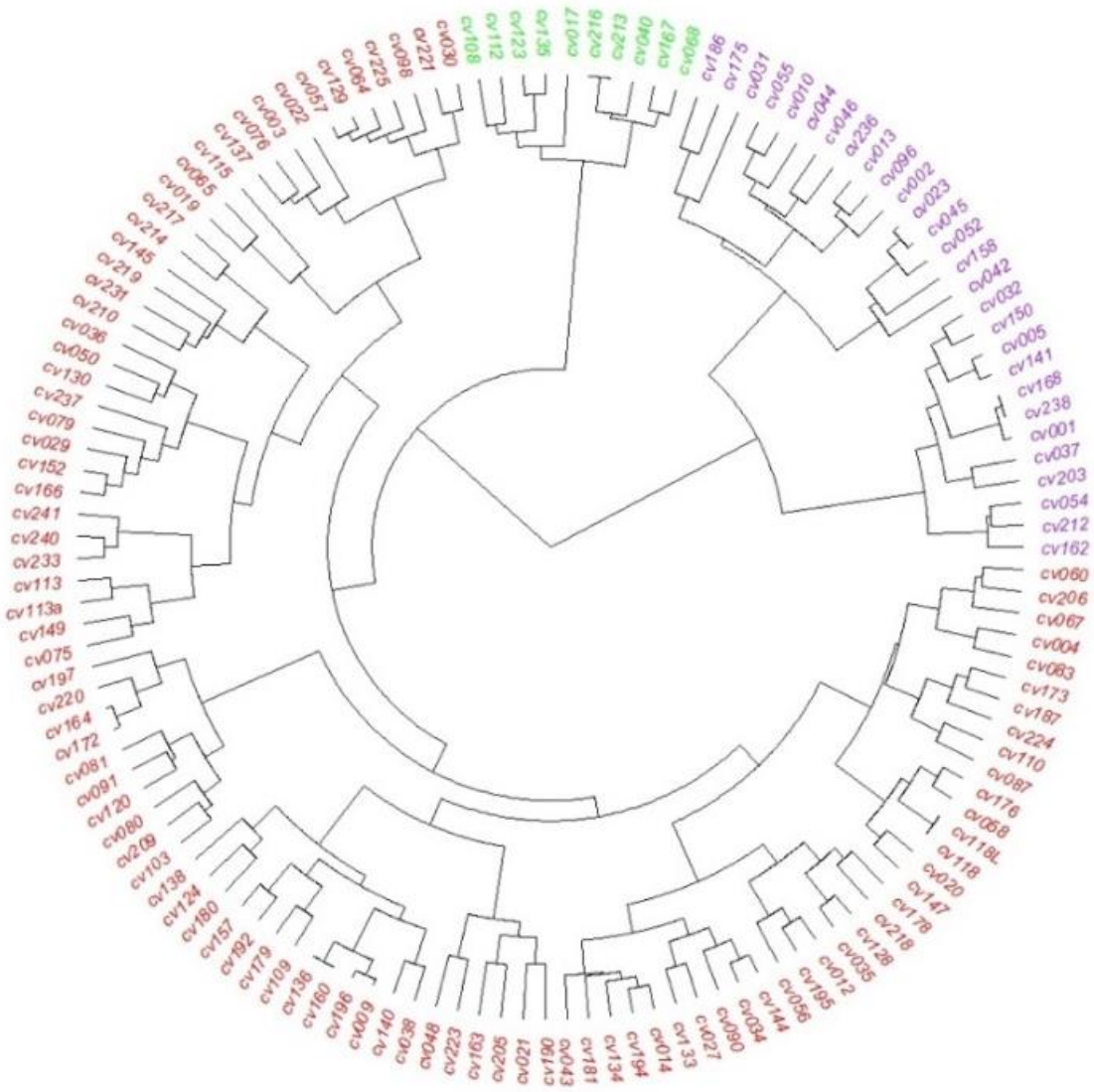

Figure 2. Dendrogram on the morphological variability of the qualitative characteristics of 135 cowpea accessions in the collection based on the Ward D2 classification method using Euclidean distance.

and 2 consisted of the same accession's numbers, respectively coriaceous (35.56%) and intermediate (35.56%) textures. Group 3 had membranous texture (28.89%). Plant hairiness allowed classification of the cowpea accessions into three groups. Gathering 38.52% of accessions, the first group seeds were characterized by short oppressed hairs, the second (36.3%) by pubescent to hirsute hairs and the third (25.19%) by glabrescent ones. Toyin (2019) reported similar results which allow them cowpea genotypes classification into three groups and differs from those noted by Barik et al. (2023).

Multiple correspondence analysis (MCA) was assessed to understand each studied trait contribution to phenotypic variation among accessions and identify the most discriminating ones. According to Doumbia et al. (2013), this step is fundamental to any selection and conservation programme. Indeed, our three first axes explained most total phenotypic variance (19.17%). With a 10.74% variance, axis 1 was correlated with 10 of 15 studied traits. Traits concerned colours of seed, pod, flower and eye; seed texture, pod curvature, raceme position, grown habit, plant hairiness, and stem pigment. Therefore, seed colour (Ishikawa et al., 2020) and both colour and texture (Lopes et al., 2003) being taken into account, respectively in farmers and traders selection criteria, this axis can be retained for possible selection studies. So, this analysis allowed the 135 accessions classification into very distinct three groups.

Based on discriminating quantitative traits, hierarchical classification allowed the 135 accessions sharing into three groups. This suggests that the accessions of CNRA

cowpea collection were greatly diversified among them. This result confirms those obtained with the MCA, which revealed three phenotypic groups. Covering all the seeds, pods and plants characteristics, group 1a is very diversified. As such, it could be conserved, and then used as core collection.

Conclusion

This study revealed high level of genotypic variation in the CNRA cowpea collection. The MCA and HAC analyses lead to similar results, allowing the 135 accessions classification into three genetic groups. Each group characteristics exploration could provide more genetic diversity for breeding programmes. Seed colour was on all the three factorial axes, indicating its importance for cowpea breeding. These results provide guidelines for possible cowpea improvement in Côte d'Ivoire.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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