Research in Plant Sciences, 2023, Vol. 11, No. 1, 1-8
Available online at http://pubs.sciepub.com/plant/11/1/1
Published by Science and Education Publishing
DOI:10.12691/plant-11-1-1

Genetic Diversity and Structure in Groundnut (*Arachis hypogaea* L.) Accessions Collected in Central and Northern Côte d'Ivoire Based on Agro-morphological Traits

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Received April 12, 2023; Revised May 07, 2023; Accepted May 17, 2023

Abstract The agronomic potential of local groundnut cultivars grown in Central and Northern Côte d'Ivoire is less well known. This study aims to characterize the different groundnut accessions with a view to improving pod and seed yield. Thus, 14 groundnut accessions were evaluated using 19 agro-morphological traits. The results showed significant variability for the majority of these traits. The analysis of the agro-morphological structuring showed that the 4 traits, namely the number of pods (Ngo), number of seeds (NGr), pod yield per hectare (RGof), and yield per hectare of the dry weight of pods (RGoS) were the most relevant to discriminate the accessions into 3 distinct classes. The study of the existing correlation between vegetative and production traits revealed that seed yield is positively correlated with stem height, number of days to flowering, seed length, and seed width. The multivariate analysis of the traits indicated that accessions PA38 and PA18 gave the best vegetative state. Regarding phenological stages, accession PA18 (Dger = 7.00 ± 0.95 days); (NJM = 91.25 ± 2.89 days) was earlier. Regarding seed yields, accession PA38 (436.97 ± 27.59 kg/ha) was the most productive. The agro-morphological groups obtained can constitute gene pools to be used by groundnut research program of Peleforo GON COULIBALY University for groundnut improvement in Côte d'Ivoire.

Keywords: *groundnut accessions, agro-morphological diversity, Côte d'Ivoire*

Cite This Article: Fofana Inza Jésus, Yao Saraka Didier Martial and Koffi Eric-Blanchard Zadjéhi, "Genetic Diversity and Structure in Groundnut (*Arachis hypogaea* L.) Accessions Collected in Central and Northern Côte d'Ivoire Based on Agro-morphological Traits." *Research in Plant Sciences*, vol. 11, no. 1 (2023): 1-8. doi: 10.12691/plant-11-1-1.

1. Introduction

Groundnut (*Arachis hypogaea* L.), is grown in more than 100 countries in tropical, sub-tropical, and warm temperate regions [1]. It is the 13th most important food crop and the 6th most important oil crop worldwide [2]. In much of sub-Saharan Africa, groundnut is an important crop for both domestic consumption and trade [3].

World groundnut production is estimated at 48.8 million tons, with 90% of this production coming from Asia (56%) and Africa (34%). China, India, Nigeria, Sudan and the United States are the top five producing countries in the world [4].

In Côte d'Ivoire groundnut production is estimated at 155.710 tons, or 1.66% of total West African production [4]. All of this production is consumed locally and mainly in the form of groundnut paste [5]. Given the many advantages of this crop, an improvement program to intensify groundnut cultivation in Côte d'Ivoire is being implemented at the Peleforo GON COULIBALY University (UPGC). However, little is known about local ecotypes' agro-morphological, biochemical and molecular characteristics. The interest in extending the cultivation of high-performance local and hybrid groundnut cultivars adapted to the different agro-climates throughout Côte d'Ivoire encourages to map of the performance of the ecotypes already cultivated, and the development or selection of high-performance varieties that are more competitive on the sub-regional or even international market.

The present study is based on the hypothesis that there is phenotypic variability within the groundnut ecotypes grown in Côte d'Ivoire. This variability could contain interesting agro-morphological potentialities based on traits of interest to be considered in the groundnut improvement plan in Côte d'Ivoire. It is in this vision that this study was initiated. The aims of this study are to describe and structure the agro-morphological variability

of groundnut cultivars and to identify the traits with high variability related to seed yield.

2. Material and Methods

2.1. Experimental Site

The different agro-morphological characterization of the groundnut accessions collected was carried out in the vegetable garden of the botanical garden (9°27'28" N, 5°37'46 W at 360 m altitude) of the UPGC located in the town of Korhogo in the north of Côte d'Ivoire.

2.2. Plant Material

The plant material used in the experiment comes from the North and Centre of Côte d'Ivoire, more precisely from the departments of Korhogo, Kong, Zuenoula, Ouangolodougou, and Dabakala (Figure 1). The accessions were collected in five departments of central (Zuenoula) and northern (Korhogo, Kong, Ouangolodougou, and Dabakala) Côte d'Ivoire in the seed form and stored in the UPGC gene bank. These are seed sets from 14 groundnut accessions (Table 1). These accessions were named according to the alphanumeric coding system composed of two letters followed by two Arabic numbers (PA15, PA16, PA17, PA18, PA19, PA21, PA34, PA35, PA36, PA37, PA38, PA51, PA52 and PA71). The first letter "P" signifies the origin of the gene bank to which the accession belongs, namely the UPGC. The second letter "A" provides information on the generic name of the plant, namely peanut. The first number following the first two letters provides information on the plant material collection department where the numbers 1, 2, 3, 5, and 7 indicate respectively Korhogo, Kong, Ouangolodougou, Zuenoula, and Dabakala. The second and last arabic numeral gives an idea of the rank of the accession collected in the Department.

2.3. Methods

2.3.1. Design and Experimental Approach

The experiment was conducted in a three replicate Fisher Block design. Each block was represented by a block 12.3 m long and 1 m wide containing the 14 accessions on the row. The blocks were spaced 0.5 m apart. On a block, the distance between accessions was 0.3 m. The accessions were randomly distributed on each block without repetition. The experimental design has an area of 49.2 m^2 (12.3 m x 4 m) or 0.00492 ha. An accession consists of 4 plants on a block and a sub-plot with 0.3 m between plants. During sowing 2 seeds were placed in each plot. In total 24 seeds were used for one accession and 336 seeds for all 14 accessions.

2.3.2. Data Collection

Nineteen agro-morphological traits according to the groundnut descriptor list [6] were evaluated. The vegetative traits were: the number of leaves (NF), stem height (HT), leaf length (LF), leaf width (laF) and germination time (Dger). Those related to production are number of days to flowering (NJF) and number of days to maturity (NJM), pod length (LGo), pod width (laGo), number of pods (Ngo), seed length (LGr), seed width (laGr), the number of seeds (Ngr), fresh weight of 100 pods (P_{100}Gof), the dry weight of 100 pods (P_{100}GoS), the weight of 100 dry seeds (P_{100}GrS), dry pods yield per hectare (RGrS), fresh pods yield per hectare (RGof) and dry seeds yield per hectare (RGoS). These nineteen agro-morphological traits and the methods of observation are recorded in Table 2.

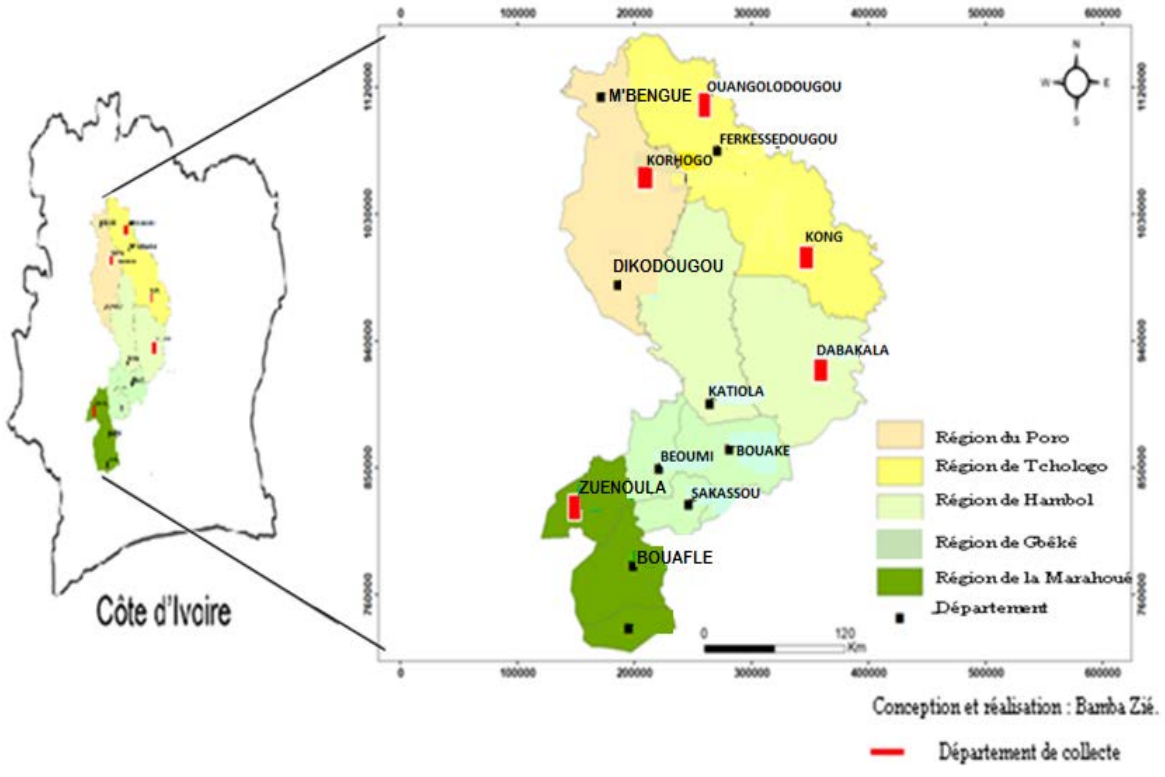


Figure 1. Sites where the groundnut cultivars were collected in Côte d'Ivoire (Groundnut research Programme at UPGC, April 2022)

Table 1. Morphological aspects of seeds, codes, and collection localities of groundnut accessions

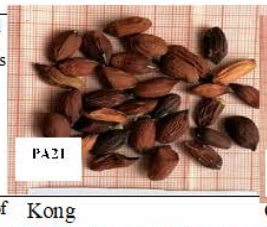
Morphological aspects of seeds of groundnut accessions	 PA15	 PA16	 PA17	 PA18	 PA19
Departments of collection	Korhogo	Korhogo	Korhogo	Korhogo	Korhogo
Morphological aspects of seeds of groundnut accessions	 PA21	 PA34	 PA35	 PA36	 PA37
Departments of collection	Kong	Ouangolodougou	Ouangolodougou	Ouangolodougou	Ouangolodougou
Morphological aspects of seeds of groundnut accessions	 PA38	 PA51	 PA52		 PA71
Departments of collection	Ouangolodougou	Zuenoula	Zuenoula	Zuenoula	Dabakala

Table 2. List of quantitative agro-morphological traits, codes used, and collection methods

Quantitative traits (SI unit)	**Codes used**	**Collection methods**
Number of leaves (unit)	NF	At 60 days after sowing, the leaves of individuals from each accession were counted.
Stem height (cm)	HT	Measured in cm with a tape measure from the cotyledonary axil to the terminal bud on plants at day 60 after emergence.
Leaf length (cm)	LF	Measured in cm with a ruler and converted to cm. The measurement was taken between the furthest points of the length on 10 leaves taken at random from each accession per block on day 60 after sowing.
Leaf width (cm)	laF	Measured in cm with a ruler and converted to cm. The measurement was taken between the most extreme points of the width on 10 leaves taken at random from each accession per block on day 60 after sowing.
Germination time (days)	Dger	This is the number of days from sowing to the appearance of sprouting buds.
Number of days to flowering (unit)	NJF	This is the number of days from sowing to flowering.
Number of days to maturity (unit)	NJM	This is the number of days from sowing to fruit maturity.
Pod length (mm)	LGo	Measured in mm with a caliper. The measurement is taken on 10 pods considered per accession.
Pod width (mm)	laGo	Measured in mm with a caliper. The measurement is taken on 10 pods considered per accession.
Number of pods (unit)	Ngo	Counted after harvest per individual of each accession.
Length of seed (mm)	LGr	Measured in mm with a caliper. The measurement is taken on 10 seeds considered per accession.
Seed width (mm)	laGr	Measured in mm with a caliper. The measurement is taken on 10 seeds considered per accession.
Number of seeds (unit)	NGr	Extracted and counted from the pods.
Fresh weight of pods (g)	P_{100}Gof	Measured in g with an electronic precision balance of 0.001 g on fresh pods obtained immediately after harvest by accession.
Dry weight of pods (g)	P_{100}GoS	Measured in g using a 0.001 g precision electronic balance on air-dried pods for 5 days at a frequency of 9 h per day (8 am to 5 pm) per individual.
Weight of 100 dry seeds (g)	P_{100}GrS	Measured in g with an electronic precision balance 0.001 g on seeds from dry pods
Dry seed yield per hectare (kg/ha)	RGrS	It is a variable calculated from the ratio between the total mass of all dry seeds per accession and the area of the field per hectare (RGrS=MGrS x 10/SP)
Fresh Pod yield per hectare (kg/ha)	RGof	It is a variable calculated from the ratio between the total mass of all fresh pods per accession and the area of the field per hectare (RGof=MGof x 10/SP)
Yield per hectare of dry pod weight (kg/ha)	RGoS	It is a variable calculated from the ratio between the total mass of all fresh pods per accession and the area of the field per hectare (RGoS=MGoS x 10/SP)

2.3.3. Statistical Data Analysis

A multiple analysis of variance (MANOVA) was performed to assess the discriminatory power of all descriptors at a 5% significance level. When the MANOVA was significant ($p<0.05$), an analysis of variance (ANOVA) was performed to assess the discriminatory power of each of the traits studied, at a 5% threshold. When the ANOVA test was significant ($p<0.05$), a Student Newman-Keuls (SNK) post ANOVA test was performed to classify the accessions. In addition, multivariate analyses (PCA, AHC) were performed to structure the groundnut accessions. The principal component analysis (PCA) was used to identify the factors of variability and the ascending hierarchical classification (AHC) was used to form groups of accessions. The classification was performed using the Unweighted Pair Groups Method of Analysis (UPGMA) to group accessions into different classes. Statistical analyses were performed using STATISTICA version 7.1 and SPSS version 20 software.

3. Results

3.1. Variability of the Traits

Significant differences were observed in the values of the vegetative and production traits. The average number of leaves ranged from 86 to 388. The stem height of the accessions ranged from 15 cm to 51 cm with an average of 21.86 cm. On average, all accessions recorded 109.4 days to maturity. The earliest accession had a day-to-maturity of 85 days after sowing. The number of pods ranged from 2 to 71. The average pod length ranged from 10.21 mm to 60.74 mm. The average pod weight and pod width ranged from 2.7 g to 105.8 g and from 8 mm to 40 mm respectively. The average dry pod yield ranged from 11.25 to 440.83 kg/ha with an average of 101.16 kg/ha (Table 3).

Table 3. Variability in 19 agro-morphological traits studied

Agro-morphological traits	Means ± SD	CV (%)	p
Dger (days)	8.86± 1.36	15.34	<0.001
NF(unit)	217.06 ± 80.80	37.22	<0.001
LF (cm)	4.63 ± 0.63	13.60	<0.001
laF (cm)	2.57 ± 0.37	14.399	<0.001
HT (cm)	21.86 ± 8.81	40.30	<0.001
NJF (unit)	23.42 ± 1.28	5.46	<0.001
NJM (days)	109.04 ± 10.18	9.33	<0.001
Ngo (unit)	17.47 ± 12.25	70.12	0.0019
LGo (mm)	26.65 ± 6.25	23.45	<0.001
laGo (mm)	12.64 ± 3.28	25.94	<0.001
LGr (mm)	13.40 ± 1.86	13.88	<0.001
laGr (mm)	7.94 ± 0.94	11.83	<0.001
NGr (unit)	34.94 ± 24.94	71.37	0.0019
P100Gof (g)	158.22 ± 118.48	74.88	0.017
P100GoS (g)	39.55 ± 29.62	74.89	0.017
P100GrS (g)	99.80 ± 15.30	15.33	<0.001
RGrS (Kg/ha)	332.69 ± 51.01	15.33	<0.001
RGof (Kg/ha)	404.64 ± 289.76	71.60	<0.001
RGoS (Kg/ha)	101.16 ± 72.44	71.61	<0.001

3.2. Expression of Vegetative Traits in the Studied Groundnut Accessions

The set of five vegetative traits discriminated against the 14 groundnut accessions ($p<0.05$). The expressions of germination time, number of leaves, leaf length, leaf width, and stem height were significantly different ($p<0.05$) between the accessions. For stem height, a significant difference was observed between accessions with a minimum height of 13.05 cm and a maximum height 30.67 cm. In terms of leaf number, the analysis of Table 4 shows that accession PA38 (NF=310.67 ± 56.53) has the highest number of leaves, while accession PA51 recorded the lowest number of leaves (124.75 leaves). However, accessions PA16, PA18, PA51 and PA52 (LF varies from 5.00 to 5.27) have the longest leaves. While accession PA37 (LF=3.99 ± 0.42) has short leaves. In terms of germination time, there was a significant difference between accessions PA15, PA16, PA18, PA19, PA35, and PA37. Accession PA37 (Dger= 10.25 ± 1.28) showed a high germination degree (Table 4).

3.3. Expression of Production Traits in the Studied Groundnut Accessions

All fourteen production traits discriminated against the 14 groundnut accessions ($p<0.05$). The number of days to flowering showed a significant difference between accession PA 18 and the other accessions. There is a significant difference between accessions from pod and seed sizes. In terms of the weight of 100 fresh pods and the weight of 100 dry pods, a significant difference was observed between accessions. The Accession coded PA21, PA37, PA38, and PA51 produced larger pods and seeds (Table 5). Accession PA34 showed a higher fresh (272.31 ± 35.71 g) and dry (68.07 ± 8.92 g) pod weight. A significant difference was observed between accession PA21 and the other accessions in terms of fresh (867.5 ± 593.36 kg/ha) and dry (216.87 ± 148.34 kg/ha) pod yield. Accession PA38 recorded a high 100 dry seed weight (131.09 ±8.27 g) and dry seed yield per hectare (436.97 ± 27.59 kg/ha) (Table 5 and Table 6).

3.4. Agro-morphological Factors of Variability Identified within Groundnut Accessions

Principal component analysis showed three axes with eigenvalues greater than 1 (Table 7). These axes or agro-morphological factors of variability explain 48.10% of the agro-morphological variability among the 14 groundnut accessions. Agro-morphological factor 1 is mainly the most important with 21.15% of the total variability. All traits that contribute significantly to the formation of factor 1 are negatively correlated with it. These are pod number, seed number, fresh pod yield, and dry pod yield. This factor describes the production traits. Agro-morphological factor 2 is significantly and negatively correlated with only dry seed length. It explains 15.59% of the total variability observed. Agro-morphological factor 3 is significantly and positively correlated with dry seed weight and dry seed yield. It expresses 11.35% of the total variability observed.

Table 4. Vegetative trait expressions in the studied groundnut accessions

Groundnut accessions	NF (unit)	LF (cm)	laF (cm)	HT (cm)	Dger (days)
PA15	255.92 ± 86.82^{ab}	4.08 ± 0.36^{d}	2.33 ± 0.22^{cd}	11.28 ± 3.72^{f}	9.00 ± 1.206^{abc}
PA16	149.00 ± 60.48^{de}	5.00 ± 0.78^{ab}	2.07 ± 0.32^{d}	25.92 ± 10.70^{ab}	8.25±0.965^{cd}
PA17	203.25 ± 55.12^{bcde}	4.03 ± 0.26^{d}	2.40 ± 0.28^{cd}	13.42 ± 4.54^{ef}	9.25±0.965^{abc}
PA18	251.83 ± 84.28^{ab}	5.05 ± 0.37^{ab}	2.95 ± 0.31^{a}	28.08 ± 10.13^{ab}	7.00±0.953^{e}
PA19	198.17 ± 45.06^{bcde}	4.65 ± 0.51^{bc}	2.82 ± 0.31^{ab}	27.17 ± 11.73^{ab}	7.50±0.674^{de}
PA21	260.08 ± 61.38^{ab}	4.01 ± 0.24^{d}	2.36 ± 0.33^{cd}	23.08 ± 5.60^{abc}	7.42±0.515^{de}
PA34	232.67 ± 54.20^{abc}	4.91 ± 0.62^{ab}	2.85 ± 0.26^{ab}	29.08 ± 6.14^{a}	9.33±.778^{abc}
PA35	205.67 ± 49.80^{bcde}	4.71 ± 0.44^{abc}	2.61 ± 0.25^{abc}	26.58 ± 9.67^{ab}	8.50±0.674^{bc}
PA36	259.58 ± 80.39^{ab}	4.37 ± 0.31^{cd}	2.48 ± 0.14^{bc}	20.42 ± 3.39^{abcde}	9.00±0.953^{abc}
PA37	231.00 ± 77.14^{abc}	3.99 ± 0.42^{d}	2.64 ± 0.18^{abc}	19.92 ± 2.71^{bcde}	10.25±1.288^{a}
PA38	310.67 ± 56.53^{a}	4.55 ± 0.76^{bc}	2.44 ± 0.31^{cd}	27.75 ± 7.93^{ab}	9.58±1.165^{ab}
PA51	124.75 ± 30.88^{e}	5.27 ± 0.37^{a}	2.56 ± 0.42^{bc}	16.67 ± 5.49^{cdef}	9.33±.888^{abc}
PA52	189.75 ± 105.31^{bcde}	5.22 ± 0.43^{a}	2.81 ± 0.41^{ab}	14.67 ± 2.57^{def}	9.67±.888^{ab}
PA71	166.50 ± 56.78^{cde}	4.93 ± 0.30^{ab}	2.62 ± 0.40^{abc}	22.00 ± 2.17^{abcd}	9.92±1.730^{a}
F	6.66	11.40	7.28	8.83	11.37
p	<0.001	<0.001	<0.001	<0.001	<0.001

Table 5. Expression of the pod and seed characteristics in the studied groundnut accessions

Groundnut accessions	NJF (days)	NJM (days)	LGo (mm)	laGo (mm)	LGr (mm)	laGr (mm)
PA15	23.67±1.073^{a}	111.83±7.20^{bcd}	25.40 ± 1.94^{cdef}	12.39 ± 0.58^{c}	14.06 ± 0.55^{cd}	8.22 ± 0.75^{abc}
PA16	23.08±1.084^{a}	102.17±7.42^{e}	23.80 ± 1.77^{cde}	11.49 ± 1.25^{c}	13.78 ± 0.60^{cde}	8.90 ± 0.53^{a}
PA17	23.33±.888^{a}	111.33±7.95^{bcd}	26.17 ± 5.58^{cde}	11.94 ± 0.70^{c}	14.34 ± 1.74^{bc}	8.04 ± 0.96^{bc}
PA18	21.33±1.231^{b}	91.25±2.89^{f}	22.73 ± 1.38^{def}	11.73 ± 0.53^{c}	12.88 ± 0.50^{ef}	7.96 ± 0.44^{bc}
PA19	23.00±1.128^{a}	101.67±7.15^{e}	24.77 ± 3.79^{cdef}	11.92 ± 0.96^{c}	13.03 ± 0.67^{def}	7.78 ± 0.57^{bc}
PA21	23.08±.900^{a}	104.67±9.25^{cde}	32.77 ± 2.54^{b}	13.49 ± 1.57^{bc}	15.13 ± 0.63^{b}	8.67 ± 0.67^{ab}
PA34	23.75±.866^{a}	111.92±6.80^{bcd}	27.35 ±2.25^{cd}	11.30 ± 0.33^{c}	13.24 ± 0.84^{def}	8.32 ± 0.56^{abc}
PA35	23.25±1.485^{a}	102.58±9.48^{e}	25.17 ± 5.06^{cdef}	11.92 ± 0.63^{c}	10.83 ± 0.25^{h}	7.83 ± 0.91^{bc}
PA36	24.17±.937^{a}	114.92±5.21^{ab}	31.83 ± 4.02^{b}	13.42 ± 0.61^{bc}	14.51 ± 1.25^{bc}	8.22 ± 0.80^{abc}
PA37	24.25±.965^{a}	117.75±6.09^{ab}	38.13 ± 8.65^{a}	17.02 ± 9.48^{a}	17.30 ± 1.01^{a}	7.57 ± 0.41^{c}
PA38	24.25±1.215^{a}	105.92±6.999^{cde}	24.23 ± 2.49^{def}	12.31 ± 0.80^{a}	13.34 ± 0.51^{de}	7.94 ± 1.03^{bc}
PA51	23.08±.900^{a}	117.67±3.420^{ab}	20.95 ± 6.90^{ef}	11.22 ± 1.11^{a}	12.27 ± 1.08^{fg}	7.66 ± 1.14^{c}
PA52	24.08±1.379^{a}	111.67±6.184^{bcd}	29.42 ± 2.11^{bc}	10.64 ± 1.25^{a}	10.97 ± 0.66^{h}	7.92 ± 0.53^{bc}
PA71	23.50±1.087^{a}	121.17±5.890^{a}	20.43 ± 3.53^{f}	16.13 ± 3.85^{ab}	11.92 ± 1.45^{g}	6.11 ± 0.45^{d}
F	5.72	16.88	15.89	4.95	4.74	39.42
p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Groundnut accessions	Ngo (unit)	P_{100}Gof (g)	P_{100}GoS (g)	NGr (unit)	P_{100}GrS (g)	RGrS (kg/ha)
PA15	16.08 ± 9.25^{ab}	152.71 ± 67.88^{ab}	38.17 ± 16.97^{ab}	32.16 ± 18.51^{ab}	86.85 ± 6.51^{g}	289.53 ± 21.70^{g}
PA16	16.50 ± 9.85^{ab}	131.57 ± 34.37^{ab}	32.89 ± 8.59^{ab}	33.00 ± 19.71^{ab}	118.55 ± 9.49^{b}	395.18 ± 31.63^{b}
PA17	12.08 ± 6.68^{b}	123.88 ± 49.80^{ab}	30.97 ± 12.45^{ab}	24.00 ± 13.36^{ab}	96.42 ± 7.61^{f}	321.43 ± 25.38^{f}
PA18	16.08 ± 10.31^{ab}	121.54 ± 19.49^{ab}	30.38 ± 4.87^{ab}	24.00 ± 20.63^{b}	89.43 ± 6.92^{g}	298.13 ± 23.06^{g}
PA19	20.75 ± 10.83^{ab}	122.14 ± 22.56^{ab}	30.53 ± 5.64^{ab}	32.00 ± 21.67^{ab}	103.23 ± 7.77^{ef}	344.11 ± 25.90^{ef}
PA21	29.92 ± 25.10^{a}	220.59 ± 98.85^{ab}	55.14 ± 24.71^{ab}	41.5 ± 50.21^{ab}	88.55 ± 8.15^{g}	295.17 ± 27.19^{g}
PA34	19.83 ± 12.07^{ab}	272.31 ± 35.71^{a}	68.07 ± 8.92^{a}	59.83 ± 24.14^{a}	104.67 ± 8.02^{cde}	348.93 ± 26.75^{cde}
PA35	22.25 ± 10.47^{ab}	133.04 ± 32.25^{ab}	33.26 ± 8.06^{ab}	39.66 ± 20.94^{ab}	85.47 ± 5.72^{g}	284.93 ± 19.07^{g}
PA36	20.00 ± 15.26^{ab}	162.42 ± 41.2^{ab}	40.60 ± 10.30^{ab}	44.50 ± 30.52^{ab}	110.91 ±7.13^{cd}	369.71 ± 23.77^{cd}
PA37	12.58 ± 7.45^{b}	208.71 ± 131.97^{ab}	52.19 ± 32.99^{ab}	40.00 ± 14.90^{ab}	110.71 ±6.61^{cd}	369.04 ± 22.04^{cd}
PA38	11.08 ± 6.98^{b}	170.03 ± 66.43^{ab}	42.50 ± 16.60^{ab}	25.16 ± 13.97^{b}	131.09 ±8.27^{a}	436.97 ± 27.59^{a}
PA51	23.00 ± 12.41^{ab}	96.02 ± 34.91^{b}	24.24 ± 8.72^{b}	22.16 ± 24.81^{b}	98.33 ± 7.59^{ef}	327.79 ± 25.32^{ef}
PA52	11.08 ± 4.73^{b}	168.022 ± 84.97^{ab}	42.00 ± 21.24^{ab}	46.00 ± 9.47^{ab}	87.30 ± 5.79^{g}	291.01 ± 19.30^{g}
PA71	13.33 ± 2.64^{b}	131.038 ± 38.98^{ab}	32.75 ± 9.74^{ab}	22.16 ± 5.28^{b}	85.72 ± 4.63^{g}	285.75 ± 15.46^{g}
F	2.69	2.09	2.09	2.69	45.21	45.21
p	0.0019	0.017	0.017	<0.001	<0.001	<0.001

Table 6. Expression of the fresh and dry pod in the studied groundnut accessions

Groundnut accessions	RGof (kg/ha)	RGoS (kg/ha)
PA15	377.16 ± 201.65[b]	94.29 ± 50.41[b]
PA16	352.08 ± 179.77[b]	88.02 ± 44.94[b]
PA17	238.88 ± 204.75[b]	59.72 ± 51.18[b]
PA18	325.13 ± 237.44[b]	81.28 ± 59.36[b]
PA19	444.77 ± 292.83[b]	111.19 ± 73.20[b]
PA21	867.5 ± 593.36[a]	216.87 ± 148.34[a]
PA34	525.69 ± 212.20[b]	131.42 ± 53.05[b]
PA35	468.05 ± 219.38[b]	117.01 ± 54.84[b]
PA36	505.83 ± 261.44[b]	126.45 ± 65.36[b]
PA37	386.25 ± 271.55[b]	96.56 ± 67.88[b]
PA38	271.66 ± 133.19[b]	67.91 ± 33.29[b]
PA51	334.76 ± 156.30[b]	83.69 ± 39.07[b]
PA52	279.86 ± 115.77[b]	69.96 ± 28.94[b]
PA71	287.36 ± 100.26[b]	71.84 ± 25.06[b]
F	4.747	4.747
p	<0.001	<0.001

Table 7. Eigenvectors and percentage of variation expressed by the first three axes of variability identified in 14 groundnut accessions from 19 agro-morphological traits

	Factor 1	Factor 2	Factor 3
Eigenvariance	4.018	2.96	2.15
Total variance (%)	21.15	15.59	11.35
Cumulative variance (%)	21.15	36.75	48.10
Dger	0.32	-0.24	-0.03
NJFl	0.07	-0.43	-0.05
NF	-0.20	-0.25	0.05
LF	0.16	0.45	-0.02
LaF	-0.06	0.30	-0.26
HT	-0.32	0.06	0.26
NJM	0.24	-0.29	-0.18
Ngo	**-0.90**	0.19	0.14
Lgo	-0.30	-0.54	-0.22
LaGo	-0.11	-0.30	-0.28
LGr	-0.16	**-0.71**	0.06
LaGr	-0.24	-0.15	0.25
NGr	**-0.90**	-0.19	-0.14
P_{100}Gof	-0.005	-0.51	-0.60
P_{100}GoS	-0.005	-0.51	-0.60
P_{100}Gr	0.07	-0.59	**0.70**
RGof	**-0.94**	-0.09	-0.14
RGoS	**-0.94**	-0.09	-0.14
RGr	0.07	-0.59	**0.70**

3.5. Morphological Clusters Identified within Groundnut Accessions

The hierarchical ascending classification of the 14 groundnut accessions based on the seven variables revealed by the PCA, revealed three clusters (Figure 2). These clusters are distinct at the Euclidean distance of 160. Examination of the data shows that this difference arises from four of the characters analyzed (Table 8). These four characters reveal a distinction between the three groups. These characters are: Ngo, NGr, RGof and RGoS.

Cluster I composed of PA15, PA18, PA51, PA17, PA52, PA71, PA16, PA37, and PA38 accessions are distinguished mainly by accessions with a small mean number of pods (14.64 ± 1.09), a small mean number of seeds (29.29 ± 2.19), a low yield of fresh pods (334.98 ± 16.56 kg/ha) and a low yield of dry pods (79.25 ± 3.92 kg/ha). Cluster II consists of accessions PA19, PA35, PA34, and PA36 and is represented by accessions with an average number of pods per plant (20.70 ± 1.64), an average number of seeds per plant (41.41±3.28), an average fresh pod yield (486.09 ± 23.56 kg/ha) and an average dry pod yield (121.52±5.89 kg/ha). Cluster III is composed of accession PA21 only differs from other accessions with a high mean number of pods (29.91±3.28), a high mean number of seeds (59.83±6.57), a high yield of fresh pods (867.00±47.12 kg/ha) and a high yield of dry pods (216.87±11.78 kg/ha).

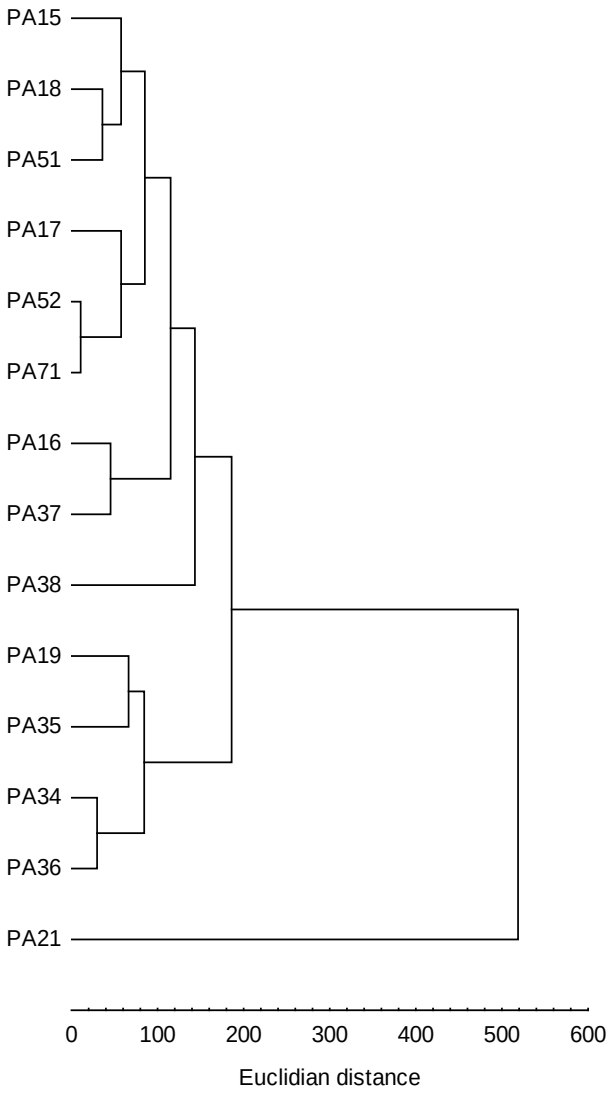


Figure 2. UPGMA dendrogram structuring the 14 groundnut accessions into three agro-morphological clusters

Table 8. Characteristics of the three clusters of groundnut accessions from the AHC

Agro-morphological traits	Agro-morphological clusters of groundnut accessions (Mean ± SD)				
	Cluster I	Cluster II	Cluster III	F	p
Ngo	14.64 ± 1.09[b]	20.70 ± 1.64[b]	29.91 ± 3.28[a]	12.41	0.001
NGr	29.29 ± 2.19[b]	41.41 ± 3.28[b]	59.83 ± 6.57[a]	12.41	0.001
LGr	13.43 ± 0.58[a]	12.90 ± 0.87[a]	15.13 ± 1.74[a]	0.65	0.537
P_{100}GoF	36.23 ± 3.82[a]	43.11 ± 5.73[a]	55.14 ± 11.46[a]	1.49	0.266
RGrS	334.98 ±16.56[a]	336.92 ± 24.85[a]	295.16 ±49.70[a]	0.30	0.740
RGof	317.02 ±15.70[c]	486.09 ±23.56[b]	867.50 ± 47.12[a]	69.75	<0.001
RGoS	79.25 ±3.92[c]	121.52 ±5.89[b]	216.87±11.78[a]	69.75	<0.001

4. Discussion

To carry out plant breeding, knowledge of genetic variability is very important. Thus, in the description of genetic resources, the identification of this genetic variability for certain morphological traits is the first step (Radhouane, 2004).

In this study, all traits were and discriminated through the agro-morphological evaluation of the 14 groundnut accessions. Eight traits (with CV>30%) show heterogeneity within the accessions. These are NF, HT, Ngo, NGr, P100Gof, P100GoS, P100GoS, RGof, and RGoS. The other traits showed homogeneity (with CV<30%). The homogeneity of the traits may be due to the self-pollinating nature of the groundnut. When a plant is fertilized by its pollen, the resulting individuals show the same expression of the phenotypic characters.

The germination time varied from 7 to 10 days within studied accessions. The PA18, PA19, and PA21 accessions have the lowest germination rate while the PA37 accession has the highest germination rate. Higher seed germination depends on the availability of favorable environmental factors like adequate temperature, light, salinity, humility, and water [8] and the presence of seed-borne pathogens [9]. In the case of flowering, the number of days to flowering of the accessions varies from 21 days to 24 days with PA18 which has a lower number of flowering days, and the accessions PA36, PA37, PA38, and PA52 which have several higher flowering day (24 days). Accessions with several days of maturity between 90 and 105 days belong to early varieties while accessions with several days between 106 days and 125 days are late varieties. This shows that the PA18 accession with a small number of flowering days is the one with the shortest maturation time. Our results are similar to those of [10]. In their study, they demonstrated that the varieties with the shortest initiation times are the earliest to reach maturity. The variability that was observed at the level of the phenological stages (flowering and maturation) in the accessions, could be linked to the interaction of the different genotypes and the environment.

In this study, vegetative characters were used to discriminate groundnut accessions. Accession PA34 is the tallest accession while PA15 is the smallest among the accessions studied. The height of the accessions depends on their intrinsic characteristics and above all on the particular soil and climatic conditions that allow them to develop their growth potential to the maximum.

The variability observed in vegetative development and height of the groundnut accessions studied would therefore result from the difference in their capacity to adapt to the environment. These results are similar to the previous work on the evaluation of the agronomic performance of nine tomato varieties that showed the difference observed in the growth of various tomato varieties would be linked to their genotype and the environment in which they were tested [11].

The highest unhulled seed yield expressed by the accessions in this study was below 1000 kg/ha (436.97 Kg/ha). This result, as well as those obtained in previous work on groundnut, are significantly lower [12]. The latter obtained yields varying between 4200 and 2900 kg/ha. The difference in pod yields could be due to agro-climatic conditions that differ from one site to another. Indeed, the previous work was carried out on fertile and less cultivated soil. It should be noted that our experiment was conducted on soil without fertilizer to approximate growing conditions in rural areas [13].

5. Conclusion

The specific objectives of our study were to describe and structure the agro-morphological diversity of groundnut cultivars to reveal those with interesting agro-morphological potentialities, and then to identify the traits of high variability related to seed yield that should constitute a base of traits of interest to be considered in subsequent groundnut improvement schemes in Côte d'Ivoire. At the end of our study, the evaluation of the agro-morphological variability of the 14 groundnut accessions collected revealed the existence of significant variability between them. The multivariate analysis of the traits indicated that accessions PA38 and PA18 gave the best vegetative state. Regarding phenological stages, accession PA18 (Dger = 7.00 ± 0.95 days); (NJM = 91.25 ± 2.89 days) was earlier. Regarding seed yields, accession PA38 (436.97 ± 27.59 kg/ha) was the most productive.

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