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Improvement indices and agromorphological diversity of false sesame (*Ceratotheca sesamoides* Endl.) in Burkina Faso

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ABSTRACT: The objective of this work was to evaluate the improvement indices and the agro-morphological diversity of *Ceratotheca sesamoides* accessions from the Sudan-Sahelian and Sudanian climatic zones of Burkina Faso. For this purpose, a randomized Fisher block design with three replications was set up. Univariate analysis was used to evaluate the level of diversity and the varietal improvement indices. The evaluation of the links between the traits was done by Person's correlation test. The structuring of the diversity was done by multivariate analyses. The results of this experiment reveal the existence of a high agro-morphological diversity on several traits. This diversity made it possible to divide the accessions collected into four groups. Of these, group I is made up of the best performing accessions. The best performing traits were dry and fresh leaf biomass, plant height and number of primary branches. The genetic parameters recorded that Group I accessions are best suited in a breeding and development program for the creation of varieties that meet the needs of producers. The study assessed the level of diversity, diversity structuring and improvement indices.

KEYWORDS: Accessions, Fisher blocks, improvement indices, agro-morphological diversity and genetic parameters.

1 INTRODUCTION

Agriculture plays a very important socio-economic role for the population in Burkina Faso [11]. It covers more exotic species that have a surplus yield profile. This obvious potential of exotic species is due to the modernization and mechanization of agriculture [3]. However, exotic species are nowadays difficult to adapt because of climate change [17]. This difficulty in adapting exotic species to climate change would reduce their productivity [3]. Thus, production could be compensated by using traditional local species known as neglected species [7]. Indeed, the food resilience of local populations would necessarily depend on the mastery of neglected local plant genetic resources [7]. Among them is the false sesame, which contains important nutritional and therapeutic properties. False sesame has a high iron content in the leaves [18]. Therefore, consumption of its leaves contributes to the normal functioning of the central nervous system and the oxidation of carbohydrates, proteins and fats [19]. *Ceratotheca sesamoides* leaves also contain high levels of phosphorus and calcium [4]. In addition, it is used in the treatment of cancer and cardiovascular diseases due to the high concentration of flavonoids in its aerial organs [15]. Despite the high nutritional and therapeutic potential of false sesame, it remains a marginalized species in the plant production system in Burkina Faso. This justifies the present study, which aims to understand the agromorphological diversity of false sesame for a better valorization of this plant species in Burkina Faso.

2 MATERIALS AND METHODS

2.1 STUDY SITE

The study was carried out at the experimental station of the Institut of Rural Development (IDR) of Gampèla, located about 20 km from Ouagadougou (Burkina Faso). The site is located in the North Sudanese phytogeographic domain. It is geographically identified by the coordinates 1°21'96" West longitude and 12°24'29" North latitude.

2.2 Vegetable Material

The plant material consists of 49 accessions (Table I). These accessions were collected in the Sudan-Sahelian zone and the Sudanian zone.

Table 1. Distribution of accessions by provinces

Climate zone	province	number of accessions
sudano-sahelian zone	Nayala	3
	boulkiemdé	6
	Mouhoun	3
	Sanguié	5
	Balé	5
	Ziro	3
Sudanian zone	Tuy	5
	Houet	4
	Bougouriba	5
	Poni	6

2.3 Methods

2.3.1 Experimental Design And Cultivation Practices

The experimental design adopted was the Fisher design with three replicates. The distance between the replicates was 2 m. Within a block, each accession is represented by a line (elementary plot) of 3.2 m on which six (06) seedlings were sown at a rate of 6 seeds per seedling. The row spacing and the spacing between successive pits were respectively 0.8 m and 1 m. After the experimental set-up, sowing was carried out on 13 July 2020 at a rate of six (06) seeds per plot. Two weeks after sowing, a weeding with one seedling per stake was carried out in the plot, followed by a weeding. Further weeding took place 25 and 42 days after sowing respectively in order to reduce weed competition with the plants and also to better aerate the soil. After the first weeding, it was followed by an application of NPK fertiliser (12-30-17) at a rate of 25 kg/ha.

2.3.2 Data Collection

A total of 16 quantitative characteristics were collected. These are:

number of days to 50% flowering (NJF), number of days to emergence (NJL), plant height (HPL), stem diameter (DTI), number of primary branches (NRP), leaf blade length (LOL), leaf blade width (LAL), petiole length (LOP), fresh leaf biomass (FMB), dry leaf biomass (DLB), number of sepals (NSE), number of petals (NPE), number of stamens (NET), length of fruit (LGca), width of fruit (LRca) and height of insertion of the first capsule (HIPC).

2.4 Data Analysis

These collected quantitative data were analysed with the Xlstat 2016 software. An analysis of variance (ANOVA) was performed to assess the differences between the studied accessions in the sense of perceiving their level of variability. Genotypic and phenotypic variances (VG and VP), genotypic and phenotypic coefficients of variation (GCV and PCV), broad heritability (H^2) and expected genetic gain (GA) were calculated from the ANOVA results. Multivariate analysis (PCA and HAC) was used to assess and structure the diversity of all accessions. The hierarchical ascending classification (HAC) was established on the basis of the Euclidean distance according to the aggregation criterion of [20]. Discriminant factor analysis (DFA) was carried out using the groups obtained in the hierarchical ascending classification as categorical variables. The DFA was used to characterize the groups obtained from the HAC.

Table 2. Average performance of the studied accessions for quantitative traits

Variables	Minimal	Maximal	Average	CV (%)	R^2 (%)	F	Pr > F
NJL	6,00	13,00	8,97	12	28,43	6,75**	< 0,001
NJF	42,00	61,00	51,57	5,08	61,03	26,56**	< 0,001
HPL	28,00	126,67	82,96	20,44	19,87	4,21**	0,001
DTI	0,40	5,00	2,04	37,65	13,92	2,75**	< 0,001
NRP	1,00	46,00	23,00	30,47	10,96	2,09**	< 0,001
LOL	1,167	5,83	3,21	21,29	18,84	3,94	< 0,001
LAL	0,76	4,10	1,94	26,52	16,25	3,29	< 0,001
LOP	0,23	3,16	1,09	35,26	13,20	2,58	< 0,001
BMS	0,80	55,60	12,62	46,00	30,34	7,40	< 0,001
BMF	2,00	155,90	41,20	46,66	23,14	5,11	< 0,001
LGCa	0,50	2,40	1,29	14,69	13,66	2,69	< 0,001
LRCa	0,30	0,7	0,43	18,44	13,71	2,70	< 0,001
HIPC	6,00	25,00	12,59	19,78	23,10	5,10	< 0,001

Legend: NJL: number of days to emergence; NJF: number of days to flowering; HPL: plant height; DTI: stem diameter; NRP: number of primary branches; LOL: leaf blade length; LAL: leaf width; LOP: petiole length; BMS: dry leaf biomass; BMF: fresh leaf biomass; LGCA: boll length; LRCA: boll width; HIPC: height of first boll insertion; CV: coefficient of variation; R^2: coefficient of determination

3 RESULTS

3.1 LEVEL OF TRAIT DIVERSITY

The analysis of variance showed that all the variables studied discriminate very significantly between accessions at the 1% level (Table II). This difference within traits was revealed by p-value values strictly lower than 0.001. Similarly, the Fisher's F for each parameter showed values strictly greater than 2.

The results of the analysis also show significant differences in the coefficient of variation (CV). The coefficient of variation ranged from 5.08% for the number of days to 50% flowering to 46.66% for the fresh leaf biomass.

The coefficient of determination (R^2) varied from 10.96% for the number of primary branches to 61.03% for the number of days to flowering. The measured traits all had a coefficient of determination below 30% except for dry leaf biomass and days to flowering which had a coefficient of determination of 30.34% and 61.03% respectively.

Table 3. Correlations between quantitative characters of Ceratotheca sesamoides from Burkina Faso

Variables	NJL	HPL	DTI	NRP	LOL	LAL	BMS	BMF	LGCa	HIPC	NJF 50%
NJL	**1**										
HPL	0,115	**1**									
DTI	-0,147	**0,474***	**1**								
NRP	0,176	**0,701****	**0,409***	**1**							
LOL	-0,230	0,017	**0,433***	0,149	**1**						
LAL	0,002	0,128	**0,440***	**0,346***	**0,654***	**1**					
BMS	**-0,331***	-0,016	0,039	-0,112	0,201	0,213	**1**				
BMF	**-0,411***	-0,032	-0,010	-0,110	0,227	0,173	**0,929****	**1**			
LGca	0,030	0,087	0,046	0,007	**-0,461***	**-0,313***	-0,027	-0,039	**1**		
HIPC	-0,069	0,060	**0,326***	0,128	**0,509***	**0,450***	0,262	0,253	-0,162	**1**	
NJF 50%	**0,361***	0,192	0,164	0,234	0,100	0,250	0,000	-0,072	-0,053	0,068	**1**

**NJL: Number of days to emergence, NJF: Number of days to 50% flowering, HPL: Plant height, DTI: Stem diameter, NRP: Number of primary branches, LAL: Leaf blade width, LOL: Leaf blade length, LGCa: Capsule length, BMS: Dry leaf biomass, BMF: Fresh leaf biomass, HIPC: Height of insertion of the first capsule*

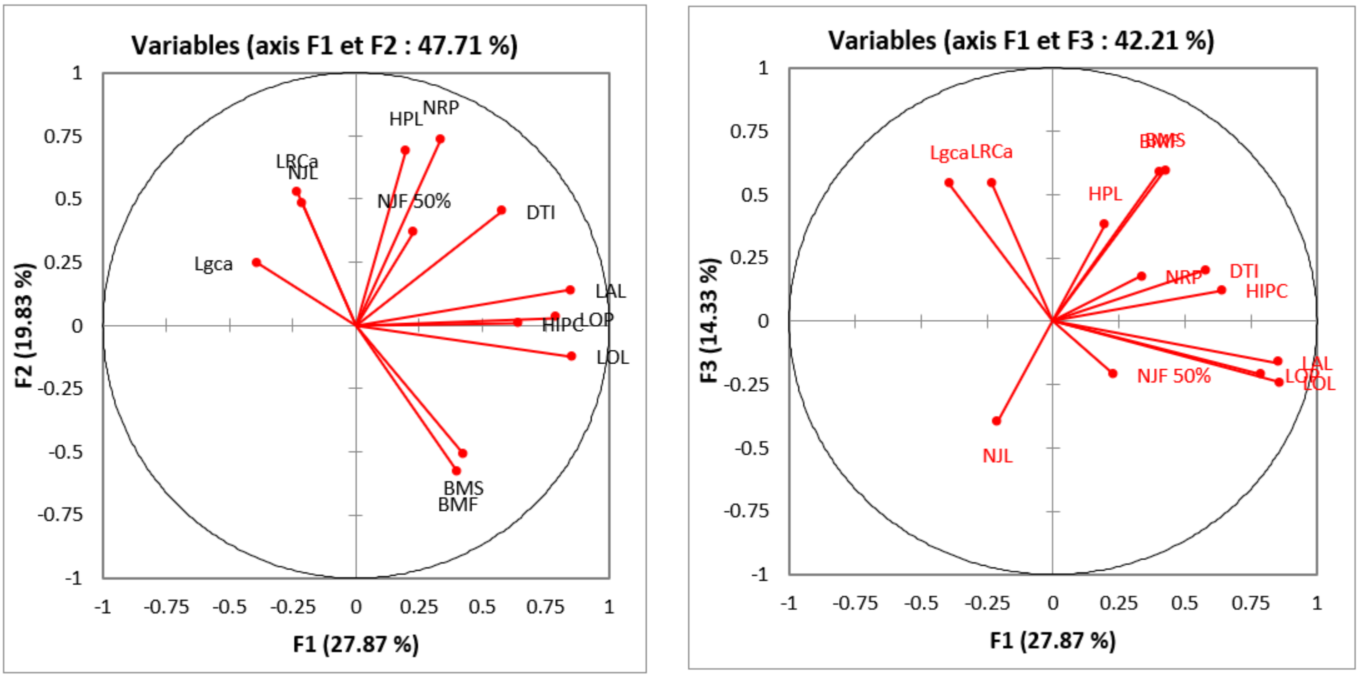
3.2 Relationships Between The Studied Traits

The Pearson correlation matrix in Table III showed significant correlations at the 1% level. Among these correlations studied, there are positive and negative correlations. Indeed, fresh leaf biomass is correlated with dry leaf biomass (r =0.93). Blade length is correlated with petiole length (r = 0.68), blade width (r = 0.65), stem diameter (r = 0.43) and height of the first capsule insertion (r = 0.51). Blade width was correlated with petiole length (r = 0.78), height of first capsule insertion (r = 0.45) and stem diameter (r = 0.44).

Negative correlations were also observed. Dry leaf biomass was correlated with the number of days to emergence (r = -0.33). Leaf width is correlated with capsule length (r = -0.31). Leaf length is correlated with capsule length (r = -0.46).

3.3 Association Between Traits

The graphical representation (Projection of variables in the ½ plane) of the variables that formed axis 2 shows the existence of two opposite groups of variables (Figure 1 A). Indeed, the first group of variables negatively correlated to axis two (2) is constituted by dry leaf biomass (r = -0.51) and fresh leaf biomass (r = -0.58). On the other hand, the second group of variables positively correlated to axis 2 is plant height (r = 0.74) and the number of primary branches (r = 0.70). Finally, concerning the graphical representation (Projection of the variables in the 1/3 plane), axis three 3 positively associates traits such as dry leaf biomass (r = 0.60), fresh leaf biomass (r = 0.59), capsule length (r = 0.54) and capsule width (r = 0.55) (Figure 1 B).



A: Projection des variables dans le plan ½ B: Projection of variables in the 1/3 plane

Fig. 1. Projection of the measured variables in the plane formed by the first three axes of the principal component analysis (PCA)

3.4 Structure Of Agro-Morphological Diversity

The dendrogram resulting from the hierarchical ascending classification (HAC) made it possible to subdivide all the accessions into four (4) groups (Figure 2). Group I includes 20 accessions from two climatic zones of Burkina Faso (the Sudanian zone and the Sudan-Sahelian zone). Group II is the group with the lowest number of accessions. These accessions also come from the Sudanian zone and the Sudan-Sahelian zone. Group III contains five accessions from both climatic zones. Group IV covers 11 accessions, the majority of which are from the Sudanian zone. The Ward Euclidean distance matrix between the barycentres and the calculation of the interclass inertia revealed that groups II and IV are the most distant with a distance value of 37.28, followed by group II and I with a distance value of 28 and group I and III which are distant by 21.96. Group I and IV are the closest with a distance value of 15.45 followed by group III and IV which are distant by 18.78 (Table IV).

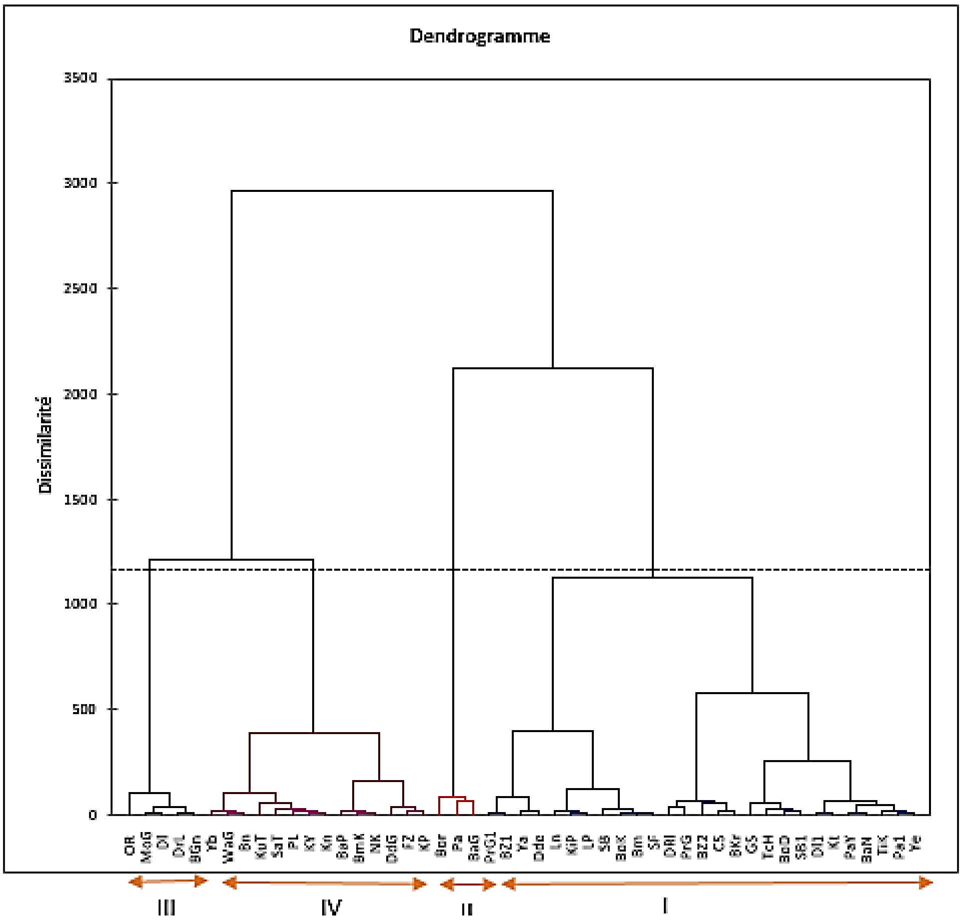


Fig. 2. Hierarchical ascending classification of the 49 accessions of Ceratotheca sesamoides

Table 4. Distances between class barycentres

	Group I	Group II	Group III	Group IV
Group I	0			
Group II	28	0		
Group III	21,96	25,09	0	
Group IV	15,45	37,28	18,78	0

3.5 Characterisation Of Accessions

Discriminant factor analysis (DFA) was used to characterise the four obtained from the AHC. The grouping criteria were plant height, number of primary branches, dry leaf biomass and fresh leaf biomass. Indeed, the analysis of variance of these groups showed the highest Fisher's F and coefficient of determination (R^2) for plant height (< 0.0001; R^2 = 64.2), number of primary branches (< 0.001; R^2 = 30.2), dry leaf biomass (< 0.0001; R^2 = 52.5) and fresh leaf biomass (< 0.0001; R^2 = 65.2). In addition, the relationship between groups and axes showed that axis 1 is positively correlated with group I and group II. It is negatively correlated with group IV. Axis 2 is negatively correlated with group III (Figure 3).

Group I is characterised by large accessions (88.78 cm) and a high number of primary branches (24.87). Group I associates accessions with purple stems. Group II gathers accessions with average agronomic performance for stem height and number of primary branches. This group combines accessions with green and purple stems. Group III is made up of the accessions with the lowest agronomic performance in number of primary branches and plant height. However, it includes accessions that have a higher agronomic performance in dry and fresh leaf biomass than those in group IV. It is made up of accessions with purple stems. Group IV groups accessions with average height and number of primary branches behind group I and group II. However, this performance is superior to those of group III. Group IV combines accessions with green, purple and violet stems.

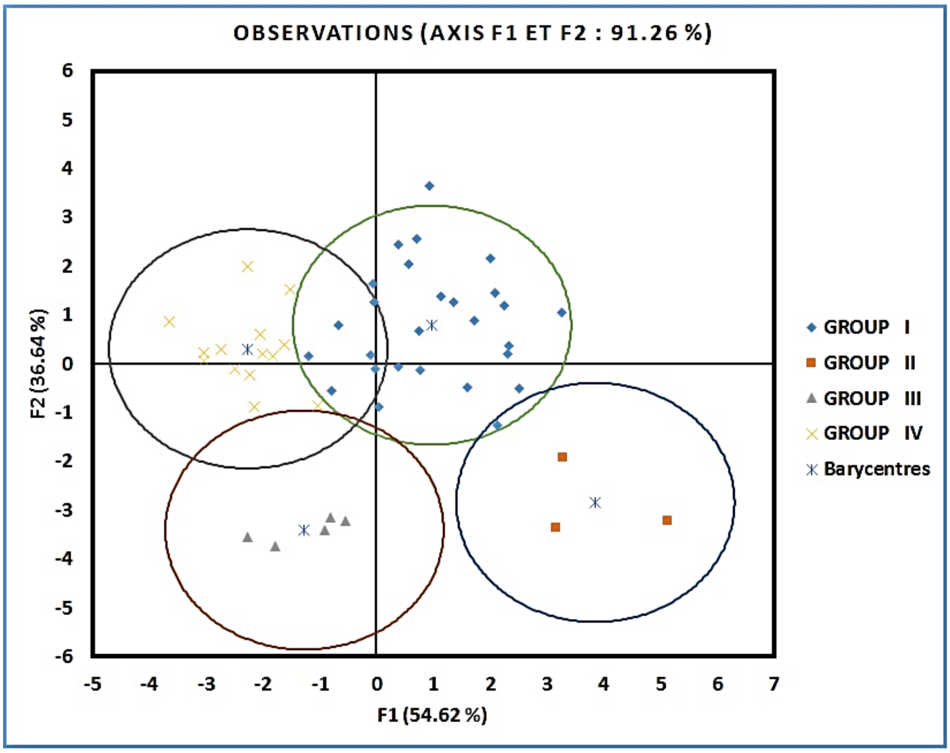


Fig. 3. Representation in the ½ plane of the DFA of the groups of accessions from the HAC

3.6 Estimation Of Genetic Parameters

From these results, genotypic values ranged from 0.01 for capsule width to 504.63 for fresh leaf biomass. In this study, heritability was greater than 50% for all thirteen (13) variables with H2 values ranging from 55.32% to 96.33%. The study showed phenotypic variances greater than genotypic variances. The expected genetic advance over the trait mean (GAx) ranged from 17.55% to 129.26% for boll length and dry leaf biomass respectively (Table V).

Table 5. Estimation of genetic parameters of Ceratotheca sesamoides from Burkina Faso

Variables	VG	VP	H2 (%)	GCV (%)	PCV (%)	GA	GAx (%))
NJL	2.30	2.68	85.82	16.89	18.23	2.89	32.23
HPL	373.11	465.37	80.18	23.29	26.01	35.63	42.96
DTI	0.35	0.55	64.10	29.03	36.26	0.98	47.88
NRP	21.14	38.21	55.32	19.46	26.16	7.04	29.81
LOL	0.46	0.62	74.64	21.08	24.39	1.21	37.51
LAL	0.21	0.29	69.94	23.31	27.87	0.78	40.15
LOP	0.08	0.13	61.14	25.51	32.62	0.45	41.08
BMS	72.33	83.54	86.58	67.43	72.47	16.30	129.26
BMF	504.63	627.91	80.37	54.56	60.86	41.48	100.76
LGCa	0.02	0.03	61.95	10.82	13.75	0.23	17.55
LRCa	0.01	0.01	64.82	14.40	17.89	0.10	23.89
HIPC	8.68	10.74	80.85	23.41	26.03	5.46	43.36
NJF 50%	58.91	61.16	96.33	14.88	15.16	15.52	30.09

NJL: Number of days to emergence, NJF: Number of days to 50% flowering, HPL: Plant height, DTI: Stem diameter, NRP: Number of primary branches, LAL: Leaf blade width, LOL: Leaf blade length, LOP: Petiole length, LGCa: Boll length, BMS: Dry leaf biomass, BMF: Fresh leaf biomass, LRCa: Capsule width, HIPC: Height of first capsule insertion, VG: Genotypic variance, VP: Phenotypic variance, H^2: Heritability in the broad sense, GCV: Coefficient of genotypic variation, PCV: Coefficient of phenotypic variation, GA: Expected genetic gain, GAx: Expected genetic gain compared to the mean.

4 DISCUSSION

The quantitative data showed the existence of characters that discriminate the 49 accessions. This reflects the existence of a high agro-morphological variability of Ceratotheca sesamoides from Burkina Faso. The analysis of variance applied to the characters, except for floral parts, showed significant differences for all variables ($P < 0.001$). This also indicates the existence of variability within the accessions evaluated. By the same analysis (ANOVA), the plant height obtained was different from that obtained by [4] in Benin on accessions of *Ceratotheca sesamoides*. This difference in plant height could be explained either by the difference in edaphic factors or by the difference in ultraviolet radiation received by each experimental site. Indeed, similar results were reported by [16] where plant height reached about 120 cm. The accessions showed relatively shorter and less broad leaves than those observed by [14]. This difference in leaf size could therefore be explained either by the difference in the amount of water received at each of the sites or by the difference in temperatures at each site as water scarcity and high heat would lead the plants to reduce their leaf area. Most of the variability is explained by plant height, number of primary branches, dry leaf biomass and fresh leaf biomass which have very high coefficients of determination ($R^2 \geq 52\%$). For leaf biomass, Person's correlation test revealed a significantly positive correlation ($r = 0.92$) between fresh and dry leaf biomass. These results are similar to those obtained by [4] on false sesame from Benin.

The high coefficients of variation of the characters would reflect the existence of a large agro-morphological variability within the accessions. These results are similar to those obtained by [1] *on Sesamum radiatum* and by [5] on *Sesamum indicum*.

The multivariate analyses distributed the accessions according to an affinity linked to their similarities. Indeed, the variability of the characters followed by the characterization of the accessions into four (4) groups show the presence of non-fixed individuals within the collection of false sesame. This heterogeneity of individuals shows the existence of variability between the sub-populations of the Sudan-Sahelian zone and the Sudanian zone.

For all the traits studied, the phenotypic coefficients of variation (PVC) were higher than the genotypic coefficients of variation (GVC). However, the differences between the VSCs and GVCs were small for all the traits studied. Indeed, these small differences between these two parameters indicate that the variability of *Ceratotheca sesamoides* traits is very little influenced by the environment [12]. Thus, the expression of traits in false sesame are influenced by genetic control. Similar results were obtained on leafy vegetables such as amaranth [6], white caya [8], African aubergine [13] and fetid cassia [9].

Plant height, stem diameter, leaf blade length, leaf blade width, petiole length, fresh leaf biomass, dry leaf biomass and height from insertion to first boll with high phenotypic and genotypic coefficients of variation would reflect the possibility that these traits are heritable [14]. However, coefficients of variation alone cannot better explain trait inheritance accurately as they do not estimate the proportion of the trait that will be transmitted to the progeny [8]. Indeed, plant height, height of first capsule insertion, dry leaf biomass and fresh leaf biomass that showed the highest heritability values ($H^2 > 80\%$) are heritable. The high values of these traits would show firstly that the contribution of genotypes to the expression of the traits is important and secondly that environmental factors have a small effect on the expression of the variables [8]. However, the value of heritability alone does not give any indication of the amount of genetic progress that would result from the selection of the best accessions [2]. Thus, the highest broad heritability and genetic progress results obtained showed that plant height, leaf blade width, height of first capsule insertion, dry leaf biomass and fresh leaf biomass are heritable. These high values would indicate that additive genetic effects are important in determining these traits [10]. In contrast, capsule length, capsule width, number of primary branches and number of days 50% flowering which showed low values of expected genetic progress would indicate that dominance/epistasis type gene effects are very important for these traits [2]. This information provided by genetic progress claims that CAH group I accessions would be better suited in a breeding program.

5 CONCLUSION

This work has allowed to highlight an important agro-morphological variability within the accessions of false sesame. As a result of this study, four (4) agro-morphological groups were obtained. Dry biomass, plant height, length and number of primary branches showed high heritability and genetic gain. These heritability and genetic gain values are indicators that pave the way for an improvement program.

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