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Characterization of the agronomic potential of sesame accessions (*Sesamum indicum* L.) in the locality of ouangolodougou in the north of Côte d'Ivoire

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ABSTRACT

Climatic variability and the decline in soil fertility are leading producers to increasingly turn to crops that require less water and inputs, such as sesame (Sesamum indicum L.), to diversify their income. Native to Africa and India, it is cultivated for its seeds, which are rich in oil, vitamins, and proteins, excellent for health. The objective of this study was to characterize the agronomic potential of 17 accessions from several localities in Côte d'Ivoire, to identify those best adapted to the growing conditions of the agro-climatic zone of Ouangologougou. The experimental design was in complete blocks randomized with one factor (accession) and 3 repetitions. The results of the study noted significant diversity around agromorphological parameters and yield. Principal component analysis (PCA) and hierarchical ascending classification (CAH) highlighted three agromorphological groups. The first group contains 6 accessions, which are early (85 days), with low values for growth parameters but high yield components. The second group (1 accession), with an intermediate cycle (93 days) was distinguished by high yield values (2,393.73 kg/ha) and its components. As for the third group, it brings together the accessions (10) at the latest (101 days) with high values of growth parameters, but less productive. Group 2 accessions with good agronomic potential could be recommended to producers in the study locality. Those from other groups could serve as elite parents in a varietal improvement program meeting the needs of producers in Côte d'Ivoire.

Keywords: *sesame accessions, agronomic potential, rainfall variability, Ouangolodougou.*

Introduction

Sesame (*Sesamum indicum* L.) is an annual self-pollinating oilseed crop, generally with indeterminate growth. This oilseed belongs to the Pedaliaceae family and is important because of the resistance of its oil to oxidation and rancidity. Originally from Africa and India, it is cultivated for its seeds, which are rich in oil, vitamins, and proteins [1]. Sesame has many agronomic advantages. Indeed, sesame has a deep taproot to extract moisture from the lower soil layers, grows well in pure stands and in intercropping, is undemanding, and fits well into crop rotation. Its seeds have a high market value and can be eaten as they are, or added to confectionery and pastries.

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The oil is also used in industry in the preparation of soaps, perfumes, or as edible oil [2]. It is also excellent for health.

Sesame cultivation has experienced a resurgence of interest in recent years due to the recovery of global prices and an increasingly growing demand. Indeed, between 2008 and 2017, production volume increased from 5, 015,600 t to 6, 314,700 t [3]. The same is true for the sown areas, which have expanded over the last decade, but with an average yield per hectare still low (596 kg ha^{-1}). It is generally cultivated by small farmers, with almost all of its production in developing countries. In West Africa, among the largest sesame-exporting countries in 2022, we find Nigeria with 365,000 t, Burkina Faso with 208,795 t, and Niger with 104,088 t [4].

The degradation of the agricultural environment in Africa, linked to the decrease, poor distribution of rainfall, and/or the decline in soil fertility, has caused a drop in productivity and production of the main food and cash crops in West Africa and in Côte d'Ivoire in particular. This current situation has led producers, to ensure their livelihood, to turn to less demanding crops that adapt to the current context of climate change. Sesame cultivation, known for its modest water and fertilizer requirements [5] and which seems to meet the demands of this new context, is experiencing strong enthusiasm in Africa. The promotion of this crop undoubtedly constitutes an opportunity to diversify crops but also to fight against poverty and food insecurity affecting third-world countries. Thus, in recent years, sesame has been increasingly cultivated in Côte d'Ivoire, especially in the northern, western, and northwestern regions of the country. In Côte d'Ivoire, 14.000 ha were sown in 2013 for a production of 3.000 t compared to 14.502 ha in 2022 for a production of 3.030 t [4].

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This production remains low compared to that of the major producing countries in West Africa, according to [4]. This low level of production can be attributed to a lack of knowledge of cultivation techniques, the purely traditional nature of the crop [6], phytosanitary constraints [7], the low performance of the available plant material (varietal impurity and varietal confusion), the absence of varieties adapted to local growing conditions and to climate change [8]. Given the enormous diversity of local sesame varieties, knowledge of the natural diversity of sesame accessions in terms of morphological and agronomic traits proves necessary through a varietal selection program in order to identify elite local genotypes to be improved. To do this, one of the approaches in this field is defined by the prospecting, collection, and characterization of the collected sesame accessions [9]. It is in this context that the study entitled: "Characterization of the agronomic potential of sesame (*Sesamum indicum* L.) accessions in the agro-climatic zone of Ouangolodougou in the North of Côte d'Ivoire" was conducted in the locality of Diawala. The general objective of this study is to characterize the agronomic potential of 17 accessions from various localities in Côte d'Ivoire. Specifically, it will aim to characterize the agro-morphological parameters of the collected sesame accessions and to evaluate the structuring of the agromorphological diversity of the different collected accessions.

I. Material and Methods

1.1. Plant material

The plant material consisted of 17 sesame (*Sesamum indicum* L.) accessions from different localities in Côte d'Ivoire.

1.2. Technical equipment

The equipment that was used for cleaning the plot, plowing, and sowing mainly consisted of machetes, hoes, and oxen. A tape measure, stakes, strings, and labels, a graduated ruler, a caliper, a sprayer, and a precision scale were respectively used for setting up the experimental device, measuring plant organ dimensions, measuring collar diameter, phytosanitary treatment, and determining the dry weight of the grains after harvest. Packaging was also used to collect the capsules during harvest.

1.3. Experimental site

The study was conducted in a rural setting on an experimental farm during the rainy season in the Ouangolodougou area, specifically in the village of Tiaplé in the Sub-Prefecture of Diawala (Figure 1). Rainfall surveys were carried out in the study area.

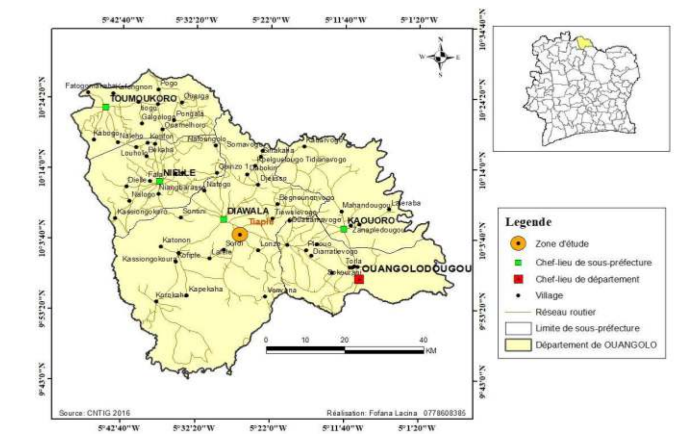

Figure 1: Map of the study area

1.4. Experimental setup and treatments studied

The sesame accessions were sown in a randomized complete block experimental design with one factor and four (4) replications, separated by paths of one and a half meters (1.5 m). Each block consisted of 17 elementary plots, separated from each other by one meter (1 m). Each elementary plot consisted of 4 sowing rows, each with 5 hills, with spacings of 0.3 m between sowing rows and 0.75 m between the hills in the row (with dimensions of 3 m x 0.9 m = 2.7 m^2). This experimental setup included a total of sixty-eight (68) elementary plots and measured 31.3 meters in length and 16.5 meters in width, for a total area of 516.45 m^2. The factor that was studied is the access to 17 levels.

1.5. Crop management

The soil preparation consisted of deep plowing of 20 to 30 cm of soil, to ensure a good seedbed preparation. After a rainfall, the microplots were delineated, followed by sowing. It was done manually on the ridges, in small holes along the sowing lines. Furthermore, this operation was carried out delicately, considering the size of the seeds. Indeed, about ten seeds were placed in each sowing hole at a depth of 1 to 3 cm, and covered with a thin layer of soil aimed at facilitating the emergence of seedlings after germination. A thinning to two plants per hole was done one month after sowing, followed by transplanting of the thinned plants into missing holes or those that had poorly germinated. Regarding fertilization, an application of NPK (15 N-15 P-15 K) at a dose of 1.5 g/hole, or 30 g/plot, was carried out as recommended by [10] two days after thinning. Manual weeding was performed when necessary. Throughout the trial period, the phytosanitary condition of the different accessions was monitored through daily observations of the various plant organs (leaves, stems, flowers, capsules). At this stage, only one insecticide treatment was carried out during the peak flowering period with a contact insecticide whose active ingredient was Kapaas 80 EC, at a rate of 62.5 ml in a 15-liter watering can for the entire plot.

1.6. Observations and measurements

The characterization of the accessions was based on a set of parameters related to phenology, plant morphology, as well as yield and its components. Phenological observations were carried out daily on all the plants in each elementary plot. For each plot, each stage was considered achieved when 50% of the plants had reached it. At maturity, agro-morphological parameters were measured from the plants of four hills per elementary plot. At harvest, the yield was determined in a yield square measuring 1.35 m^2 (0.6 m x 2.25 m), representing six (6) plants per elementary plot. Located at the center of each elementary plot, this yield square was thus composed of three (3) rows of two (2) hills. The yield was calculated using the ratio of the dry weight of the grains per yield square to the area of the yield square (Table I).

Table I: List of variables used in agromorphological characterization

Studied characters	Designations
50% Floral Buds	BF50%
50% Flowering	FLO50%
50% Capsule	CAP50%
Maturity	MAT
Plant Height	HP
Plant Diameter	DP
Number of Branches per Plant	NRP
Height of First Capsule Insertion	HIPC
Number of Capsules per Plant	NCP
Capsule Length	LongC
Capsule Width	LargC
Number of Seeds per Locule	NGL
Number of Seeds per Capsule	NGC
Thousand-Seed Weight	P1000G
Dry weight grains	PSG
Yield	RDT

1.7. Data analysis

The data processing was carried out using the Excel spreadsheet. In the first phase, the data were subjected to a descriptive analysis. The structuring of morpho-phenological diversity was done through multivariate analyses. First, a principal component analysis (PCA) was used to highlight the traits that best discriminate the different accessions and their association. Then, a hierarchical ascending classification (HAC) was performed to elucidate the phyletic relationships existing among the analyzed accessions. A one-way analysis of variance (ANOVA) was conducted to compare the mean values of the different classes from the hierarchical cluster analysis in order to identify the genotypes with the best morpho-phenological characteristics. All these analyses were carried out using R software version 4.4.0. Finally, a discriminant factorial analysis (DFA) was used to highlight the traits that discriminate the groups obtained from the principal component hierarchical classification. The values of the ranking functions and the unidimensional test of equality of means made it possible to determine the most discriminating variables of the groups. These analyses were conducted using XLSTAT software version 2016.

II. Results

2.1. Distribution of rainfall during the experiment

The distribution of rainfall by month recorded during the experiment is shown in Figure 1. A total amount of 817 mm was recorded over the course of the cropping cycle.

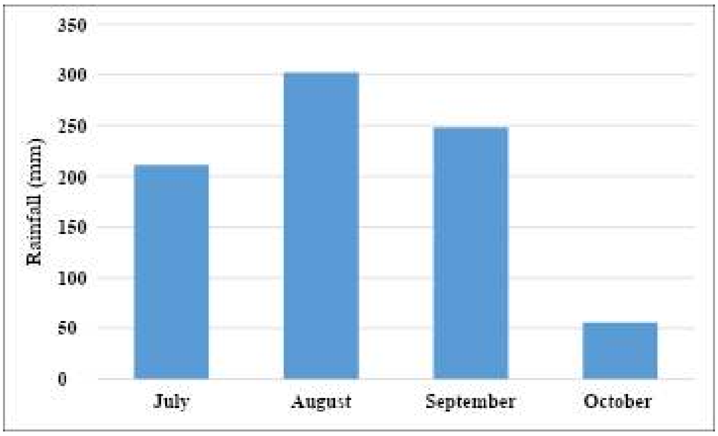

Figure 1: Distribution of rainfall by month during the experiment

2.2. Characteristics of accessions

The results of the descriptive analysis recorded in Table II indicate significant variations for most of the variables studied. The coefficient of variation is high for the number of branches per plant (51%). It is medium for the number of capsules per plant (29%), the dry weight of seeds (25%), yield (25%), the height of insertion of the first capsule (23%), the date for 50% floral buds (24%) and that for 50% flowering (20%), and low for capsule width (3%). Large discrepancies were observed between the minimum and maximum values for the majority of variables. This is the case for the least branched accessions, which have a minimum of 4 shoots, and the most branched ones, with a maximum of 34 shoots. Depending on the accessions, the dates for 50% flowering and maturity range from 39 to 82 days after sowing (DAS) for the earliest to 69 to 101 DAS for the latest. Plant height at maturity varies from 142.91 cm for the shorter accessions to 211.16 cm for the tallest. Yield per hectare was 755.25 kg/ha for the least productive accessions and 2393.72 kg/ha for the most productive.

Table II: Characteristics of the accessions

Variables	Average	Minimum	Maximum	Standard deviation	Coefficient of variation	Variance
BF50% (jas)	51.784	33.000	64.000	12.452	24.045	155.041
FLO50% (jas)	56.902	39.000	69.000	11.722	20.601	137.413
CAP50% (jas)	65.745	44.000	87.000	13.111	19.942	171.896
MAT (jas)	94.941	82.000	101.000	8.174	8.609	66.809
HP (cm)	183.689	142.917	211.167	23.448	12.765	549.794
DC (mm)	17.583	12.437	20.909	2.474	14.068	6.119
NRP	20.713	4.375	34.125	10.593	51.141	112.205
HIPC (cm)	105.282	59.792	136.792	25.013	23.758	625.655
NCP	116.507	65.389	190.639	29.586	25.394	875.315
LongC (cm)	2.460	2.306	2.780	0.136	5.527	0.018
LargC (cm)	0.510	0.488	0.561	0.020	3.837	0.000
NGL	15.687	14.889	17.033	0.637	4.058	0.405
NGC	62.748	59.556	68.133	2.546	4.058	6.483
P1000G (g)	2.831	2.527	3.317	0.206	7.268	0.042
PSG (g)	183.318	101.960	323.153	46.560	25.398	2167.818
RDT (kg/ha)	1357.914	755.259	2393.728	344.888	25.398	118947.481

BF50%: 50% flower buds, FLO50%: 50% flowering, CAP50%: 50% capsule, MAT: maturity, HP: plant height, DC: collar diameter, NRP: number of branches per plant, HIPC: height of first capsule insertion, NCP: number of capsules per plant, LongC: capsule length, LargC: capsule width, NGL: number of grains per compartment, NGC: number of grains per capsule, P1000G: weight of a thousand grains, PSG: dry grain weight, RDT: yield

2.3. Assessment of the structuring of the agromorphological diversity of sesame accessions
2.3.1. Principal component analysis
2.3.1.1. Source of variability

Table III provides the eigenvalues and the percentage of variance for each axis. According to the Kaiser criterion, any axis with an eigenvalue greater than 1 should be retained for analysis [11]. Consequently, the first four axes were retained to describe the maximum variability of the accessions. These first four axes explain 93.55% of the total variance. The first axis accounts for 57.68% of the variability, the second axis 20.83%, the third axis 8.21%, and the fourth axis 6.82%. The correlations of the coordinates of all variables with the principal components are recorded in Table III and shown in Figure 2. The analysis of the variable coordinates highlighted that the first principal component (axis 1) was defined by eight variables: the dates of 50% flower buds, 50% flowering, 50% capsule, from maturity to harvest, the height and collar diameter of the plant, the number of branches per plant, and the height of insertion of the first capsule. This axis can be considered as the axis of phenology and plant morphology. Three variables contributed to the formation of the second component (axis 2), namely the number of capsules per plant, the dry weight of the grains, and the grain yield. This axis is identified as a yield axis and some of its components. Three variables contributed to the formation of the third component (axis 3), namely the length of the capsules, the number of grains per locule, and the number of grains per capsule. Finally, two variables contribute to the formation of the fourth component (axis 4). These last two axes provide complementary information to axis 2. The variables that contribute to the formation of the different axes are positively correlated.

The coordinates of the observations in Table III and shown in Figure 2 revealed that accessions A1, A2, A4, A7, A8, A9, A11, A14, A15, and A16 contributed to the formation of axis 1. As for the formation of axis 2, it is accessions A5, A6, A10, and A12 that contributed positively to its formation.

Table III: Eigenvalues and percentage of variation explained by the first four axes and correlation of the variables with the components

Principal Component	Axis 1	Axis 2	Axis 3	Axis 4
Own Variance	9.22	3.33	1.31	1.09
% Total Variance	57.68	20.83	8.21	6.82
%Cumulative Total Variance	57.68	78.51	86.73	93.55
Variables	**Coordinates**			
	AXIS 1	**AXIS 2**	**AXIS 3**	**AXIS 4**
50% Floral Buds	**0.965**	-0.201	0.085	-0.068
50% Flowering	**0.953**	-0.215	0.001	-0.121
50% Capsule	**0.915**	-0.359	-0.016	-0.135
Maturity	**0.938**	-0.267	-0.075	-0.022
Plant Height	**0.855**	0.210	0.157	0.357
Plant Diameter	**0.275**	0.387	0.596	0.609
Number of Branches per Plant	**0.935**	0.113	0.081	-0.186
Height of First Capsule Insertion	**0.876**	-0.090	0.321	0.067
Number of Capsules per Plant	0.233	**0.922**	-0.098	-0.032
Capsule Length	-0.902	0.024	**0.345**	-0.027
Capsule Width	-0.736	-0.172	-0.047	**0.445**
Number of Seeds per Locule	-0.850	-0.041	**0.395**	-0.293
Number of Seeds per Capsule	-0.850	-0.041	**0.395**	-0.293
Thousand-Seed Weight	-0.593	-0.278	-0.564	**0.348**
Dry weight grains	0.057	**0.966**	-0.157	-0.102
Yield	0.057	**0.966**	-0.157	-0.102

BF50%: 50% flower buds, FLO50%: 50% flowering, CAP50%: 50% capsule, MAT: maturity, HP: plant height, DC: collar diameter, NRP: number of branches per plant, HIPC: height of first capsule insertion, NCP: number of capsules per plant, LongC: capsule length, LargC: capsule width, NGL: number of grains per compartment, NGC: number of grains per capsule, P1000G: weight of a thousand grains, PSG: dry grain weight, RDT: yield

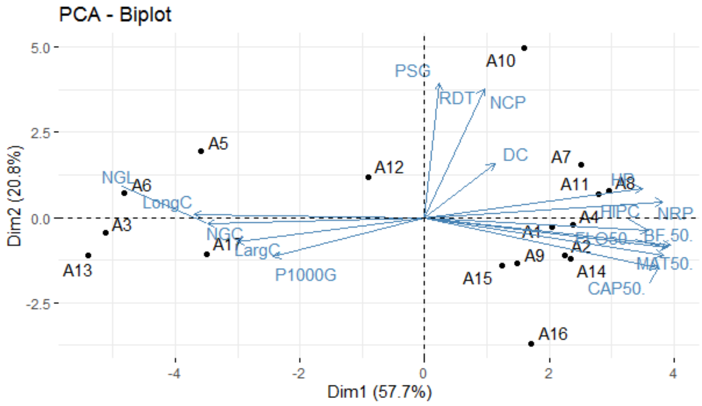

Figure 2: Representation of the variables in the plane of axes 1 and 2 of the PCA

2.3.2. Agromorphological structuring of sesame accessions

For the structuring and grouping of accessions, the HAC (Hierarchical Ascending Classification) approach on Principal Components was used on the data from the principal component analysis. This classification, carried out with sixteen agromorphological variables, resulted in three main groups (figure 3).

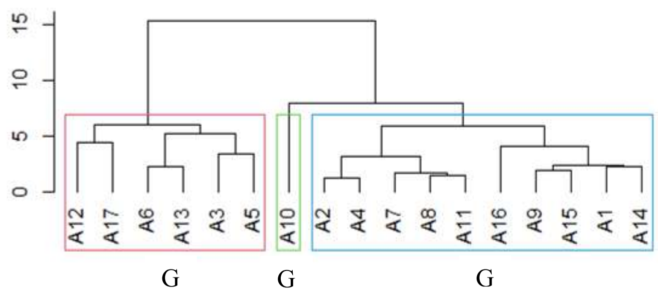

Figure 3: Dendrogram based on agromorphological characteristics classifying the 17 sesame accessions into three distinct groups G1, G2, and G3

An analysis of variance carried out on the different groups resulting from the hierarchical classification on principal components made it possible to highlight the main distinctive characteristics (Table IV). Group 1, which is composed of six sesame accessions (A12, A17, A6, A13, A3, and A5), is characterized by the shortest durations for 50% flower bud appearance (36.16 days), 50% flowering (42.5 days), 50% capsule formation (50.16 days), and the maturity date (85.16 days). These accessions also have the smallest heights (160.73 cm), fewer branches (7.48 branches), and the lowest first capsule insertion heights (76.02 cm), however, with the highest values for yield components (capsule length and width, number of seeds per locule and per capsule, and thousand-grain weight). They have shorter cycle durations (85 days). Group 2 was composed solely of accession A10. This accession contains intermediate values for the durations until 50% flower buds, 50% capsules, and the maturity date (93 JAS). It had plants with a large number of branches (33.79 branches), higher heights of the first capsule insertion (106.20 cm), greater capsule production (190.63 capsules), and the highest values of grain dry weight (323.15 g) and yield (7181.18 kg/ha). The other yield components had the lowest values. This accession had an intermediate cycle duration (93 days).

Group 3 was made up of ten sesame accessions (A1, A2, A4, A7, A8, A9, A11, A14, A15, and A16). This group is represented by the latest accessions (101 days) in terms of earliness. These are the dates for 50% floral buds (61.03 days), 50% flowering (65.33 days), 50% capsules (75.36 days), and maturity (101 days).

At this stage, plant height (197.17 cm), number of branches (27.34), and height of insertion of the first capsule (122.74 cm) showed the highest values compared to those of Group 1. Regarding yield components and yield, the accessions in this group had the lowest values.

2.3.3. Structuring of diversity by discriminant factor analysis

The three groups formed by hierarchical classification on principal components were subjected to a discriminant analysis aimed at identifying the variables that best discriminate between the determined groups. The three groups resulting from the hierarchical classification on principal components were used as categorical variables. The test for equality of group means shows that 14 of the 16 variables tested allow perfect discrimination of the groups (Table V). Moreover, regarding the validity of the study, Box's test is significant (Box's M = 979.494; F = 1.788; p = 0.000). This indicates that the variance-covariance matrices of the variables are equal for the 3 groups. In addition, the confusion matrix for the cross-validation results showed that 72.22% of the cross-validated observations are correctly classified (Table VI).

Table IV: Main characteristics of the different groups obtained from the hierarchical classification on principal components

Variables	Group 1 (6 accessions)	Group 2 (1 accessions)	Group 3 (10 accessions)	Pr > F	significant
BF50% (jas)	36.16 c	53 b	**61.03 a**	0.000	Yes
FLO50% (jas)	42.5 b	**59 a**	**65.33 a**	0.000	Yes
CAP50% (jas)	50.16 c	63 b	**75.36 a**	0.000	Yes
MAT (jas)	85.16 c	93 b	**101 a**	0.000	Yes
HP (cm)	160.73 b	186.54 ab	**197.17 a**	0.001	Yes
DC (mm)	16.81 a	16.39 a	18.16 a	NS	No
NRP	7.48 b	**33.79 a**	**27.34 a**	0.000	Yes
HIPC (cm)	76.02 b	**106.20 a**	**122.74 a**	0.000	Yes
NCP	111.27 b	**190.63 a**	112.23 b	0.01	Yes
LongC (cm)	**2.60 a**	2.38 b	2.37 b	0.000	Yes
LargC (cm)	**0.52 a**	0.48 b	0.50 b	0.01	Yes
NGL	**16.30 a**	15.47 ab	15.33 b	0.001	Yes
NGC	**65.20 a**	61.91 ab	61.35 b	0.001	Yes
P1000G (g)	**2.99 a**	2.52 b	2.76 b	0.01	Yes
PSG (g)	184.54 b	**323.15 a**	168.59 b	0.001	Yes
RDT (kg/ha)	1366.99 b	**2393.73 a**	1248.88 b	0.001	Yes

The values in bold are significant at the 5% level
BF50%: 50% flower buds, FLO50%: 50% flowering, CAP50%: 50% capsule, MAT: maturity, HP: plant height, DC: collar diameter, NRP: number of branches per plant, HIPC: height of first capsule insertion, NCP: number of capsules per plant, LongC: capsule length, LargC: capsule width, NGL: number of grains per compartment, NGC: number of grains per capsule, P1000G: weight of a thousand grains, PSG: dry grain weight, RDT: yield

Table V: Test of equality of group means

Variable	Lambda de Wilks	F	DF1	DF2	p-value
BF50%	0.065	108.65	2	15	< 0,0001
FLO50%	0.108	61.67	2	15	< 0,0001
CAP50%	0.131	49.80	2	15	< 0,0001
MAT	0.116	56.94	2	15	< 0,0001
HP	0.433	9.84	2	15	0,002
DC	0.902	0.81	2	15	0,463
NRP	0.069	101.03	2	15	< 0,0001
HIPC	0.182	33.70	2	15	< 0,0001
NCP	0.425	10.14	2	15	0,002
LongC	0.313	16.48	2	15	0,000
LargC	0.537	6.47	2	15	0,009
NGC	0.454	9.04	2	15	0,003
P1000G	0.480	8.12	2	15	0,004
RDT	0.244	23.27	2	15	< 0,0001

BF50%: 50% flower buds, FLO50%: 50% flowering, CAP50%: 50% capsule, MAT: maturity, HP: plant height, DC: collar diameter, NRP: number of branches per plant, HIPC: height of first capsule insertion, NCP: number of capsules per plant, LongC: capsule length, LargC: capsule width, NGL: number of grains per compartment, NGC: number of grains per capsule, P1000G: weight of a thousand grains, PSG: dry grain weight, RDT: yield, ddl: degree of freedom.

Table VI: Confusion matrix for the cross-validation results

	Group 1	Group 2	Group 3	Total	% correct
Group 1	6	0	0	6	100.00%
Group 2	0	1	0	1	100.00%
Group 3	5	0	5	10	50.00%
Total	11	1	5	17	72.22%

The first function (axis 1) strongly discriminates the dates of appearance of 50% floral buds, 50% flowering, 50% capsule, the maturity date, plant height, number of branches per plant, and the height of insertion of the first capsule. This axis records the highest magnitude (194.974) and accounts for 85.408% of the total variability. This first function allows classifying group 1 as a group representing early accessions, less branched, with a small height of insertion of the first capsule. This group contrasts with group 3, which includes late accessions, more branched, and a greater height of insertion of the first capsule. The second discriminant function (axis 2) with a magnitude of 33.311 accounts for 14.592% of the total variability. This function allows group 2 to be classified as a group representing accessions that produced the most capsules per plant with better yield. The variables capsule width and thousand-grain weight and capsule length and number of grains per locule contributed negatively, respectively, to the formation of axes 1 and 2 (Table VII).

Figure 4 shows, in the discriminant factorial plane, the three groups formed by canonical axes 1 and 2 of the discriminant analysis. The different groups 1 and 2 contain the same number of accessions as those defined by hierarchical classification on principal components. Group 3 contains five accessions instead of ten as defined by hierarchical classification on principal components.

Table VII: Percentage of inertia and definition of axes in canonical discriminant analysis

	Axis 1	Axis 2
Eigenvalue	194.974	33.311
Discrimination percentage	85.408	14.592
Cumulative discrimination percentage	85.408	100.000
50% Flower Buds	**0.941**	0.238
50% Flowering	**0.911**	0.261
50% Capsule	**0.927**	0.122
Maturity	**0.936**	0.114
Plant height	**0.729**	0.201
Collar diameter	**0.293**	-0.112
Number of branches per plant	**0.765**	0.599
Height of first capsule insertion	**0.884**	0.204
Number of capsules per plant	-0.145	**0.755**
Capsule length	-0.749	**-0.364**
Capsule width	**-0.463**	-0.507
Number of seeds/locules	-0.692	**-0.269**
Thousand seed weight	**-0.414**	-0.600
Yield	-0.310	**0.825**

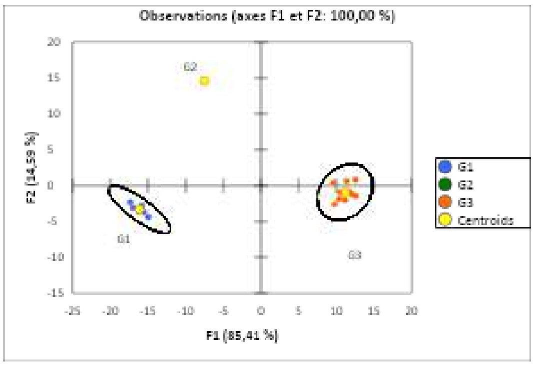

Figure 4: Representation of the different groups in the discriminant factorial plane formed by canonical axes 1 and 2

Discussion

The agromorphological characterization of the collected sesame accessions made it possible to assess the existing diversity in this material. The descriptive analysis allowed for the evaluation of the agromorphological and phenological diversity observed among these accessions. Indeed, the significant gaps recorded between the minimum and maximum values revealed by this analysis reflect a considerable variability within the collection. This variability could be explained by the fact that all these accessions were collected from different locations and therefore may originate from parents with distant genetic backgrounds. This could have caused significant differences at the morphological level. It could also be explained by environmental factors since the expression of a given trait may result from the interaction between genetic factors and those of the plant's living environment. Certain ecological conditions could also lead to a flow of seeds between populations of diverse geographical origins. Although sesame has been described as a self-pollinating plant, a recent indication raises the possibility of natural crossing within it [12].

Following this evaluation, the multivariate analyses (PCA and HAC) allowed them to be structured into three groups. The results related to the different phenological stages showed that there is a difference between the plants. Indeed, the accessions of the third group recorded a long cycle (101 days) compared to those of the second group (93 days) and the first group, which were early (85 days). These durations corroborate those found by [11] on sesame in Niger.

The total rainfall recorded was 817 mm. This amount of recorded rainfall is higher than the overall average (525 mm). The crop cycle took place under good humidity conditions. The results related to the growth parameters of the different studied sesame accessions showed that the best morphological values were obtained by the accessions of the third group. These results could be attributed to their cycle duration (long) and the sufficient amount of water obtained during the growth cycle. However, the overall average plant height (183.689 cm) remains higher than the average plant height (139.75 cm) of the Nigerien collection [11] and that obtained by [9] in Côte d'Ivoire at Korhogo (160 and 169.42 cm). This situation could be explained by their diverse origins. Indeed, according to [11], sesame exhibits indeterminate growth, which leads to asynchronous maturity and a very tall plant height. However, reducing plant height improves lodging resistance. But a shorter plant height seems to be a disadvantage in terms of seed yield, as taller plants tend to carry more capsules and therefore produce more seeds [11].

Regarding the height of insertion of the first capsule, it varied on average from 76.02 cm to 122.74 cm. It was higher in long-cycle accessions than in short-cycle ones. According to [11], a low height of insertion of the first capsule is a sought-after trait as it can contribute to increasing the number of capsules per plant, which in turn contributes to the formation of sesame seed yield.

In this study, the average number of branches varied from 7 for short-cycle accessions to 33 for long-cycle ones. Indeed, the number of branches is one of the important selection criteria in sesame breeding programs, as a higher number of branches allows for more capsules per plant and results in better seed yield [13]. This was the case during our experimentation. The number of capsules per plant, the components of yield, the dry weight of the grains, and the grain yield at harvest were sources of variability among sesame accessions.

The accession of the second group was more productive than that of the other two groups in terms of the number of capsules per plant, dry weight of the grains, and grain yield. This difference may be due to agro-climatic conditions (precipitation) and the cultivation techniques in our study area. Indeed, water is an essential element for the survival of plants on the surface of the earth. Its insufficiency negatively affects plant growth depending on the stage of development.

Sesame is no exception to this rule, despite the fact that it is drought-resistant, due to its highly developed root system. Thus, certain rainfall thresholds are necessary to achieve good growth and better yield. According to [14], an average annual rainfall of 441 to 800 mm is sufficient for sesame during the vegetative cycle to have a good production. However, our results demonstrated the opposite in the sense that the accessions of group 1 and group 3, which meet the conditions of 441-800 mm of rainfall during the vegetative phase, were the least productive. However, the number of capsules per plant would better explain the yields of the different groups. Capsule production is one of the most important traits defining the ideal type of sesame [13]. It was also identified by [15] as the most contributive characteristic influencing grain yield. Thus, the accessions of group 2, having recorded the highest number of capsules per plant, were the most productive.

Discriminant factor analysis (DFA) showed that earliness, plant height, collar diameter, number of branches per plant, height of insertion of the first capsule, number of capsules per plant, length and width of capsules, number of seeds per locule, thousand-seed weight, and yield are the main traits that allow discrimination of these three groups. These traits, therefore prove to be the most useful for studying the variability of accessions. [17] suggested that using traits such as plant height, number of seeds per capsule, and seed yield could save considerable time in identifying sesame genetic material for downstream breeding work. The phenology and morphology of the different sesame accessions are the most variable traits within the accessions, as evidenced by the number of parameters these traits encompass. The same is not true for seed yield. Indeed, phenological and morphological traits could be explained by environmental and climatic factors that are not completely fixed. Similar observations were reported by [18]. According to him, the expression of a given trait can be the result of the interaction between genetic factors and those of the plant's living environment. On the other hand, the expression of yield traits would be due to the availability of nutrients in the soil for the benefit of each variety. Similar observations were reported by [19].

Conclusion

This study made it possible to characterize the agro-morphological parameters of sesame accessions collected in Côte d'Ivoire in the Ouangolodougou agro-climatic zone. The agromorphological diversity of sesame clearly shows that the analyzed accessions exhibit variation for all the characters used, particularly those related to phenology, plant architecture, yield components, and yield. Based on these different variables, three morphological groups were formed. A group of early accessions with the best yield component values, a group of productive accessions with an intermediate earliness cycle, and a group of late and less productive accessions, but with the best morphological values. Earliness, plant height, stem diameter at the base, number of branches per plant, height of insertion of the first capsule, number of capsules per plant, length and width of capsules, number of seeds per pod, thousand-seed weight, and yield are the main traits that allow the discrimination of these three groups. The different groups thus formed offer the possibility of choosing parents for the creation of sesame varieties with high yield potential and adapted to the agro-ecological conditions of Côte d'Ivoire.

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Authors' contributions

SIENE Laopé Ambroise Casimir contributed to the drafting of the experimental protocol, the setup of the experimental design, data analysis, interpretation of results, and drafting of the manuscript. BONNY Beket Séverin contributed to the setup of the experimental design, data analysis, and proofreading of the manuscript. KOUAME Aya Kan Marie Louise, KONE Issa Zaki, and NGUETTIA Tah Valentin Félix contributed to the setup of the experimental design and data collection.

Conflict of Interest

The authors have declared no conflicts of interest.

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