World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Agromorphological traits contributing to the selection of high yielding Cowpea genotypes in Côte d'Ivoire

Deless Edmond Fulgence THIEMELE *, Jean Simon Konan ASSOUMAN, Saraka Didier Martial YAO and Nafan DIARRASSOUBA

Department of Genetics and Biochemistry, Genetics Research Unit, Peleforo GON COULIBALY University of Korhogo, Po Box 1328 Korhogo, Côte d'Ivoire.

World Journal of Advanced Research and Reviews, 2025, 27(01), 2430-2443

Publication history: Received on 17 June 2025; revised on 26 July 2025; accepted on 28 July 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.27.1.2781

Abstract

Cowpea (*Vigna unguiculata* L. Walp.) is an important household staple in sub-Saharan Africa (SSA), particularly in West Africa. The objective of this study was to identify the agromorphological traits that contribute to high yield for exploitable in breeding programmes in Côte d'Ivoire. A study was conducted at the Peleforo GON COULIBALY University Botanical Garden, in Côte d'Ivoire involving 32 cowpea accessions from the *in-situ* collection of Peleforo GON COULIBALY University. The accessions were evaluated in a Fisher block design with three replications on the basis of 16 quantitative variables. The results of the Principal Component Analysis (PCA) confirmed this morphological variability at 73.78%. Hierarchical Ascending Classification classified accessions into three distinct diversity groups according to yield. Group 1 includes accessions with high yield (3728.75 kg/ha), followed by group 2 (2693.93 kg/ha) and group 3 (1620.28 kg/ha). Accessions NFE011, NTE015, NTE02 and NKO03 from group 1 were identified as high-yielding accessions, with respective mean yields of 3855.07, 3737.30, 3668.89 and 3653.74 kg/ha. Regression model indicates that traits including plant width, number of nodes per plant, pod size and number per plant and 100-seed weight were the most significant contributors to grain yield. These results suggest that the selection of high-yielding accessions could be improved by focusing on these specific agromorphological traits.

Keywords: Agromorphological Traits; High Yield Cowpea Accessions; Vigna Unguiculata; Côte d'Ivoire

1. Introduction

Cowpea, Vigna unguiculata (L.) Walp, is a legume of the Fabaceae family, native to sub-Saharan Africa (SSA) [1, 2]. It is widely cultivated in tropical regions and beyond [3]. It plays an important role in human nutrition, food security, and income generation for farmers and food vendors in the region [4]. Cowpea seeds are very rich in protein, minerals, and vitamins (folic acid and vitamin B). It is also involved in combating malnutrition [5]. Cowpea is also important in cropping systems due to its drought resistance [6] and as a nitrogen-fixing plant, it contributes to soil fertility restoration and is beneficial in crop associations with cereals [7].

More than 87% of African production comes from West Africa [8], highlighting its importance for many populations. Globally, the annual production of dry seeds is 28.35 million tonnes ; more than 97% of which is produced in Africa [8]. In Côte d'Ivoire, cowpea is mainly grown in savannah areas for its seeds, which are eaten as a dry vegetable. Young leaves are also eaten fresh. However, yields under traditional cultivation generally do not exceed 400 to 500 kg of seeds per hectare [9], with annual production around 38,127 tonnes, representing less than 1% of African production [8]. Despite its importance, cowpea remains a marginal crop [10].

* Corresponding author: Deless Edmond Fulgence THIEMELE.

Several studies have been conducted on various aspects of cowpea, including growth characteristics and yield components of improved varieties [11, 12], intercropping with other legumes (groundnut-soybean) for improving soil fertility [13] and cultural techniques such as seeding density [14] have also been reviewed. Preliminary research work of [15, 16] on the morphological diversity of cowpea accessions, made it possible to have an in-situ collection of accessions conserved in the gene bank of Peleforo GON COULIBALY University. Their work also made it possible to identify the different modalities of the qualitative traits of the accessions in said collection. However, no predictive study on the yield of newly collected accessions from the UPGC gene bank has been carried out to date. Moreover, in a farming environment, cultivar differentiation is made through traits that are directly observable. Also, the identification of high-yielding accessions through these observable traits could improve their selection conditions. The objective of this study was to identify the agromorphological traits that contribute to high yield for exploitable in breeding programmes in Côte d'Ivoire.

2. Material and methods

2.1. Experimental site

The study was conducted at the Peleforo GON COULIBALY University Botanical Garden (9°27'28"N, 5°37'46"W) in Korhogo, northern of Côte d'Ivoire. The site is characterised by a tropical Sudano-Guinean climate, with two seasons, wet and dry. The seasons included a dry season from November to April and a rainy season from May to October, with mean annual rainfall ranging from 1100 to 1600 mm. The mean annual temperature is 27 °C, and the soils are Ferralitic [17].

2.2. Treatments and design

Thirty-two cowpea accessions, conserved at the Peleforo GON COULIBALY University genebank in Côte d'Ivoire, were used in this study (Table 1). The accessions were previously collected from the Poro, Bagoué, and Tchologo regions [15].

Table 1 Profiles and characteristics of cowpea accessions used in this study

Accessions	Origin	Seed characteristics
NBO04	Boundiali	No coloration on the integument
NOU06	Ouangolodougou	White color with ovoid shape
NTE02	Tengrela	Dark red color
NTE011	Tengrela	Grey color with spots on the coat
NTE013	Tengrela	Dark red color
NFE011	Ferkéssedougou	Light red color
NTE012	Tengrela	Ochre color
NTE015	Tengrela	Couleur ocre, sans coloration sur le tégument
NKO03	Korhogo	White color
NKO01	Korhogo	No coloration on the integument
NOU03	Ouangolodougou	Dark red color with spots on the integument
NKO02	Korhogo	Light red color
NFE012	Ferkéssedougou	Light red color
NBO011	Boundiali	Light red color
NTE03	Tengrela	White color
NSI01	Sinématiali	No coloration on the integument
NFE02	Ferkéssedouou	Light red in color and ovoid in shape
NKO08	Korhogo	Black in color and globular in shape

NKN01	Kong	Dark red color
NOU012	Ouangolodougou	Small, smooth seeds with ovoid or globular shape
NOU05	Ouangolodougou	Ochre color and globular shape
NOU04	Ouangolodougou	Ochre color and globular shape
NBO012	Boundiali	Small, smooth seeds with ovoid or globular shape
NOU02	Ouangolodougou	White color
NTE014	Tengréla	Small, smooth seeds with ovoid or globular shape
NOU011	Ouangolodougou	Light red color
NSI02	Sinématiali	No coloration on the integument
NBO014	Boundiali	Ochre-red color
NKN02	Kong	Ochre-red color
NBO013	Boundiali	Ochre-red color
NKO011	Korhogo	Ochre-red color
NBO02	Boundiali	White color

N = Cowpea; BO = Boundiali; TE = Tengréla; OU = Ouangolodougou; KO = Korhogo; SI = Sinématiali; FE = Ferkessédougou; and KN = Kong.

The accessions were sown using a Fisher block design, with three replicates. Each of the three blocks consisted of 32 rows, each 5 m long, with each row representing an accession composed of 10 individuals. The accessions were randomly assigned to the rows. Fifteen days after sowing, thinning was done to one plant per hill. Weeding was carried out manually and regularly whenever found necessary.

2.3. Data collection and analysis

Data collection was done according to the variables defined in the Cowpea Descriptor Table [18]. A total of 16 quantitative variables were considered for this study (Table 2). Data analysis was done using descriptive statistics (minimum, maximum, mean, and coefficient of variation) to obtain coefficients of variation to demonstrate the variability of the various quantitative traits measured. Analysis of variance (ANOVA) was done at the 5% probability threshold, to verify existence of differences between accessions with respect to the traits studied. Where the effects were significant, a Turkey test was performed to classify the different groups.

Correlations between variables were also estimated using Pearson's correlation coefficient. Principal Component Analysis (PCA) was used to assess the similarity between individuals to highlight homogeneous groups using relationships between variables. Hierarchical Ascending Classification (HAC) was used to classify the accessions into different homogeneous groups. A multiple linear regression analysis was performed to predict bulb yield based on agromorphological traits using the model: Y = A + b1X1 + b2X2 +….bn Xn

Where: Y = Grain yield, A = constant, X = vegetative variable, and b = Coefficient. The collected data were analysed using XLSTAT-Pro version 2019.

Table 2 Quantitative traits used for agromorphological characterisation of cowpea accessions used in this study

N°	Traits	Code	Scoring
1	Plant height (cm)	PH	Measurement of plant height at 6 weeks after sowing
2	Plant width (cm)	PW	Measurement of plant width at 6 weeks after sowing
3	Leaflet length (cm)	Ll	Measurement of leaflet length at 6 weeks after sowing
4	Leaflet width (cm)	Lw	Measurement of leaflet width at 6 weeks after sowing
5	Number of nodes	NbNd	Recorded 6 weeks after sowing. Mean of 10 randomly selected plants
6			Mean of the 10 longest mature pods from 10 randomly selected plants

	Pod length (cm)	PodL	
7	Pod width (cm)	PodW	Mean of the 10 widthest mature pods from 10 randomly selected plants
8	Pod weight (g)	PodWe	Average measurement (weighing) carried out on three pods per plant after harvesting
9	Number of lodges per pod	NbLod	Record the number of lodges per pod after harvest on three pods per plant.
10	Number of seeds per pod	NbSP	Record number of seeds per pod per plant after harvest on three pods per plant.
11	Seed length (cm)	SL	Mean of 10 mature seeds excluding those from the extremities of pods after harvest
12	Number of pods per plant	NbP	Mean number of mature pods from 10 randomly selected plants
13	Hundred weight seeds (g)	HWS	After harvesting, weigh 100 seeds per plant
14	Grain yield (kg/ha)	Yield	After harvesting, weigh the seeds per plant to estimate the yield per hectare.
15	Time to first flower (day)	TFF	Date of first flowering
16	Maturation time (day)	MaT	First pod ripening date

3. Results

3.1. Quantitative traits

Descriptive analysis showed that some quantitative traits exhibited significant variations between the cowpea accessions (Table 3). Traits such as plant width (PW), number of nodes (NbNd), leaflet length (Ll), leaflet width (Lw), time to first flower (TFF), maturation time (Mat), pod length (PodL), pod width (PodW), number of lodges per pod (NbLod), number of seeds per pod (NbSP), and seed length (SL), exhibited low variability, with coefficients of variation less than 20%. Furthermore, plant height (PH), number of pods per plant (NbP), pod weight (PodWe), hundred weight seeds (HWS), and grain yield (Yield) varied considerably, with coefficients of variation of 41.5, 48.6, 23.4, 24.5 and 49.9%, respectively.

Plant height (PH) ranged from 6 to 39.9 cm and was more uniform, with a mean of 13.37 ± 5.55 cm. The number of pods (NbP) was very variable, ranging from 8 to 134, with a mean of 44.91 ± 21.83. Pod weight (PodWe), had values ranging from 1.2 to 3.4 g, plus a mean of 2.31 ± 0.54 g. The weight of 100 seeds (HWS), ranged from 6.8 to 19.5 g, with a mean of 11.17 ± 2.74 g. Grain yield in kg per hectare (kg ha^{-1}) was extremely variable, ranging from 244.05 to 6283.68 kg ha^{-1} with a mean of 2179.69 ± 1087.73 kg ha^{-1}.

Table 3 Descriptive statistics of quantitative traits considered in this study

Traits	Minimum	Maximum	Means ± Standard Deviation	CV (%)
PH (cm)	6	39.9	13.37 ± 5.55	41.5
PW (g)	24	56	40.14 ± 5.62	14
NbNd	5	13	8.69 ± 1.2	13.8
Ll (cm)	5	16.3	9.91 ± 1.89	19.1
Lw (cm)	2.3	9	6.27 ± 1.15	18.4
TFF (days)	40	79	46.39 ± 7.48	16.1
MaT (days)	56	91	65.70 ± 6.56	10
NbP	8	134	44.91 ± 21.83	48.6

PodL (cm)	13	21	17.34 ± 1.62	9.3
PodW (cm)	5.59	9.71	7.38 ± 0.89	12
PodWe (g)	1.2	3.4	2.31 ± 0.54	23.4
NbLod	10	21	17.10 ± 2.12	12.4
NbSP	10	20	16.61 ± 2.18	13.2
SL (cm)	5.69	11.3	7.2 ± 1.07	14.8
HWS (g)	6.8	19.5	11.17 ± 2.74	24.5
Yield (kg ha^{-1})	244.05	6283.68	2179.69 ± 1087.73	49.9

PH: Plant height, PW: Plant width, Ll: Leaflet length, Lw: Leaflet width, NbNd: Number of nodes, PodL: Pod length, PodW: Pod width, PodWe: Pod weight, NbLod: Number of lodges per pod, NbSP: Number of seeds per pod, SL: Seed length, NbP: Number of pods per plant, HWS: Hundred weight seeds, Yield: Grain yield, TFF: Time to first flower, MaT: Maturation time, CV: Coefficient of Variation.

Table 4 presents the mean values of various vegetative traits measured in different cowpea accessions. The results showed significant differences ($P < 0.001$) between the accessions for all traits studied. Accession NBO04 was distinguished by high leaflet length (Ll) and leaflet width (Lw), with values of 12.9 and 7.12 cm, respectively. Accession NSI02 displayed exceptionally high values for time to first flowering (TFF) and time to physiological maturity (MaT), with values of 78.250 and 89.250 days, respectively.

Table 5 presents a detailed comparative analysis of the accessions, measuring key production variables. The results showed significant differences ($P < 0.001$) between the accessions for all production variable. Accession NFE011 had the highest grain yield of 3855.073 kg ha^{-1}, and again the highest number of pods (76.750); and high seed weight. Accession NSI02, on the other hand, had the lowest values for number of pods (8) and yield (317.88 kg ha^{-1}). Accession NKO04 had outstanding pod width (8.99 cm), the highest overall. In terms of 100 seed weight, NFE011 and NTE015 were among the highest, with 10.55 and 13.27 g, respectively.

Table 4 Data for the cowpea vegetative traits evaluated in this study

Accessions	PH	PW	NbNd	Ll	Lw	TFF	MaT
NBO011	16.7 ^{abc}	43.37 ^{abc}	9 ^{abcdef}	10.45 ^{abc}	7 ^{abcd}	44 ^{abcd}	63.75 ^{ab}
NBO012	11.45 ^{abc}	41.05 ^{abcd}	9.25 ^{abcdef}	8.75 ^{abc}	5.62 ^{def}	45.25 ^{abcd}	64.5 ^{ab}
NBO013	11 ^{abc}	38.35 ^{abcd}	8.25 ^{bcdef}	8.9 ^{abc}	5.37 ^{def}	46.5 ^{abcd}	65.25 ^{ab}
NBO014	11.67 ^{abc}	39.5 ^{abcd}	8.25 ^{bcdef}	9.9 ^{abc}	5.62 ^{def}	44.25 ^{abcd}	64.5 ^{ab}
NBO02	9.77 ^{bc}	36.12 ^{abcd}	7.25 ^{f}	8.82 ^{abc}	5.750 ^{def}	47.25 ^{abcd}	64.75 ^{ab}
NBO04	13.87 ^{abc}	36.7 ^{abcd}	10.5 ^{ab}	12.9 ^{ab}	7.12 ^{abcd}	61.25 ^{ab}	82.25 ^{a}
NFE011	12.95 ^{abc}	39.82 ^{abcd}	8.75 ^{abcdef}	10.2 ^{abc}	6.32 ^{bcdef}	41 ^{d}	57.5 ^{b}
NFE012	13.35 ^{abc}	40.52 ^{abcd}	7.750 ^{def}	9.07 ^{abc}	6.6 ^{abcdef}	42.75 ^{abcd}	63.25 ^{ab}
NFE02	12.12 ^{abc}	39.72 ^{abcd}	8.75 ^{abcdef}	8.35 ^{bc}	5.8 ^{def}	45.5 ^{abcd}	65.25 ^{ab}
NKN01	13.77 ^{abc}	41.07 ^{abcd}	7 ^{f}	9.92 ^{abc}	6.6 ^{abcdef}	46 ^{abcd}	65 ^{ab}
NKN02	8.125 ^{c}	34.87 ^{bcd}	7.75 ^{def}	8.75 ^{abc}	5.37 ^{def}	47.25 ^{abcd}	66.75 ^{ab}
NKO01	28 ^{ab}	41.72 ^{abcd}	10.75 ^{a}	8.67 ^{abc}	5.1 ef	58.25 ^{abc}	79.25 ^{a}
NKO011	13.05 ^{abc}	40.37 ^{abcd}	9.75 ^{abcde}	9.05 ^{abc}	6.12 ^{bcdef}	44 ^{abcd}	63.5 ^{ab}
NKO02	13.72 ^{abc}	44.75 ^{abc}	9.25 ^{abcdef}	8.35 ^{abc}	5.95 ^{cdef}	43.75 ^{abcd}	64 ^{ab}
NKO03	10.6 ^{abc}	32.52 ^{cd}	9.75 ^{abcde}	11.62 ^{abc}	7.15 ^{abcd}	41.75 ^{abcd}	57.5 ^{b}
NKO08	11.37 ^{abc}	36.72 ^{abcd}	9 ^{abcdef}	11.12 ^{abc}	7.85 ^{ab}	41.75 ^{bcd}	63.75 ^{ab}
NOU011	9.25 ^{c}	36.92 ^{abcd}	8.5 ^{abcdef}	8.17 ^{bc}	5.8 ^{def}	45.5 ^{abcd}	64.75 ^{ab}

NOU012	11.37 ^{abc}	40.87 ^{abcd}	10 ^{abcd}	9.5 ^{abc}	6.1 ^{bcdef}	46.75 ^{abcd}	65 ^{ab}
NOU02	10.32 ^{abc}	41.62 ^{abcd}	8.5 ^{abcdef}	9.62 ^{abc}	6.1 ^{bcdef}	44.5 ^{abcd}	63 ^{ab}
NOU03	17.82 ^{abc}	47.02 ^{ab}	9 ^{abcdef}	9.42 ^{abc}	6.27 ^{bcdef}	41.5 ^{bcd}	63.25 ^{ab}
NOU04	11.37 ^{abc}	35.1 ^{abcd}	8.25 ^{bcdef}	10.15 ^{abc}	6.72 ^{abcdef}	42.25 ^{abcd}	64.25 ^{ab}
NOU05	13.55 ^{abc}	39.05 ^{abcd}	8 ^{cdef}	10 ^{abc}	6.85 ^{abcde}	41.25 ^{cd}	63 ^{ab}
NOU06	8.87 ^{c}	44.6 ^{abc}	8.5 ^{abcdef}	13.07 ^{ab}	7.85 ^{ab}	50 ^{abcd}	64 ^{ab}
NSI01	33.475 ^{a}	42.45 ^{abcd}	10.25 ^{abc}	8.77 ^{abc}	5.02 ^{f}	50 ^{abcd}	70 ^{a}
NSI02	16.97 ^{abc}	30.47 ^{d}	7.5 ^{ef}	6.27 ^{c}	2.9 ^{g}	78.25 ^{a}	89.25 ^{a}
NTE011	10.07 ^{abc}	42.95 ^{abcd}	7.75 ^{def}	12.47 ^{ab}	7.67 ^{abc}	41.75 ^{abcd}	63 ^{ab}
NTE012	13.57 ^{abc}	44.2 ^{abc}	8.75 ^{abcdef}	9.97 ^{abc}	6.25 ^{bcdef}	45.25 ^{abcd}	64.75 ^{ab}
NTE013	14.15 ^{abc}	47.8 ^{a}	8.5 ^{abcdef}	10.12 ^{abc}	6.55 ^{abcdef}	42.5 ^{abcd}	63.5 ^{ab}
NTE014	10.62 ^{abc}	41.4 ^{abcd}	8.5 ^{abcdef}	9.45 ^{abc}	5.8 ^{def}	45.5 ^{abcd}	65 ^{ab}
NTE015	11.17 ^{abc}	38.55 ^{abcd}	8.75 ^{abcdef}	15.25 ^{a}	6.77 ^{abcdef}	41.25 ^{cd}	58.25 ^{b}
NTE02	11.3 ^{abc}	45.02 ^{abc}	7.75 ^{def}	11 ^{abc}	8.27 ^{a}	41 ^{d}	63 ^{ab}
NTE03	12.42 ^{abc}	39.3 ^{abcd}	8.5 ^{abcdef}	9.07 ^{abc}	6.35 ^{bcdef}	46.75 ^{abcd}	67.25 ^{ab}
Pr > F	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

PH: Plant height, PW: Plant width, Ll: Leaflet length, Lw: Leaflet width, TFF: Time to first flower, MaT: Time to first pod maturation, NbNd: Number of nodes per plant. Means followed by the same letter within a column are not significantly different at $P < 0.05$.

Table 5 Mean values of agronomic traits evaluated in cowpea accessions used in this study

Accessions	NbP	PodL	PodW	PodWe	NbLod	NbSP	SL	HWS	Yield
NBO011	55.5 ^{abcd}	17.87 ^{cdef}	7.05 ^{defgh}	1.95 ^{fghijkl}	17.25 ^{abcd}	17 ^{abcd}	6.63 ^{abc}	9 ^{abc}	2319.08 ^{abcdef}
NBO012	45.25 ^{abcde}	18 ^{bcdef}	6.38 ^{gh}	2.15 ^{efghijk}	18.5 ^{a}	17.5 ^{abc}	6.47 ^{abcd}	9.3 ^{abc}	2006.46 ^{abcdef}
NBO013	44.5 ^{abcde}	17 ^{defgh}	6.50 ^{fgh}	1.82 ^{ghijkl}	17.5 ^{abc}	16.75 ^{abcd}	6.33 ^{bcd}	8.75 ^{bc}	1696.49 ^{bcdef}
NBO014	55.5 ^{abcd}	16.5 ^{defghi}	6.55 ^{efgh}	1.72 ^{ijkl}	17.250 ^{abcd}	16.75 ^{abcd}	6.42 ^{bcd}	7.575 ^{c}	1962.34 ^{abcdef}
NBO02	30 ^{bcde}	18 ^{bcdef}	6.80 ^{efgh}	1.9 ^{fghijkl}	17.500 ^{abc}	16.75 ^{abcd}	6.39 ^{bcd}	8.55 ^{bc}	1102.83 ^{def}
NBO04	49 ^{abcde}	16.8 ^{defgh}	8.99 ^{a}	2.97 ^{abc}	14.500 ^{cde}	13.5 ^{de}	10.78 a	17.67 ^{a}	3068.14 ^{abcd}
NFE011	76.75 ^{a}	18.42 ^{bcde}	7.07 ^{defgh}	2.47 ^{abcdefgh}	19 ^{a}	18 ^{ab}	6.92 ^{abcd}	10.55 ^{abc}	3855.073 ^{a}
NFE012	40 ^{abcde}	18.57 ^{abcd}	7.24 ^{bcdefgh}	2.55 ^{abcdefg}	19.25 ^{a}	18.25 ^{ab}	6.82 ^{abcd}	10.4 ^{abc}	2014.04 ^{abcdef}
NFE02	33.25 ^{abcde}	17.2 ^{cdefg}	7.08 ^{defgh}	2.55 ^{abcdefg}	18 ^{a}	17.5 ^{abc}	6.91 ^{abcd}	10.17 ^{abc}	1593.1 ^{cdef}
NKN01	57.5 ^{abcd}	15.5 ^{ghi}	7.71 ^{abcdefg}	1.625 ^{kl}	16.5 ^{abcd}	16.25 ^{abcd}	6.44 ^{abcd}	10.5 ^{abc}	2554.25 ^{abcde}
NKN02	20.25 ^{de}	17.45 ^{cdefg}	7.06 ^{defgh}	2.22 ^{defghijk}	17.5 ^{abc}	17.25 ^{abc}	6.65 ^{abcd}	10.17 ^{abc}	931.29 ef
NKO01	34.75 ^{abcde}	15.95 ^{fghi}	7.69 ^{abcdefg}	3.05 abc	12.25 ^{e}	11.75 ^{e}	10 ^{a}	19.37 ^{a}	2076.26 ^{abcdef}
NKO011	36 ^{abcde}	16.5 ^{defghi}	6.748 ^{efgh}	1.67 ^{jkl}	16.5 ^{abcd}	16.5 ^{abcd}	6.345 ^{cd}	8.76 ^{bc}	1414.55 ^{def}
NKO02	44.5 ^{abcde}	17.22 ^{cdefg}	7.32 ^{bcdefgh}	2.45 ^{bcdefghi}	18.5 ^{a}	18.25 ^{ab}	6.728 ^{abcd}	9.95 ^{abc}	2133.98 ^{abcdef}
NKO03	71 ^{ab}	18.4 ^{bcde}	7 ^{efgh}	2.32 ^{cdefghijk}	19.25 ^{a}	18.75 ^{a}	6.793 ^{abcd}	10.3 ^{abc}	3653.74 ^{abc}
NKO08	32.75 ^{abcde}	17.02 ^{defgh}	7 ^{efgh}	2.8 ^{abcde}	17.25 ^{abcd}	16.5 ^{abcd}	7.16 ^{abcd}	10.9 ^{abc}	1576.22 ^{cdef}
NOU011	24.75 ^{cde}	18.2 ^{bcde}	6.99 ^{efgh}	2.47 ^{abcdefgh}	17.75 ^{ab}	17.5 ^{abc}	6.77 ^{bcd}	10.35 ^{abc}	1200.6 ^{def}
NOU012	75.25 ^{a}	16.37 ^{efghi}	6.36 ^{gh}	1.87 ^{ghijkl}	17.25 ^{abcd}	17.25 ^{abc}	6.35 ^{bcd}	8.52 ^{bc}	3021.71 ^{abcde}
NOU02	43.25 ^{abcde}	17.1 ^{defg}	6.98 ^{efgh}	2.1 ^{efghijkl}	18.25 ^{a}	17.75 ^{ab}	6.70 ^{abcd}	9.32 ^{abc}	1863.59 ^{abcdef}
NOU03	44 ^{abcde}	17.37 ^{cdefg}	7.84 ^{abcdef}	2.11 ^{efghijkl}	14.75 ^{bcde}	14.75 ^{bcde}	8.05 ^{abcd}	14.79 ^{ab}	2492.74 ^{abcde}
NOU04	26.5 ^{bcde}	19.25 ^{abc}	6.77 ^{efgh}	2.4 ^{bcdefghij}	18.5 ^{a}	18 ^{ab}	6.48 ^{abcd}	11.05 ^{abc}	1396.48 ^{def}
NOU05	34.75 ^{abcde}	18.5 ^{bcd}	7.20 ^{cdefgh}	2.47 ^{abcdefgh}	18 ^{a}	17.5 ^{abc}	6.64 ^{abcd}	10.05 ^{abc}	1631.96 ^{cdef}
NOU06	48 ^{abcde}	20.62 ^{a}	8.60 ^{ab}	2.95 ^{abcd}	17.75 ^{ab}	17.5 ^{abc}	7.76 ^{abcd}	13.12 ^{abc}	2967.69 ^{abcde}
NSI01	26.5 ^{bcde}	14.62 ^{ij}	7.26 ^{bcdefgh}	2.07 ^{efghijkl}	14.25 ^{de}	14 ^{cde}	8.35 ^{abc}	12.22 ^{abc}	1251.29 ^{def}

NSI02	8 ^{e}	13.21 ^{j}	7.87 ^{abcde}	1.67 ^{jkl}	12.75 ^{e}	12.25 ^{e}	7.85 ^{abcd}	12.07 ^{abc}	317.88 ^{f}
NTE011	41 ^{abcde}	18.37 ^{bcde}	8.86 ^{a}	3.12 ^{ab}	18 ^{a}	18 ^{ab}	7.56 ^{abcd}	13.22 ^{abc}	2582.64 ^{abcde}
NTE012	34.5 ^{abcde}	17.3 ^{cdefg}	7.47 ^{bcdefg}	2.42 ^{bcdefghi}	18.75 ^{a}	18.25 ^{ab}	6.89 ^{abcd}	11.15 ^{abc}	1862.51 ^{abcdef}
NTE013	42.25 ^{abcde}	20.07 ^{ab}	8.41 ^{abcd}	2.62 ^{abcdef}	17.25 ^{abcd}	16.250 ^{abcd}	7.858 ^{abcd}	13.15 ^{abc}	2424.078 ^{abcde}
NTE014	69 ^{abc}	16.62 ^{defghi}	6.05 ^{h}	1.37 ^{l}	17.75 ^{ab}	17.5 ^{abc}	6.21 ^{d}	7.6 ^{c}	2427.46 ^{abcde}
NTE015	66 ^{abc}	17.77 ^{cdef}	8.55 ^{abc}	3.200 ^{a}	17 ^{abcd}	16.25 ^{abcd}	7.31 ^{abcd}	13.27 ^{abc}	3737.3 ^{ab}
NTE02	62.5 ^{abcd}	18.07 ^{bcde}	8.85 ^{a}	2.97 ^{abc}	19.5 ^{a}	19 ^{a}	7.09 ^{abcd}	11.5 ^{abc}	3668.89 ^{abc}
NTE03	64.5 ^{abcd}	15 ^{hij}	7.78 ^{abcdef}	1.8 ^{hijkl}	13.25 ^{e}	12.5 ^{e}	8.55 ^{abc}	14.05 ^{ab}	2945.44 ^{abcde}
Pr > F	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

PodL: Pod length, PodW: Pod width, PodWe: Pod weight, NbLod: Number of lodges per pod, NbSP: Number of seeds per pod, SL: Seed length, NbP: Number of pods per plant, HWS: Hundred weight seeds, Yield: Grain yield. Means followed by the same letter within a column are not significantly different at P < 0.05

3.2. Correlation between the traits

Positive and highly significant correlations (P<0.0001) were observed between the measured variables. Plant width (PW) had a strong correlation with Lw (r = 0.708) and MaT (r = 0.950). On the other hand, the number of nodes (NbNd) showed a moderate correlation with Lw (r = 0.566) and TFF (r = 0.564); but a more significant one with MaT (r = 0.675). The number of pods per plant (NbP) showed positive correlations with PodL (r = 0.528), and PodW (r = 0.535) correlated with PodWe (r = 0.712). The number of lodges per pod (NbLod) also showed significant positive correlations with PodL (r = 0.684), with seed length (r = 0.758) and with hundred weight seeds (HWS) (r = 0.690). Grain yield had a high correlation with PodWe (r = 0.712), with SL (r = 0.684), HWS (r = 0.758) and number of seeds per pod (r = 0.615).

3.3. Morphological diversity

The results of the principal component analysis (PCA) revealed that the first three principal axes explained a large portion of the total variance in the data, accumulating up to 73.784% (Table 6). Axis 1, which alone explained 37.459% of the variance, was primarily positively correlated with variables including time to first flower (TFF), time to physiological maturity (MaT), seed length and 100 seed weight (HWS). It also showed significantly negative correlations with the number of lodges per pod (NbLod) and the number of seeds per pod (NbSP).

Table 6 Eigenvalue matrix and correlations between variables and axes of PCA in plane 1-2

	Axis 1	**Axis 2**	**Axis 3**
Eigen value	5.993	3.969	1.843
Total variance (%)	37.459	24.803	11.522
Cumulative variance (%)	37.459	62.262	73.784
Traits	Correlations between traits and axes		
PH	0.445	0.078	0.494*
PW	-0.108	0.362	0.363
NbNd	0.460	0.198	0.455
Ll	-0.109	0.815**	-0.067
Lw	-0.396	0.763**	-0.076
TFF	0.869**	-0.111	-0.126
MaT	0.903**	-0.144	-0.158
NbP	-0.209	0.511	0.710**
PodL	-0.485	0.517	-0.367*
PodW	0.480	0.710**	-0.320*
PodWe	0.297	0.713**	-0.454*
NbLod	-0.890**	0.179	-0.173
NbSP	-0.902**	0.158	-0.162
SL	0.936**	0.285	-0.111
HWS	0.869**	0.404	-0.144
Yield	0.025	0.819**	0.415

PH: Plant height, PW: Plant width, Ll: Leaflet length, Lw: Leaflet width, NbNd: Number of nodes, PodL: Pod length, PodW: Pod width, PodWe: Pod weight, NbLod: Number of lodges per pod, NbSP: Number of seeds per pod, SL: Seed length, NbP: Number of pods per plant, HWS: Hundred weight seeds, Yield: Grain yield, TFF: Time to first flower, MaT: Maturation time 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.

Axis 2 which explained 24.803% of the variance, was strongly positively correlated with leaflet length (Ll), width (Lw), grain yield, pod weight (PodWe) and pod width (PodW). Axis 3 explained 11.522% of the variance, which showed positive correlations with the number of pods (NbP) and plant height (PH); and negative correlations with pod weight; and their length and width, although these correlations were less pronounced.

The dendrogram obtained from the Hierarchical Ascending Classification, grouped the 32 accessions into 3 distinct classes (Fig. 1). The results showed that Class 1 was characterised by relative homogeneity, with lower values of variance and distances to the barycenter grouping accessions NFE011, NTE015, NTE02 and NKO03. Class 2, on the other hand, presents intermediate variability, including the accessions NBO04, NOU02, NSI01, NTE03, NTE013, NOU011, NKN01, NOU04, NTE014 and NBO011. Finally, Class 3 shows the greatest heterogeneity and dispersion, with the highest variance and barycenter distance values, including accessions NKO02, NKO01, NFE012, NBO012, NBO014, NKO08, NOU03, NTE012, NBO013, NOU06, NFE02, NSI02, NKO011, NOU05, NOU012, NBO02, NKN02 and NTE011. The average characteristics of the different classes obtained and the significance of differences between them are summarised in Table 7.

The results showed significant variations between classes for several traits studied (Table 7). Plant height (PH), plant width (PW), number of nodes (NbNd), time to first flower (TFF) and pod weight (PodWe), did not show significant differences between classes (P > 0.05). However, significant differences appeared for leaflet length (Ll), leaflet width (Lw), time to maturity (MaT), pod width (PodW), seed length (SL), 100-seed weight (HWS) and grain yield. Leaflet length was significantly higher in Class 1 (12.02 cm) compared to Classes 2 (10.56 cm) and 3 (9.25 cm); while leaflet width followed a similar pattern with higher values in Class 1 (7.15 cm) and lower in Class 3 (5.99 cm).

Time to maturity was greater in classes 2 (68.7 days) and 3 (65.72 days), compared well to Class 1 (59.07 days) (Table 7). Pod width was also significantly higher in Classes 1 (7.87 cm) and 2 (8.03 cm), compared to Class 3 (6.97 cm). Seed length was higher in Class 2 (8.08 cm) compared to Classes 1 (7.04 cm) and 3 (6.91 cm); and 100 seed weight was higher in Classes 1 (11.41 g) and 2 (13.21 g), compared to Class 3 (10.35 g). Finally, grain yield was significantly higher in Class 1 (3728.75 kg ha^{-1}); followed by Class 2 (2693.93 kg ha^{-1}) and Class 3 (1620.28 kg ha^{-1}), showing a clear differentiation of classes in terms of productivity.

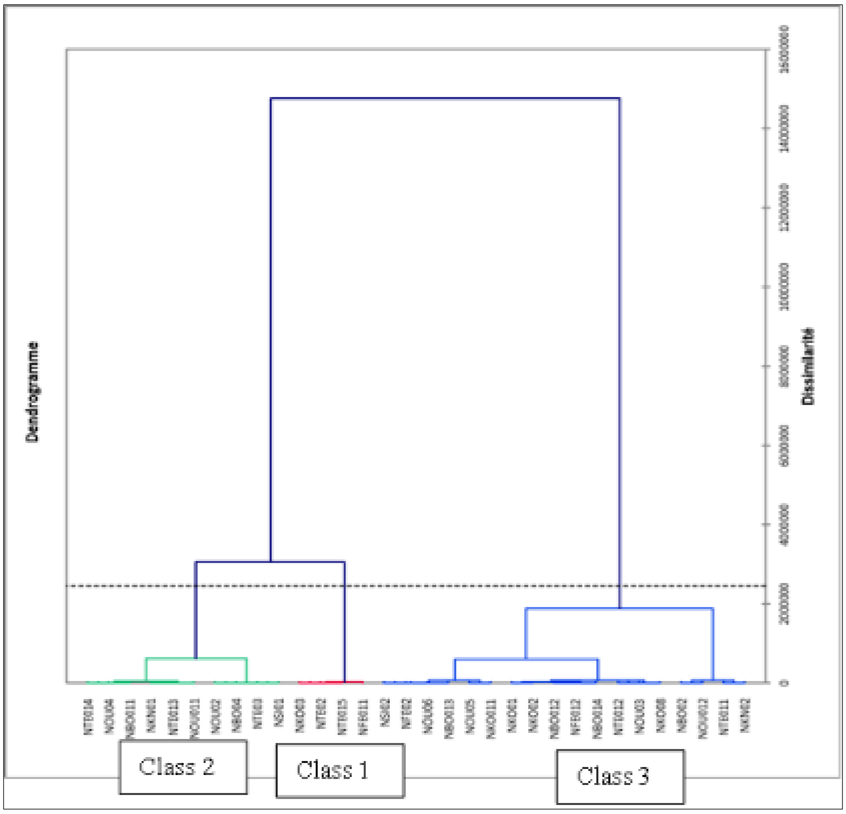

Figure 1 Agromorphological structuring of cowpea accessions using the CAH method

Table 7 Mean characteristics for the three groups established by the CAH method

Traits	Class			Pr > F
	1	2	3	
PH	11.525	12.940	12.461	0.803
PW	38.975	42.360	39.422	0.144
NbNd	8.800	8.860	8.617	0.784
Ll	12.025[a]	10.560[b]	9.256[b]	0.001
Lw	7.150[a]	6.650[ab]	5.989[b]	0.021
TFF	41.275	49.000	45.811	0.105
MaT	59.075[b]	68.700[a]	65.722[a]	0.045
PodW	7.870[a]	8.035[a]	6.974[b]	0.001
PodWe	2.748	2.400	2.236	0.151
SL	7.035[b]	8.076[a]	6.907[b]	0.044
HWS	11.408[b]	13.215[a]	10.339[b]	0.043
Yield	3728.750[a]	2693.932[b]	1620.277[c]	< 0.0001

PH: Plant height, PW: Plant width, Ll: Leaflet length, Lw: Leaflet width, NbNd: Number of nodes, PodW: Pod width, PodWe: Pod weight, SL: Seed length, HWS: Hundred weight seeds, Yield: Grain yield, TFF: Time to first flower, MaT: Maturation time. Means followed by the same letter within a line are not significantly different at P < 0.05.

3.4. Seed yield prediction model

The regression test results reveal that several predictors have a significant impact on seed yield. Among the predictors, LaP ($p = 0.010$), NbNd ($p = 0.043$), Nbre Gsse ($p < 0.0001$), Larg Gsse ($p = 0.000$) and P100Graine ($p < 0.0001$) are statistically significant, meaning that they have a substantial effect on yield. On the other hand, other predictors such as HtP, LoFo, LaFo, TAFl, Long Gsse, Weight Gsse, Nbre Loges, Nbre Gr/Gsse and Long Graine do not show statistical significance, their p-values exceeding the threshold of 0.05. The overall F-statistic of the model is 257.808 with a p-value less than 0.0001, confirming that the regression model is statistically significant and that at least one of the predictors is significantly related to yield. The regression equation:

Y=-3938.58-15.52*LaP+72.45*NbNd+44.71*NbreGsse+302.35*LwGsse+132.46*P100Seed with Y= Yield (Kg/ha) obtained incorporates the statistically significant predictors of the analysis. Positive coefficients (NbNd, Nbre Gsse, Larg Gsse, P100Graine) indicate a positive contribution to yield, while the negative coefficient (LaP) indicates a negative contribution. The proximity of the blue dots to the dotted line suggests good model accuracy, showing that the predictions are consistent with the observed data.

4. Discussion

Assessment of the agromorphological diversity of 32 cowpea accessions from the UPGC genebank revealed significant variability within this study collection. The results of the analysis showed varied coefficients of variation highlighting this variability within the cowpea accessions. Thus, coefficients of variation greater than 20% were highlighted for plant height (CV = 41.5%), number of pods (CV = 48.6), pod weight (CV = 23.4%), weight of 100 seeds (CV = 24.5%) and grain yield (CV = 49.9%); representing significant heterogeneity among accessions; which could be exploited to improve these characteristics. These results corroborate the work of [19] on local cowpea varieties in Benin and [20] on 45 varieties from Chad; where they observed high coefficients of variation for number of pods (CV = 38,70), pod weight (CV = 42,50%) and 100 seeds weight of (CV = 21,80%).

The results of analysis of variance showed a significant difference ($P < 0.001$) between the accessions for each trait studied. Considering grain yield, accession NFE011 had the highest yield with 3855.07 kg ha^{-1}, while NSI02 had the lowest one with a value of 317.88 kg ha^{-1}. Grain yield had a high correlation with pod weight ($r = 0.712$), seed length ($r = 0.684$) and number of seeds per pod ($r = 0.615$) indicating that these variables are good indicators of yield. A close relationship between the size of the lodges (r = 0.684), grains (r = 0.758) and the weight of 100 grains (r = 0.690) was also been highlighted.

Results of the principal component analysis (PCA) revealed that the first three principal axes explained a large part of the diversity, accumulating 73.78% of the total variance. Thus, the first axis was mainly correlated with traits related to seed size and weight, as well as fruit morphology with variables such as time to maturity (MaT), time to first flower (TFF), seed length and hundred weight seeds. The second axis was associated with leaf and pod dimensions and yield; while the third axis brought together less marked correlations. These results are consistent with the work of [20] in Côte d'Ivoire and [21] in Chad, which demonstrated and confirmed the existence of high variability among cowpea accessions with a variability of 70.01 and 73.04% respectively.

The analysis of the Ascending Hierarchical Classification (AHC), coupled with ANOVA, divided the accessions studied into three groups; which differed significantly for leaflet length and width; pod width, seed length, hundred weight seeds and grain yield. However, only grain yield clearly disintegrated the groups, forming three clusters with the post-hoc. Thus, those belonging to Class 1 (NFE011, NTE015, NTE02 and NKO03) had the highest seed yields, with a mean of 3728.75 kg ha^{-1}. These accessions are better candidates for improving productivity of cowpea in Côte d'Ivoire, especially since their grain yield are significantly higher than those of the improved varieties developed by IITA [10]; whereby the highest yield was 2100 kg ha^{-1}.

The grouping of accessions into the different groups was done independently, of their origins and could be explained by the fact that some accessions have common ancestors [22]. The distribution of accessions in the different groups, regardless of their origin, was highlighted by [20]. These authors, having worked on 45 cultivars, structured them into four groups characterised by weight of seeds per pod, pod length, pods weight per plant and the stage of physiological maturity, independently of their localities of origin.

The results also showed that the traits plant width, number of nodes, number of pods, pod width and 100-seed weight contributed significantly to grain yield. The relationship between these traits and grain yield provides good information to guide breeding strategies. These results support those of [23] and [10], according to whom the number of pods per plant and 100-seed weight underlie the high yields of varieties IT88DM-363 and IT86D-400, with yields of 2.10 and 2.07 t/ha respectively.

5. Conclusion

The study reveals the existence of a range of variability within the collection, highlighted by agromorphological characterisation. High coefficients of variation for several traits and principal component analysis (PCA), confirmed this variability at 73.78%. The accessions, which were structured into three genetic groups, stand out by seed yield. Group 1 comprised of NFE011, NTE015, NTE02 and NKO03 accessions, which had the highest grain yield and represent a real asset for cowpea varietal improvement programme in Côte d'Ivoire. Linear regression tests indicated that traits such as plant width (PW), number of nodes (NbNd), pod number, pod width, and 100-seed weight contributed positively and significantly to seed yield. These results suggest that the selection of high-yielding accessions could be optimized by focusing on agromorphological traits identified as reliable predictors of yield.

Compliance with ethical standards

Acknowledgments

We are very grateful to the Peleforo GON COULIBALY University Gene Bank, for providing the germplasms used in this study.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Coulibaly S, Pasquet RS, Papa R, Gepts P. AFLP analiysis of the pheneticorganization and genetic diversity of cowpea [*Vigna unguiculata* (L.) Walp.] reveals extensive gene flow between wild and domesticated types. Theoretical and Applied Genetics. 2002; 104: 258-266.

[2] Kuruma RW, Kiplagat O, Ateka E, Owuoche G. Genetic diversity of Kenyan cowpea accessions based on morphological and microsatellite markers. East African Agricultural and Forestry Journal. 2008 ; 76 : 3-4.

[3] Pasquet RS, Fotso M. Distribution of cowpea cultivars. Vigna unguiculata (L.) Walp. in Cameroon: influence of the environment and human factors. *Journal of traditional agriculture and applied botany.* 1994; 36: 93 -143

[4] Soule BG. The cowpea market in the countries of the Gulf of Guinea (Côte d'Ivoire, Ghana, Togo, Benin and Nigeria). Laboratoire d'Analyse Régionale et d'Expertise Sociale. 2007. P. 31.

[5] Dagnon YD, Diop S, Bammite D, Glato K, Gbaguidi AA, Dansi A, Tozo K. Agromorphological variability of local cowpea cultivars [Vigna unguiculata (L.) Walp.] in Togo. Africa Science. 2017; 13(4): 164 – 177

[6] Tarawali SA, Singh BB, Gupta SC, Tabo R, Harris E, Nokoe S, Fernangez-Rivera S, Bationo A, Manyong VM, Makinde K, Odion EC. Cowpea as a key factor for a new approach to integrated crop-livestock systems research in the dry savannas of West Africa. In Challenges and Opportunities for Enhancing Sustainable Cowpea Production. 2002; 233-251.

[7] Pungulani LLM, Millner JP, Williams WM. Screening cowpea (*Vigna unguiculata*) germplasm for canopy maintenance under water stress. *Agronomy new zealand*. 2012; 42: 23 -32

[8] Faostat 2022. Agricultural production, crop primary database. Food and Agricultural Organisation of the United Nations, Rome. https://www.fao.org/faostat/en/#data/QCL

[9] Langyintuo AS, Lowenberg-DeBoer J, Faye M, Lambert D, Ibro G, Moussa B, Ntoukam G. Cowpea supply and demand in West and Central Africa. Field crops research. 2003; 82(2-3). 215-231.

[10] N'Gbesso MFDP, Fondio L, Didi KB., Djidji AH, Kouame NC. "Study of the yield components of six improved cowpea varieties [Vigna unguiculata (L.) Walp]. Journal of Applied biosciences. 2013a ; 63 : 4754- 4762.

[11] N'Gbesso MFDP, Zohouri GP, Fondio L, Djidji AH, Konate D. Study of the growth characteristics and health status of six improved varieties of cowpea [Vigna unguiculata (L.) Walp] in the central zone of Côte d'Ivoire. International journal of biological and chemical sciences. 2013b; 7(2): 457-467.

[12] N'Gbesso MFDP, N'Guessan CK, Zohouri GP, Konate, D. Final evaluation of yield and phytosanitary parameters of soybean lines [Glycine max (L.) Merrill] in two savannah agro-ecological zones of Côte d'Ivoire. International Journal of Biological and Chemical Sciences. 2013c; 7(2): 574-583.

[13] Kouame N, Kouassi NJ, Ayolie K, Yao KB, Yatty KJ. Influence of crop association on nodulation capacity of three legume species: Peanut. cowpea and green soybean. Journal of Applied Biosciences. 2020; 145: 14930-14937.

[14] Gore BBN, Koffi AMH, Anzara KG, Akaffou DS. Comparing the growth performance and yield parameters of two cowpea varieties (*Vigna unguiculata (L) Walp*.) under different sowing densities. Journal of Experimental Agriculture International. 2020; 42(8): 01-07.

[15] Assouman JSK, Diarrassouba N, Yao SDM. Preliminary study on morphological diversity of cowpea accessions [*Vigna unguiculata* (L.) Walp.] collected in the North of Côte d'Ivoire. International Journal of Current Research in Bioscience and Plant. 2021 ; 8(9) : 1-12.

[16] Assouman JS., Koffi EBZ, Daramcoum MPWA, Yao SDM, Diarrassouba N. Phenotypic diversity of cowpea accessions from the gene bank of Peleforo GON COULIBALY University of Korhogo (Ivory Coast) according to the expression of qualitative traits. Ivoirian Journal of Science and Technology. 2024; 43: 226 - 244

[17] N'Guessan K., Diarrassouba N, Alui KA Nangha KY, Fofana IJ, Yao-Kouame A. Indicators of physical soil degradation in northern Côte d'Ivoire : the case of Boundiali, Korhogo and Ferkessedougou. Africa Science. 2015 ; 11(3) : 115-118.

[18] IBPGR. Descriptors for Cowpea. IBPGR: Rome. Khan A. Bari A. Khan S. Shan NH. Zada I. 2010. Performance of cowpea genotypes at higher altitude of NWFP. Pakistan Journal of Botany. 1983; 42(4): 2291-2296.

[19] Dansi A, Gbaguidi A, Assogba P, Dansi M, Yedomonhan H. Agromorphological characterization of cowpea varieties grown in Benin. International Journal of Biological and Chemical Sciences. 2015; 9 (2): 1050- 1066.

[20] Nadjiam D, Doyam AN, Bedingam LD. Study of the agromorphological variability of forty-five local cultivars of cowpea (Vigna unguiculata. (L.) Walp.) from the Sudanian zone of Chad. Africa Science. 2015; 11(3): 138-151.

[21] Sangare D. Agromorphological characterization of local cultivars of cowpea (Vigna unguiculata (L.) Walp.) collected in Northern Côte d'Ivoire. Thesis. Peleforo GON COULIBALY University. Korhogo. Côte d'Ivoire. 2019 ; p. 62.

[22] Dane F, Liu, J. Diversity and origin of cultivated and citron type watermelon (*Citrullus lanatus*). Genetic Resources and Crop Evolution. 2007; 54: 1255-1265.

[23] Falalou H. Physiological, biocimical and agronomic parameters relevant to cowpea amelioration and adaptation programs to water deficits. Thesis, University of Ouagadougou. 2006, p.189.