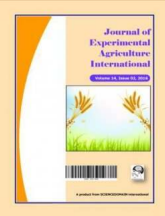

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Agro-morphological Diversity of Six Peanut (*Arachis hypogaea* L.) Breeding Lines from Three Geographical Areas

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To improve peanut (*Arachis hypogaea* L.) performance, morphological traits of agronomic importance were assessed for genetic diversity of six breeding lines. These lines are from different geographical origins Burkina Faso, Senegal and the USA.
Study Design: The experimental was performed as a Fisher randomized complete block with three replications.
Place and Duration of Study: The morphological experiment was conducted at the research station of Rural Development Institute (IDR) at Gampêla in the East-Central area of Burkina Faso during the cropping season of 2015-2016.

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Methodology: Twenty character traits (qualitative and quantitative morphological parameters and resistance components) described in the peanut descriptor were used for characterization.
Results: Analysis of variance revealed a wide variability between these six lines for different traits of characters used. Principal Component Analysis (PCA) and the hierarchical cluster analysis (HCA) indicate that this variability is structured into three groups. Group I includes early breeding lines, productive and susceptible to leaf spot (early and late) SH470P, CN94C and (AS) the second group includes a single line resistant and late GM656; and the third group include resistant and latest maturing breeding lines, NAMA and PC79-79.
Conclusion: GM656 and CN94C could be potential parents in the breeding program to combine resistance with early and high yield potential.
Molecular characterization of these breeding lines will better distinguish these and understand the genetic control of different traits; this will allow an improvement of this important crop for performance and leaf spot resistance.

Keywords: Arachis hypogaea L.; agro-morphological traits; characterization; diversity; breeding lines; Burkina Faso.

1. INTRODUCTION

Cultivated peanut (*Arachis hypogaea* L.) or groundnut is an annual species having underground fruiting, and belonging to the family of Fabaceae. Given its socio-economic importance, peanut production has grown steadily in recent years [1]. However, the production varied because of many challenges (diseases, working conditions, quality seeds…). For example production which was 42.73 million tons in 2010 reduced to 40.76 and 40.67 million tons during 2011 and 2012 respectively, then increased to 44.73 million tons in 2013 and again reduced to 42.44 million tons during 2014. Area under cultivation has increased from 20 million ha in 1994 [2] to 25.4 million ha in 2013 [3]. In addition, the average yields of groundnut in most parts of West Africa are lower (903 kg ha^{-1}) than those in South Africa (2000 kg ha^{-1}), Asia (1798 kg ha^{-1}), or the rest of the world (1447 kg ha^{-1}) [3]. The lower yields in West Africa are attributed considerably to leaf spot disease [4], low soil fertility and water limitation. Early leaf spot caused by *Cercospora arachidicola* and late leaf spot caused by *Phaeoisariopsis personata* are critical yield-limiting diseases of groundnut in West Africa [5,6], accounting for yield reductions of 50 to 70% where fungicides are not used [7]. A distinction based on the vegetative growth and reproduction model show two subspecies of *A. hypogaea*. One is the subspecies *hypogaea* which has two varieties (*hypogaea* and *hirsuta*) and the second is subspecies *fastigiata* with four botanical types that are *fastigiata, vulgaris*, *peruviana* and *aequatoriana* [8]. *A. hypogaea* is the only domesticated species, widely used and used directly in food and oil extraction. Cultivated peanut is an allotetraploid plant (2n = 4x = 40) resulting from a recent hybridization event between two wild species followed by a doubling of the chromosomes [9]. The existing genetic variability in the cultivated compartment is low, with limited genetic diversity due to a genetic bottleneck in formation of the polyploid from A-genome ancestors. A. duranensis and B-genome ancestor A*. ipaënsis* [10,11]. Peanut is a self-pollinating legume although places where bee activity is high occasional, limited cross-pollination (pollination) can occur [12]. In general individuals are generally homozygous. Plant morphological characters can be used for improving the conservation of agricultural diversity. Indeed morphological characterization allows to identify varieties or accessions from a collection and contributes to a better understanding of genetic diversity. Parents with diverse origins have a higher probability of producing superior progenies than those of similar ancestry, but it has become increasingly difficult to find high-yielding genotypes that do not have common parentage [13]. This study aims to study the variability of a panel of peanut lines, from Senegal, Burkina Faso and the United States by (i) evaluating morphological characters of agronomic traits and the level of resistance to leaf spot, (ii) analyzing how the diversity of these traits is structured and, (iii) identifying potential combination of parents for hybridization to improve performance and leaf spot resistance.

2. MATERIALS AND METHODS

2.1 Experimental Location

This experiment was conducted at Gampêla district (12°22'N, 12°25'E) in Burkina Faso. The

means of temperature during the cropping seasons of 2015-2016 were 21.5℃ (minimum) and 42.8℃ (maximum). The annual rainfall varied from 700 mm to 900 mm. The rainy season was relatively short and lasted for about five months (June-October). Soil pH ranged from 5.0 to 6.3 and has other constraints namely low organic matter content, and high amounts and of low water retention capacity. The soil had a fine texture, with sand and silt [14].

2.2 Plant Material

Plant material for the study composed of six cultivars or breeding lines of various origins, and includes three resistant to leaf spot and three lines susceptible to the disease. The characteristics of these different genotypes are reflected in Table 1.

2.3 Experimental Design

The experiment was performed as a Fisher randomized complete block with three replications. Each replication consisted of 6 entries, planted in plots of two rows each 3 m long. The spacing was 0.5 m between rows and plots. There is 1.5 m between ranges. Seed were planted a one seed per hole and spacing is 15 cm between holes. However, no treatment has been made on the seeds before sowing. A first application of fertilizer (NPK) background was made before sowing at 100 kg ha^{-1}. This ensures a good effect in the plants during the first weeks of development before the formation of nodules. A second application of fertilizer (NPK) was carried out during the period of strong flowering at 100 kg ha^{-1}. The use of NPK is just a blanket application to cover the needs of the plant. Two manual weeding after flowering were made. Notes were taken on each row of the plots and values were averaged.

2.4 Morphological Parameters Measured

Qualitative and quantitative parameters as recommended in groundnut descriptors [15] were recorded for six genotypes used in the study and are as follows.

2.4.1 Qualitative morphological parameters

The plant habit measured during pod formation stage for plants with a spacing of 10-15 cm between plants. The plant can have a spreading decumbent; erect or another.

The branching pattern was determined by the (n + 1) cotyledon lateral branch. It is either alternate, sequential or otherwise.

The leaf color measured of the full stage of development. The color is variable; it can be yellow, light yellow, green, light green, dark green or bluish green etc.

The pigmentation of the main stem at maturity green, purple or brown.

2.4.2 Quantitative morphological parameters

Stem height (cm) (HTP), this is the distance from the cotyledonary axil to the terminal bud. It is the average of ten (10) plants recorded the 60 or 85 days after sowing (DAS).

The width or spreading of the plant (cm) (ETP) is the distance measured between the two extreme ends of the plant width. It is the average of ten (10) plants in the 45 or 60 DAS.

Leaflet length (mm) (LongF) is the length of the apical leaflet of the third leaf of the main stem at full stage of development. The measurement was made on the average of ten (10) leaflets of different plants.

Width of the leaflet (mm) (LargF) was measured of the third leaf of the main stem. The recorded measure is the average of ten (10) leaflets of different plants.

Number of days to first flower appearance ($D1^{er}F$) is relative to the date of plant emergence. The observation was made on the entire elementary plot.

Number of days to 50% flowering is until the appearance on 50% of the plants in the plot (D50F). This was relative to the date of emergence for the plot.

Number of days to seedling emergence (Lev 15 DAS) was measured on the period from the planting date to emergence of the first seedling in the plot.

Table 1. Characteristics of the six parental lines used for the test

Code	Origin	Growth cycle (days)	Botanical classifications	Leaf spot resistance
GM656	Texas (USA)	110	Spanish	Resistant
NAMA	Local(BURKINA)	120	Virginia	Resistant
PC79-79	ISRA(SENEGAL)	110	Virginia	Resistant
A.S	Local (BURKINA)	90	Spanish	Susceptible
SH470P	INERA(BURKINA)	90	Spanish	Susceptible
CN94C	INERA(BURKINA)	90	Spanish	Susceptible

2.5 Others Parameters

The notation of the disease: the rating scale of leaf spot severity [16] was used to rate the severity of the disease on peanut plants. This rating was made on 40, 60 and 80 DAS. The observation was the average of the rating of the two rows of each plot.

Defoliation (DEFO): the number of fallen leaves was obtained by counting leaves on the main stem of the peanut plant. The percentages are calculated by taking the ratio of the number of fallen leaves divided by the total number of leaves, multiplied by 100 [2].

Weight of 100 seed (POIDS100G): was made on 100 mature seed selected at random, but having a non-rough surface [15].

Weight of harvested pods (PGR) was expressed in grams (g) according to descriptors for groundnut [15].

Pod yield (RDMT), Pod weight of each plot was expressed in kg per hectare (kg ha^{-1}) [15].

Number of pods per plant (NGR/PLT), the average number of pods per plant was measured on ten plants [15].

Shelling efficiency (PRCT/EGR), calculated as the weight of mature seeds at 7 to 9% moisture, divided by total weight of the sampled pods multiplied by 100 [15].

2.6 Data Analysis

Quantitative morphological data were first subjected to a descriptive analysis and variance. Means, standard deviations and coefficients of variation were determined. The structure of morphological diversity was evaluated using Principal Component Analysis (PCA), Hierarchical Ascendant Classification (CAH), and correlation between the different variables. Principal component analysis is a descriptive technique to study the relationships between quantitative variables. It is a method of multivariate analysis with the objective of obtaining the most relevant summary as possible of the initial data.

All statistical analysis were performed in R.I386.2.2 software and Statistix 8 Version 8.1 software.

3. RESULTS

3.1 Analysis of Qualitative Morphological Parameters

The qualitative characteristics were compared between the six breeding lines (Table 2). These characteristics distinguished the six parental lines involved in the study. Plant habit varied between erect (CN94C, SH470P, AS), rampant-3 (PC79-79), rampant-1 (NAMA) and spreading (GM656). Leaf color ranged from light green (CN94C, SH470P, AS) to green (GM656) and dark green (PC7979, NAMA). Branch pattern were alternate (GM656 PC79-79 NAMA) and sequential (CN94C, SH170P, AS). Pigmentation was present only in GM656 and absent in the other lines.

3.2 Analysis of Morphological Quantitative Parameters

The results of quantitative trait variance analysis are reported in Table 3. For percent emergence demonstrated at 15 DAS, there was no significant difference but differences were significant at 30 DAS where the mean was 71.6%. For Nama, emergence was 80%, followed by AS with 75%, CN94C and PC79-79 with 70% respectively. GM656 and SH70P had lowest emergence rate 65.8% and 65%. For date of first flowering, a highly significant difference (P = 0.002) between the different lines was noted.

Table 2. Results of the analysis of qualitative characteristics of the six breeding lines

Lines	Plant habit	Leaf color	branching	Stem pigmentation
GM656	Spreading	Green	Alternating	Pigmentation
NAMA	Rampant-1	Dark Green	Alternating	No
PC79-79	Rampant-3	Dark Green	Alternating	No
AS	Erect	Light Green	Sequential	No
SH470P	Erect	Light Green	Sequential	No
CN94C	Erect	Light Green	Sequential	No

The average was 26.8 DAS for all lines. SH470P had the earlier flowering, 25 DAS. GM656 and CN94C followed with 25.6 DAS. Late flowering was recorded by the PC79-79 and NAMA with respectively 29 and 29.7 DAS. Two groups emerge from this analysis of variance, NAMA, AS, and PC79-79 are the first group, and the second group which included CN94C, SH470P, and GM656. The average length of time to 50% flowering is 32.2 DAS. The analysis of variance indicated a very high significant difference (P = 0.001) between the different breeding lines. SH470P flowered early at 29.7 DAS; followed by AS, CN94C and GM656 with 30.3, 30.6, 31.3 DAS respectively constitute the first group, whereas NAMA and PC79-79, which flowered late, constituted the second group. ANOVA showed significant differences among genotypes for plant height, and genotype SH470P (31.4 cm) was taller whereas NAMA (16.0cm) was shorter. ANOVA showed significant differences for plant width among the genotypes and genotype GM656 (52.7 cm) was wider and PC79-79 (37.9 cm) was narrower. Leaflet length analysis of variance revealed the existence of a very highly significant difference (P = 4.2e-6) among the lines tested. Three classification groups were found. The first group which had highest lengths included GM656, AS, CN94C, SH470P, with leaflet lengths up to 6.6 cm. The second group consisted of the PC79-79 and the third group was NAMA with a leaflet length of 4.1 cm. The average value for the width of the leaflet was 3cm. The lines were divided into two groups. The group containing CN94C, SH470P and AS had width up to 3.4 cm. The second group consisted of GM656, NAMA, and PC79-79.

3.3 Analysis of Resistance Components

The results of the analysis of variance of components of resistance are shown in Table 4. Scoring was performed on the ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) [2] scale at 40DAS, 60DAS, 80DAS and 100DAS. The variance analysis of the scores demonstrated very highly significant differences. At 40 DAS there was no significant difference among the different lines (P = 0.619). The average score on that date was 1.8 to 2.0. A highly significant difference was observed among the different lines at 60 DAS (P= 4.79e-05). The average rating for this was 4.7. Two groups were observed: the first consisted of CN94C, SH470P and AS which had record highest scores up to 5.3. The second consisted of the GM656, NAMA and PC79-79 with scores between 2.6 and 3. Rating at 80 DAS and 100 DAS followed a similar pattern as observed at 60 DAS. In the susceptible group the mean score at 80 DAS 6.5 and a mean of 3.1 for the resistant group. At 100 DAS, the mean score of the susceptible group rose to 7.4; the mean of the susceptible group was 3.2. Analysis of variance of the data on the percentage of defoliation indicates the existence of significant difference (P = 7.3e-5), the average percentage of defoliation was 49.3%. The CN94C had the highest percentage of defoliation (60.5%); this was not significantly different from the values for SH470P and AS. The lowest percentage of defoliation recorded was for NAMA (39.4%); this was not significantly different from the values for GM656 and PC79-79.

The results of ANOVA on the yield components of the data are reported in Table 5. No significant difference was observed for the number of pods per plant harvested (P = 0.186) with average of 41.3. However weight of harvested pods there was a significant difference among different lines tested (P = 0.011). AS had the most significant pod weight (414 g); CN94C had 359.8 g. The lowest weight of pods was recorded in NAMA with 218.2g; it was not significantly different from the PC79-79 that had an average weight of 256g. There was significant differences for pod yield kg/ha among genotypes and genotype CN94C recorded highest yield (1199 kg/ha) and NAMA (727.8 kg/ha) recorded the lowest.

For shelling percentage there was almost no difference among genotypes (P = 0.053). Mean

shelling percentage was 60.10%.The highest percentage was for AS genotype with 76.8%. The lowest percentage was PC79-79 with 61.3%. The mean weight of 100 mature seed was 36.3 g. PC79-79 and SH470P stood out from other lines with 39.3 g, or 39.7 g respectively; NAMA (29.6g) and AS (31.9 g) had the lowest weight 100 seed weights.

Table 3. ANOVA morphological quantitative characteristics of the six breeding lines

Lines	Lev15DAS	D1^{er}F	D50F	HTP	ETP	LongF	LargF
GM656	65.8±3.8a	25.6±0.5bc	31.3±0.5b	18.7±1.4bc	52.7±5.4a	6.6±0.1a	2.5±0.07b
NAMA	83.3±11.8a	29.7±0.5a	36±1.7a	16±3.2c	46.5±4.5a	4.1±0.1b	2.4±0.2b
PC79-79	70±4.3a	29a±2.6b	35±2.0a	23.3±3.1abc	37.9±2.6b	5.0±0.1c	2.7±0.2b
AS	75±2.5a	26.3±0.5abc	30.3±0.5b	29.5±2.8a	40.0±3.2b	6.6±0.5a	3.4±0.1a
SH470P	65±8.6a	25±1c	29.7±1.1b	31.4±7.3a	38.6±1.3b	6.3±0.3a	3.4±0.1a
CN94C	70.8±15.6a	25.6±0.5c	30.6±0.5b	29.5±2.8a	38.6±2.1b	6.5±0.1a	3.3±0.1a
Meam	71.6	26.8	32.2	24.7	42.4	6.3	3
C .V	13.74	7.85	8.81	27.7	14.9	16.8	15.6
Pvalue	0.276nsd	0.002**	0.0001***	0.001**	0.004**	4.2e-6***	4.9e-6***

*Caption: **: P = 0 .01; *** : P = 0 .001 ; nsd (no significant difference) : P = 0 .05. CV: coefficient of variation. For each variable the values with same letter are not statistically different. Lev15 DAS= percentage of emergence 15 days after sowing, D1^{er}F= days to first flowering, D50F= days to 50% flowering, HTP = Stem height of plant, ETP = width of the plant, LongF = leaflet length, LargF = leaflet width*

Table 4. Analysis of variance for leaf spot incidence among the six breeding lines

Lines	N40DAS	N60DAS	N80DAS	N100DAS	DEFO
GM656	2±0.0a	3±0.5b	3.3±0.5 b	3.6±0.5b	40.18±5b
NAMA	1.6±0.5 a	3±0.0b	3±0.0b	3±0.0b	39.35±7.3b
PC79-79	1.6±0.5 a	2.3±0.5b	3±0.5b	3±0.0b	42.26±5.8b
AS	2±0.0a	4.6±0.5a	6±0.0a	7.3±0.5a	54.57±0.7a
SH470P	2±0.0a	5.3±0.5a	7±0.0a	7.6±0.5a	58.9±4.6a
CN94C	2±0.0a	5±0.0a	6.6±0.5 a	7.6±0.5a	60.53±3 a
Mean	1.88	3.88	4.88	5.38	49.29
C .V	17.12	32.87	36.38	42.28	20.53
Pvalue	0.619nsd	4.79e-5***	6.06e-7***	1.18e-07***	7.38e-05***

*Caption: *** : P = 0 .001 ; nsd (no significant difference) : P = 0 .05. For each variable the values with same letter are not statistically different. N40DAS = Leaf spot Score 40 days after sowing, N60DAS = Leaf spot Score 60 days after sowing, N80DAS = Leaf spot Score 80 days after sowing, N100DAS = Leaf spot Score 100days after sowing, DEFO = Percentage of defoliation*

Table 5. Analysis of variance of quantitative traits of yield components of the six breeding lines

Lines	NGR/PLT	PGR (g)	RMT(Kg/Ha)	PRCT/EGR(%)	POIDS100G(g)
GM656	50.1±10.4a	320.3±67.7ab	1068±225.9ab	68.7±6.5 ab	38.6±3.4ab
NAMA	36.3±8.4a	218.2±72.3b	727.8±241.2b	64.6±1.8ab	29.6±1.8c
PC7979	31.6±10.9a	256±11.3b	853.4±37.9b	61.3±9.9b	39.3±3.4a
AS	46.8±10.5a	414±66.1a	1380±220.5a	76.8±1.5a	31.9± 3.4bc
SH470P	33.2± 2.2a	310.1±23.9ab	1034±79.9ab	70.9± 2. 1ab	39.7±6.3a
CN94C	49.6±15.2a	359.8±43.1ab	1199±143.9ab	72.2±2.5 ab	37±2.5ab
Mean	41.31	313.07	1043.6	69.1	36.03
CV	28.57	25.41	25.41	9.8	14.09
P Value	0.186nsd	0.011*	0.011*	0.053.	0.002**

**: P = 0 .05; ** : P = 0 .01 ; nsd (no significant difference) : P = 0 .05. For each variable them means followed by same letter are not statistically different. NGR/PLT = Number of pods per plant, PGR (g) = Weight of harvested pods, RDMT (Kg/ha) = Pod Yield Kg/ha, PRCT EGR (%) = Shelling efficiency, POIDS100G(g) = weight of 100 seed*

3.4 Descriptive Analysis of the Correlation between Quantitative Traits

Analysis of the correlation is shown in Table 6 below. Traits such as defoliation, plant height, width of the leaflet, length of the leaflet of the plant, and the weight of harvested pods per plant had negative association with the date to 50% flowering. Defoliation was negatively correlated with the spread of the plant (*P* = 0.030) and positively correlated with plant height (*P* = 0.0004), leaflet length (*P* = 0.010), leaflet width (*P* = 0.0001), leaf spot score at 100 DAS (*P* = 0.0001), shelling percentage (*P* = 0.007), and yield (*P* = 0.04). Plant height was positively correlated with yield (*P* = 0.04), the number of pods harvested per plant (*P* = 0.04), 100 seed weight (*P* = 0.01), disease rating at 100 DAS (*P* = 0.0008), and leaflet width (0.0001). The number of pods per plant was positively correlated with yield (0.002) and shelling percentage (*P* = 0.002).

3.5 Study of the Correlation of the Variables Studied

Fig. 1 is the correlation circle of variables. Given the figure, we can notice that the variables represented by arrows pointing in the same direction are positively correlated; those represented by arrows going in the opposite direction are negatively correlated and when the arrows between two variables are perpendicular, there is no correlation. Regarding the positive correlations, firstly there are the percentage of germination 15 days after sowing field, the days to the first flowering and 50% flowering**.** A second correlation group includes, disease score, defoliation, leaflet width, shelling percentage, plant height, the number of pods harvested, leaflet length and disease score at 90 DAS. A third group includes plant spread and 100 seed weight.

3.6 Analysis of the Main Axes of the PCA

All principal components analysis are summarized in five axes. In this study, the variability within the lines is explained by just or two dimensions. The first two principal components explained 86.68% of the variability (Fig. 2). PCA I contributed with a 69.48% PCA II (Line 2) with 17.20%. AS, SH470P, and CN94C were similar; PC79-79 and NAMA formed a second group. GM656 belong to another group. The accessions in the first group (AS, SH470P, CN94C) were also susceptible to disease; those in second group (NAMA and PC7979) as well as GM656 were resistant to leaf spot.

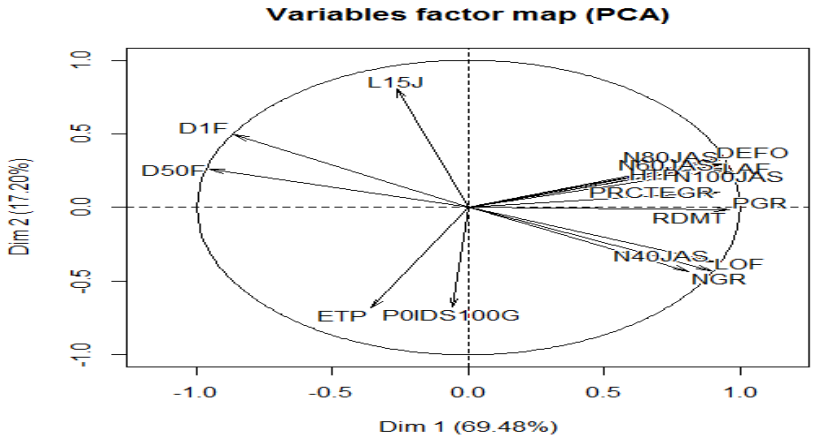

Fig. 1. Correlation circle of Principal Component Analysis (PCA)

Caption: Dim: dimension, The first correlation group variables were: L15 J= percentage of emergence 15 days after sowing, D1^{er}F= days to first flowering, D50F= days to 50% flowering. The second correlation group variables were: HTP = Stem height of plant, ETP = width of the plant, LAF = leaflet length, LOF = leaflet width, NGR = Number of pods per plant, PGR = Weight of harvested pods, RDMT = Pod yield, PRCT = Shelling efficiency, POIDS100G(g) = weight of 100 seed, N40DAS = Leaf spot Score 40 days after sowing, N60DAS = Leaf spot Score 60 days after sowing, N80DAS = Leaf spot Score 80 days after sowing, N100DAS = Leaf spot Score 100 days after sowing, DEFO = Percentage of defoliation

Table 6. Pearson correlation among selected traits

	D50F	DEFO	ETP	HTP	LAF	LOF	N100JAS	NGR	P0IDS	PGR	PRCT
DEFO	-0,75**										
ETP	0,02	-0,49*									
HTP	-0,55*	0,75*	-0,60*								
LAF	-0,76**	0,90**	-0,52*	0,82**							
LOF	-0,85**	0,56*	-0,07	0,46	0,66**						
N100JAS	-0,78**	0,85**	-0,45	0,72	0,90**	0,69**					
NGR	-0,41	0,15	0,40	0,08	0,10	0,36	0,18				
P0IDS	-0,27	0,23	-0,11	0,55*	0,25	0,34	0,03	0,08			
PGR	-0,68**	0,49*	-0,06	0,48*	0,58*	0,63**	0,62**	0,67**	0,13		
PRCT	-0,73**	0,61**	-0,05	0,42	0,61**	0,58*	0,66**	0,40	-0,07	0,52*	
RDMT	-0,68**	0,49*	-0,06	0,48*	0,58*	0,63**	0,62**	0,67**	0,13	1,00**	0,52*

*Caption: D1^{er}F= days to first flowering, D50F= days to 50% flowering. HTP = Stem height of plant, ETP = width of the plant, LAF = leaflet length, LOF = leaflet width, NGR = Number of pods per plant, PGR = Weight of harvesting pod, RDMT = Pod yield, PRCT = Shelling efficiency, POIDS100G(g) = weight of 100 seed, S100DAS = Leaf spot Score 100 days after sowing, DEFO = Percentage of defoliation. *: P = 0 .05, **: P = 0 .01*

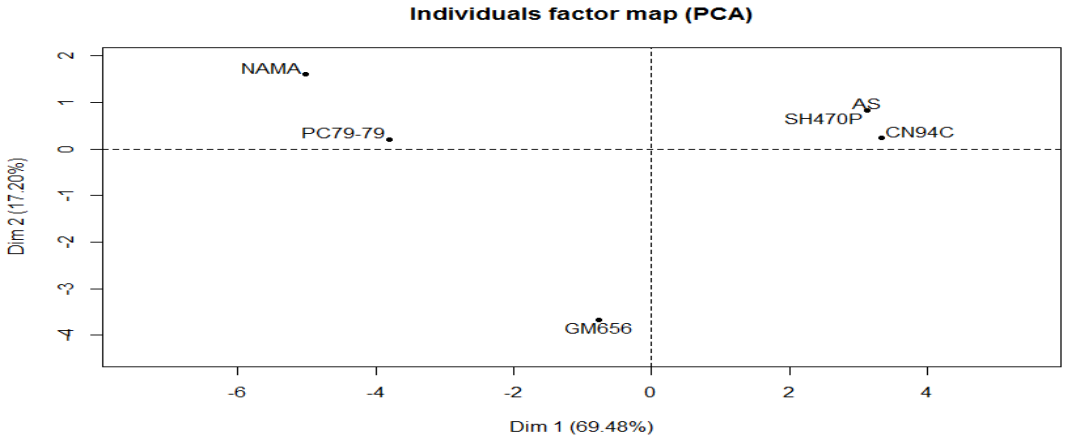

Fig. 2. Map of the individual contribution of each of the lines according to principal components (Dimensions 1 & 2)

The results of the contribution of different variables are given in Table 7. This data shows that the percentage of germination at 15DAS, spreading and weight of 100 seed contributed very little to the constitution of Axis 1 (Fig. 1). These variables contributed more to the constitution of Axis 2.

Table 7. Contribution of variables in percentage to the formation of axes

Variables	Dim1(Axe1)	Dim2 (Axe2)
L15J	0.584	22.130
D1F	6.303	8.353
D50F	7.688	2.285
HTP	5.383	2.570
ETP	1.067	15.912
LOF	6.795	6.287
LAF	7.257	3.485
N40DAS	6.964	4.726
N60DAS	7.223	2.903
N80DAS	7.473	3.033
N100DAS	7.829	2.388
DEFO	6.915	3.604
NGR	5.565	6.418
PGR	7.852	0.009
RDMT	7.852	0.009
PRCTEGR	7.223	0.372
P0IDS100G	0.372	15.516

Caption: Dim: dimension; L15 J= percentage of emergence 15 days after sowing, D1^{er}F= days to first flowering, D50F= days to 50% flowering. HTP = Stem height of plant, ETP = width of the plant, LAF = leaflet length, LOF = leaflet width, NGR = Number of pods per plant, PGR = Weight of harvested pods, RDMT = Pod yield, PRCT = Shelling efficiency, POIDS100G(g) = weight of 100 seed, N40DAS = Leaf spot Score 40 days after sowing, N60DAS = Leaf spot Score 60 days after sowing, N80DAS = Leaf spot Score 80 days after sowing, N100DAS = Leaf spot Score 100 days after sowing, DEFO = Percentage of defoliation

The results of the contribution of each individual line are noted in Table 8. Considering the results, it appears that GM656 is the only line which contributes significantly to the formation of the Axis 2. SH470P and AS contribute similarly to the constitution of the two axes. The constitution of the Axis 1 is much more related to the contribution of CN94C, PC79-79, and NAMA.

Table 8. Contribution lines to the constitution of Axes

Lines	Dim1 (Axis 1)	Dim2 (Axis 2)
GM656	0.84	77.14
MAMA	35.5	14.57
PC79-79	20.37	0.22
AS	13.81	3.87
SH470P	13.81	3.87
CN94C	15.66	0.3

Dim: Dimension

3.7 Analysis of the Hierarchical Cluster

Fig. 3 is a dendrogram showing the results of the cluster analysis. The first class consists of NAMA, PC79-79; the second class is constituted solely by GM656; and the third class by SH470P, AS, and CN94C. The first class includes two resistant genotypes of the three resistant types in this study; this class is characterized by the percentage of germination by 15DAS, time to first flowering and time to 50% flowering. The second class contains only the GM656 used as resistant genotype in the study, is characterized by 100 seed weight and the spread of the plant. The last class consists of genotypes susceptible to leaf spot study; disease score, defoliation, weight of harvested pods, width and length of the leaflets, and shelling percentage and plant height.

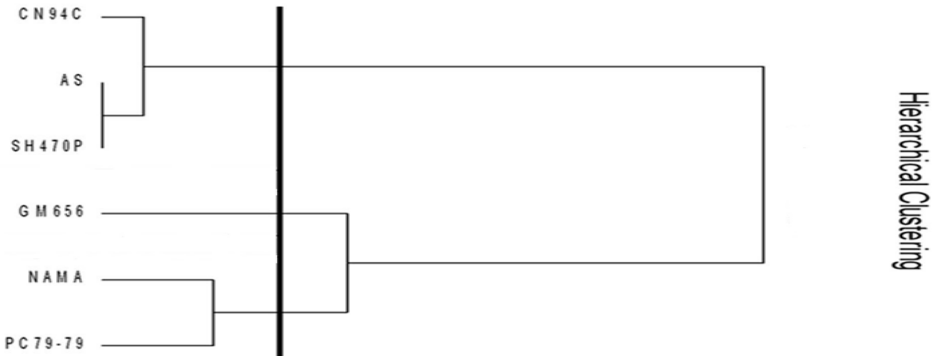

Fig. 3. Hierarchical clustering of the six breeding lines

4. DISCUSSION

The different analyses of morphological data from this study enabled us to achieve significant results that provide information on each of the breeding lines of the study. The analysis of qualitative characteristics shows that three of the six lines are erect; these were susceptible to leaf spot; of the other three, which are resistant, two are prostrate and one is spreading and similar results were reported by Zongo [17] for genotypes NAMA and PC79-79.

Susceptible lines also showed a clear green color leaves, a sequential branching habit and main stem was not pigmented. In resistant lines, GM656 is the exception with a pigmented stem and a spreading habit. Dark-green resistant genotypes and the prostrate habit could be considered characteristic of these genotypes.

Morphological quantitative characters such as plant height, length and width of the leaflet for sensitive genotypes were high. The fact that these plants are erect with large leaves is associated with their susceptibility to disease. Flowering is early in these genotypes, they could be recommended in breeding programs for earliness. Resistant genotypes had a good germination in the field, but with late flowering dates. This confirms the long cycle time of these lines. Their leaves are smaller compared to those that are susceptible. According to Clavel et al. [18] the plant reduces the extension of its leaves in response to fluid restriction. This may explain the reduction of the leaf extension in these long-cycle varieties in order to survive drought and yet produce. Quantitative traits of resistance components allowed us to confirm the differences of the ratings for the disease resistance of NAMA, PC79-79 and GM656 on the one hand, and the susceptibility of SH470P, CN94C and AS on the ICRISAT scale. NAMA, PC79-79 and GM656 are potential sources for the improvement of groundnut resistance to leaf spot. The analysis of quantitative traits of yield components showed a balance of performance values, the weight of harvested pods, number of pods per plant and shelling percentage in susceptible lines. For 100 seed weight, GM656 is the exception, with the other resistant genotypes obtaining a value (38.7 g). NAMA had the smallest 100 seed weight. Despite their susceptibility, SH470P, AS, CN94C have a satisfactory yield. Previous work on the inheritance of earliness and some characteristics associated with performance had reported that the CN94C is a very productive variety [19]. This high performance has been confirmed by more recent work [20]. These highly-productive genotypes could be used in breeding programs to improve performance. This would mean that the susceptible lines are the most productive. One might consider that the size of the leaves is associated with higher disease. The results obtained indicate that selection should consider the potential of these lines compared with those characters. The spreading of the plant and the weight of 100 seed are negatively correlated with the plant height and the width of the leaflet; these are also features of GM656; this would therefore be very interesting for selection for weight of 100 seed. This variable is correlated with the performance, we could for performance improvement make a selection for the weight of 100 seeds. One might also remember that the creeping or spreading lines suffer less defoliation compared to lines erected because of the negative correlation between the spread of the plant and defoliation. The hierarchical cluster analysis allowed us to identify three classes that discriminate against different genotypes of the study. These classes are characterized by specific variables among those we studied. Dendrogram truncation gives NAMA and PC79-79 as the first class; it is characterized by the percentage of stand establishment in the field and later times of first and 50% flowering. In this class, the choice of NAMA would be ideal for breeding programs. The second class had only GM656; the main characteristics are weight 100 seed and spreading of the plant. Here GM656 would be a good choice for selection because it contains interesting characters for resistance and yield improvement. This breeding line had already shown that it has big seed and resistance to leaf spot [21]. The last class is the one that brings together SH470P, CN94C and AS characterized by performance, weight of harvested pods, the plant height, number of pods per plant, percentageshellout, the leaf spot score, defoliation, then width and the length of the leaflet. In this class, the CN94C appears as the ideal choice capable of allowing a selection of interesting characters while reducing the impact of adverse characters.

5. CONCLUSION

This study allowed highlighting the agro-morphological performances of six accessions: GM656, NAMA, PC79-79, AS, SH470P and CN94C. These results revealed the wide phenotypic variability that exists within this

population of six individuals. There are very significant differences both in terms of quantitative and qualitative characters that were studied. Of a total of seventeen variables for each line, we estimated through the descriptive analysis the different averages of each variable for the relevant lines. Thus, NAMA and PC79-79 are the first class, the second class GM656, SH470P, AS, and CN94C are the third class. The cluster obtained clearly indicates the existence of a morphological polymorphism between the breeding lines. This indicates that these lines will be a great contribution not only in breeding programs for resistance to leaf spot but also for traits of interest, such as seed weight, yield and early maturity. For this purpose, a molecular characterization of these lines would be a great asset for the development of a breeding program based on molecular markers specifically SSRs or SNPs. This study is required in order to assess the level genotypic the different breeding lines.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Nyabyenda P. Les plantes cultivées en régions tropicales d'altitude d'Afrique: Généralités, légumineuse alimentaires, plantes à tubercules et racines, céréales. Ed. Presses Agronomiques de Gembloux. 2005;22. French.
2. Rubba Rao PV, Strange RN. Defence mechanisms of groundnut (*Arachis hypogaea* L.), to foliar pathogens. Annual report, Department of Biology Darwin building, University College London Gower Street London WC1E6BT. 1994;2-9.
3. Food and Agricultural Organization of the United Nations (FAO). Crop production statistics. Rome; 2016.
   (Accessed 16 February 2017)
   Available:http://faostat.fao.org/faostat/
4. Naab JB, Tsigbey FK, Prasad PVV, Boote KJ, Bailey JE, Brandenburg RL. Effects of sowing date and fungicide application of yield of early and late maturing peanut cultivars grown under rainfed conditions in Ghana. Crop Prot. 2005;24:325–332.
   DOI: 10.1016/j.cropro.2004.09.002
5. Waliyar F. Evaluation of yield losses due to groundnut leaf diseases in West Africa. In: B.J. Nduguru, F. Waliyar, and B.R. Ntare, Summary Proceedings of the Second ICRISAT Regional Groundnut Meeting for West Africa, 11–14 Sept. 1990, Niamey, Niger. ICRISAT. 1991;32–33. India.
6. Waliyar F, Adomou M, Traore A. Rational use of fungicide applications to maximize peanut yield under foliar disease pressure in West Africa. Plant Dis. 2000;84:1203–1211. 2000. 84.11.1203.
   DOI: 10.1094/ PDIS
7. Shokes FM, Culbreath AK. Early and late leaf spots. In: N.K. Burelle, D.M. Porter, R.R. Kabana, D.H. Smith, and P. Subrahmanyam, editors, Compendium of peanut diseases. 2nd ed. American Phytopathology Society. 1997;17–20.
8. Schilling R. L'arachide histoire et perspectives. Résumé de Conférence. Agropolis Museum, CIRAD, avenus Agropolis, 34398 Montpellier cedex 5, France. 2003;14. French.
9. Simon JP. Les principales plantes alimentaires du monde: Origine, évolution, culture et utilisation. Université de Montréal. Faculté des Arts et des Sciences, 2900 Boulevard Edouard Montpetit, Montréal QC H 3T 1 J4, Canada. 2005;Chapter 11:2-12. French.
10. Burow MD, Leal-Bertioli SCM, Simpson CE, Ozias-Akins P, Chu Y, Denwar NN, Chagoya J, Starr JL, Moretzsohn MC, Pandey MK, Varshney RK, Holbrook CC, Bertioli DJ. Marker-assisted selection for biotic stress resistance in peanut. In: Translational Genomics for Crop Breeding: Biotic Stress. Wiley Blackwell. 2013;125-150.
    ISBN: 978-0-470-96290-9.
11. Fonceka D, Tossim HA, Rivallan R, Faye I, Sall MN, Ndoye O, Favero AP, Bertioli DJ, Glaszmann JC, Courtois D, Rami JC. Genetic mapping of wild introgression into cultivated peanut: A way of enlarging the genetic basis of a recent allotetraploid. Plant Biology. 2009;9:103.
12. Nigam SN, Ramanatha RV, Gibbons RW. Utilization of natural hybrids in the improvement of groundnuts (*Arachis hypogaea*). Expl Agric. 1983;19:355-359.
13. Wang H, Pawan K, Bingyan H, Mei Y, Ramesh K, Weijian Z, Harris-Shultz K,

Moore KM, Culbreath AK, Zhang X, Varshney RK, Xie L, Guo B. Analysis of genetic diversity and population structure of peanut cultivars and breeding lines from China, India and the US using simple sequence repeat markers. Journal of Integrative Plant Biology. 2016;5:452–465.
14. Thiombiano A, Kampmann D. Atlas de la biodiversité de l'Afrique de l'Ouest, Tome II: Ouaga. Burkina Faso-Frankfurt/Main. 2010;625. French.
15. International Board of Plant Genetic Resources and International Crops Research Institute for the Semi-Arid Tropics (IBPGR and ICRISAT). Descriptors for groundnut. IBPGR, Rome, Italy; ICRISAT, Patancheru, India; 1992. ISBN: 92-9043-139-3.
16. Subrahmanyam P, McDonald D, Waliyar F, Reddy LJ, Nigam SN, Gibbons RW, Ramanatha V, Singh AK, Pande S, Reddy PM, Subba Rao PV. Screening methods and sources of resistance to rust and late leaf spot of groundnut. ICRISAT Information Bulletin No. 47. ICRISAT, Patancheru 502 324, Andhra Pradesh, India. 1995;1-20.
17. Zongo A. Analyse génétique et identification de marqueurs moléculaires SSR associés à la résistance à la cercosporiose précoce de l'arachide (*Arachis hypogaea* L.). These de doctorat, Université de Ouagadougou. 2015;182. French.
18. Clavel D, Drame NK, Diop ND, Zuily-Fodil Y.). Adaptation à la sécheresse et création variétale: le cas de l'arachide en zone sahélienne. Oléagineux, Corps Gras, Lipides. 2005;3:248-60. French.
19. Zagre MB. Hérédité de la précocité et de quelques caractères associés au rendement chez l'arachide (*Arachis hypogaea* L.). Thèse de docteur ingénieur. Université de Cocody. 2004;110. French.
20. Koïta K. Tests de l'activité antifongique et analyse phytochimique des extraits de plantes locales du Burkina Faso pour le contrôle des maladies foliaires de l'arachide (*Arachis hypogaea* L.). Thèse de doctorat unique, Université de Ouagadougou, UFR/SVT. 2013;218. French.
21. Neya FB, Nana AT, Zagre MB, Koïta K, Burow MD, Sankara P, Simpson C. Evaluation au champ de la performance de quelques lignées d'arachide (*Arachis hypogaea* L.) à grosses graines pour la résistance aux cercosporioses de l'arachide dans la zone centre du Burkina Faso de 2010 à 2012. Annale de l'Université de Ouagadougou – Série C. 2013;1-28. French.

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