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Characterization of Chadian sesame landraces through morphological traits

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Abstract

Sesame is one of the most important oilseed crops in the tropical and subtropical regions of the world. Despite the important role of sesame in Chad's agriculture and economy, information on its genetic diversity remains very limited. The objective of this study was to evaluate the genetic variability of 37 sesame landraces collected from the sudanian zone of Chad using 29 morphological traits. The experiment was laid out in alpha lattice design with three replications. A high level of genetic diversity was observed for qualitative traits except for plant growth type, branching and capsule dehiscence at ripping. A considerable level of polymorphism was also observed for all of the studied quantitative traits except for mean capsule width. This diversity allowed structuring the studied landraces into three statistically distinct groups of which group 3 clustering landraces with early maturing (100 DAS), low number of primary branches (3.667) and high seed yield per plant (20.425g). This study revealed a large agromorphological diversity of qualitative and quantitative traits of the sesame from the sudanian zone of Chad. Structuring of diversity clustered the cultivars into three groups, of which in group three were found landraces with interesting traits for sesame breading. Landraces in this group combined precocity and high productivity which are the main traits of breeding for the climate change adaptation. This group could be of highest interest for the sesame breeding program and will help to enhance selection and production of sesame in Chad.

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Introduction

Sesame (*Sesamum indicum* L.) is one of the oldest and most important oilseed crops in the tropical and subtropical area of the world. Is known to be the most ancient oilseed crop dating back to 3050-3500 B.C. (Bedigian, 2010). It is a major oilseed crop worldwide, with more than 96% of seed production accounted for Africa and Asia (FAO, 2021). It is believed to be domesticated in Africa, mainly in southern Africa where wild forms are still found (Weiss, 1971). Furthermore, most wild species of sesamum genus occur exclusively in Africa (Bedigian, 2003). Sesame is cultivated for its seeds which considered to have the highest oil content among major oilseed crops including peanut, soybean and rapeseed with 50 to 60% oil (Ashri, 1998). Sesame seeds are also rich in proteins 9 à 25 % (El Khier *et al.*, 2008; Sene *et al.*, 2017) and carbohydrates (13-14%) (Borchani *et al.*, 2010).

Sesame is an autogamous species, and populations often exist as a composite of various homozygous individuals. Therefore, genetic advance can easily be gained after selection for a few generations due to the combination of autogamy and heterogeneity (Furat & Uzun, 2010). Genetic improvement of sesame has the potential to overcome many production constraints. However, the success in genetic improvement of the crop depends on the availability of diverse genetic resources. Access to a wide range of genetic diversity is critical to the success of any crop breeding programs and the ability to identify genetic variation is indispensable for effective management and use of genetic resources (Varshney *et al.*, 2009), and it mainly depends on germplasm characterization (Ozcinar & Sogut, 2017).

In Chad, sesame has long been cultivated over a large area of the country's sahelian and sudanian zones (DSA, 2021). It provides substantial income to farmers and contributes to the country's GDP (FAO, 2021). However, the national average productivity remains low (483 kg/ha) (DSA, 2021) compared to the potential sesame production of 2 t/ha (Bedigian, 2003). This low productivity could be due to the almost exclusive use of local varieties and the absence of a national sesame breeding program. As a result of natural selection for many years, there are numerous landraces of sesame adapted to various ecological conditions of the country. Indeed, Chad exhibits a great deal of variation in sesame because heterogeneous landraces are grown in various growing areas for centuries. Despite the important role of sesame in Chad's agriculture and economy, information on its genetic diversity remains very limited. Thus, this study was undertaken to know agromorphological genetic diversity of sesame landraces of the sudanian zone of Tchad in order to select landraces with different agronomic performances and yield potential from these valuable resources.

Material and methods

Experimental site

The experiment was conducted at the regional station for the sudanian zone of the Chadian Institute of Agronomic Research for Development during the rainy season of 2022. The station is located in Bébédjia (9°55'N and 15°8'E), at the province of Logone Oriental. Annual average rainfall in the region is 1200 mm per annum. The experiment was conducted under field condition and the rainfall recorded during trial period was 804.3 mm. Minimum and maximum temperatures recorded during trial period ranged from 19,2 to 24,5 and from 32,4 to 37,7 respectively. The soil is sandy loam type consisting of total nitrogen (4,29%), carbon (0,20 %), potassium (322.8 mg/l) and organic matter (0.03%) with a pH of 7.20 (Tahir, 2013).

Plant Material

A total of 37 sesame landraces collected form five provinces of the sudanian zone of Chad were used in this study. The number of sesame landraces and their province of origin are listed in the Table 1.

Table 1. list of provinces of collection and number of sesame landraces used in this study.

Province of collection	Number of landraces
Logone Oriental	13
Moyen Chari	7
Mayo Kebbi Est	4
Mayo Kebbi Ouest	6
Tandjilé	7

Experimental design and trial management

The study was laid out in an alpha lattice design with three replications. Each plot was consisted of three rows of 3m length with a spacing of 50cm between rows and 20cm between plants. Seeds were sown manually on July 21 and three weeks after emergence, plants were thinned to maintain one plant per hole. Soil amendment consisted of application of 100 kg ha−1of NPK immediately after thinning and weeding. Weed control was done mainly using hand hoes. For pest management, three treatments were carried out, respectively on August 28, September 11 and October 20 corresponding to the periods of appearance of floral buttons and capsules, using a systemic insecticide (PACHA 25 EC with the Lamda-cyhalothrine 15g/l and Acetamipri10g/l as active principles).

Data collection

Fourteen quantitative traits and 15 qualitative traits were noted. The quantitative traits are related to plant height, primary branch, length of middle leaf, width of middle leaf, petiole length at middle (mid-level/mid-height) leaf, days to flower initiation, days to 50% flowering, number of capsules per plant, mean capsule length, mean capsule width, seeds per capsule, 1000-seed weight, days to physiological maturity and seed yield). It was also observed the plant growth type, stem hairiness, branching pattern, leaf color, leaf hairiness, petiole hairiness, number of flowers per leaf axil, extra-floral nectary development, extra-floral nectar color, corolla hairiness, exterior corolla color, number of carpels per capsule, capsule hairiness, capsule dehiscence at ripening and seed coat color) were recorded according to the sesame descriptors list of IPGRI (2004) and UPOV (2013).

All measurements were done after tagging five randomly selected plant in each plot. Average seed yield per plant (W) was estimated using the formula proposed by (Grafius, 1964):

$$W = X * Y * Z$$

With X, Y and Z are respectively the number of capsules per plant, seeds per capsule and the1000 seed weight.

Data analyses

Data from this study were subjected to descriptive statistics, analysis of variance (ANOVA), Pearson's correlation and multivariate analyses. Analysis of variance was performed to verify significance differences between landraces for all traits. The coefficient of variation allowed to assess the levels of variation observed between landraces for each variable trait. Pearson's coefficient of correlation was used to measure correlations between traits. Based on the correlation of the traits, the Principal Component Analysis (PCA) allowed a small number of uncorrelated linear combinations to be selected. These were used to build the dendrogram from the Ascending Hierarchical Classification (AHC). The classes formed by AHC were suggested to Discriminating Factor Analysis (DFA) which allowed groups to form by projecting both characters and individuals on a plane in order to assess the dispersion of cultivars and to better compare the variability between them. GenStat 12th edition, and XLSTAT-Pro 2016 softwares were used for these different analyses.

Results

Variation of qualitative traits

Morphological descriptors of qualitative traits and their frequency observed on the 37 sesame landraces are summarized in Table 2. Wide range of variation was observed for all qualitative traits, except plant growth type which was indeterminate for all the landraces. All landraces grown throughout the sudanian zone of Chad consisted of plants with branching stem, shattering capsule and indeterminate growth habit. Leaf color of the studied landraces was mostly green (59.46%) and dark green (24.324%). Great variation was observed for extra-floral nectary development and color. Most of the landraces developed either medium (40.541%), large (27.027%) or small (24.324) extra-floral nectary with yellow color (89.189%). There were large variations in stem, leaf, corolla and capsule hairiness among the assessed landraces. Most of the landraces had either sparse or no hairs on stem, leaf and capsule. Strong or profuse hair was observed only in a few landrace's capsules. Most of the landraces had one flower per axil

(83.784%) and bicarpellate capsules. However, some landraces (13.5%) had tetracarpellate capsule structure. All studied landraces had white flowers with purple shading (62.162) and deep purple shading (37.838). The sesame seeds cultivated in this area of Chad was mainly white and cream.

Table 2. frequency of qualitative traits recorded on 37 sesame landraces from Chad.

Character	Modality	Frequency %
Plant growth type	Indeterminate	100.000
Branching pattern	Basal branching	27.027
	Toward the stem	72.973
Stem hairiness	Glabrous	45.946
	Medium	2.703
	Weak or sparse	51.351
Leaf hairiness	Glabrous	64.865
	Weak or sparse	35.135
Leaf color	Dark green	24.324
	Green	59.460
	Light green	16.216
Extra-floral nectary development	Large	27.027
	Medium	40.541
	Rudimentary	8.108
	Small	24.324
Extra-floral nectar color	Light yellow	10.811
	Yellow	89.189
Petiole hairiness	Glabrous	16.216
	Medium	2.703
	Weak or sparse	81.081
Number of flowers per leaf axil	More than one	16.216
	One	83.784
corolla hairiness	Glabrous	5.405
	Medium	43.243
	Strong or profuse	8.108
	Weak or sparse	43.243
Exterior corolla color	White with deep purple shading	37.838
	White with purple shading	62.162
Number of carpels per capsule	Bicarpellate	86.486
	Tricarpellate	13.514
Capsule hairiness	Medium	32.432
	Strong or profuse	10.811
	Weak or sparse	56.757
Capsule dehiscence at ripening	Completely shattering	94.595
	Partially shattering	5.405
Seed coat color	Beige	8.108
	Cream	43.243
	White	48.649

Variation of quantitative traits

Agromorphological variability of landraces

A considerable level of polymorphism was observed among the assessed landraces for most of the quantitative traits (Table 3). These landraces differed significantly ($P< 0.05$) for all traits measured except for mean capsule width. Highly significant differences ($P< 0.01$) were observed for mean capsule length. Moreover, very highly significant differences ($P< 0.001$) were observed for the majority of assessed traits.

Thus, the mean values of these landraces for days to flower initiation, days to 50% flowering and days to maturity were 51.42, 57.84 and 114.9 days after sowing, respectively. The lowest values for these three traits were respectively 38, 44 and 100 days after sowing. While the highest values were 63, 68, and 125 days after sowing.

The average for plant height, primary branches, number of capsules per plant, number of seeds per capsule and 1000 seed weight among the landraces were 189.4, 8.6, 92.7, 76.9 and 1.72, respectively. Plant height varied between 113 and 256.6cm, primary branches ranged from 1.2 to 19.6, number of capsules per plant ranged from 33 to 208.4, number of seeds per capsule ranged from 35 to 110.8 and 1000-seed weight varied between 0.74 and 3.39g.

Table 3. Analysis of variance for 14 quantitative traits of 37 sesame landraces from Chad.

Character	Min	Max	Mean	CV%	F value
DFI	38	63	51.42	4.5	21.43^{***}
DF50	44	68	57.84	3.2	35.08^{***}
DPM	100	125	114.1	4.0	11.20^{***}
PBR	1.2	19.8	8.6	33.2	4.30^{***}
LML	7.3	23.7	17.8	11.0	1.67^{*}
WML	4.6	23.9	12.1	23.0	3.49^{***}
PML	3.5	14.6	10	16.9	3.70^{***}
PTH	113	256.6	189.4	9.5	6.75^{***}
NCP	33	208.4	92.7	30.7	1.75^{*}
MCL	2.6	4	3.4	7.2	2.25^{**}
MCW	0.6	1.1	0.97	6.5	1.20^{ns}
SPC	35	110.8	76.9	9.8	2.51^{***}
TSW	0.74	3.39	1.72	18.5	13.27^{***}
YLD	2.32	45.47	12.54	38.3	4.40^{***}

Days to flower initiation (DFI), days to 50% flowering (DF50), days to physiological maturity (DPM), primary branch (PBR), length of middle leaf (LML), width of middle leaf (WML), petiole length at middle leaf (PML), plant height (PHT), number of capsules per plant (NCP), mean capsule length (MCL), mean capsule width (MCW), seeds per capsule (SPC), 1000-seed weight (TSW), seed yield per plant (YLD).

Significance: $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; ns: not significant

The coefficient of variation (CV %) was globally low (CV< 30%) for the majority of assessed traits. However, high coefficient of variation (CV> 30%) was observed for primary branch, number of capsules per plant and average seed yield per plant.

Relations between morphoagronomic traits

Pearson's correlation coefficients of quantitative traits are recorded in Table 4. Positive and high correlation was found between plant cycle and primary branch, between plant cycle and plant height, between plant height and length of middle leaf and between number of capsules per plant and seed yield per plant. There was also positive and low correlation between mean capsule length and 1000 seed weight and between mean capsule length and seed yield per plant. Otherwise, there was a negative and high correlation between plant cycle and 1000 seed weight, between plant height and 1000 seed weight and between plant cycle and seed yield per plant.

Table 4. Pearson correlation coefficient of 14 studied quantitative traits.

Character	DFI	DF50	DPM	PBR	LML	WML	PML	PTH	NCP	MCL	MCW	SPC	TSW
DF50	0.924												
DPM	0.792	0.797											
PBR	0.671	0.697	0.557										
LML	-0.061	-0.064	0.033	-0.156									
WML	0.529	0.537	0.527	0.415	0.463								
PML	0.550	0.535	0.570	0.356	0.566	0.746							
PTH	0.655	0.671	0.681	0.511	0.174	0.459	0.629						
NCP	-0.135	-0.200	-0.098	0.057	0.254	0.034	0.130	-0.040					
MCL	-0.361	-0.440	-0.362	-0.343	0.030	-0.296	-0.285	-0.428	0.027				
MCW	0.242	0.279	0.211	0.138	0.008	0.199	0.150	0.279	-0.162	0.054			
SPC	-0.017	-0.069	0.021	-0.043	0.054	0.120	-0.039	-0.049	-0.140	0.259	0.054		
TSW	-0.787	-0.790	-0.821	-0.645	-0.094	-0.542	-0.571	-0.658	-0.004	0.397	-0.212	0.117	
YLD	-0.646	-0.689	-0.626	-0.419	0.073	-0.386	-0.374	-0.477	0.556	0.369	-0.220	0.227	0.735

Days to flower initiation (DFI), days to 50% flowering (DF50), days to physiological maturity (DPM), primary branch (PBR), length of middle leaf (LML), width of middle leaf (WML), petiole length at middle leaf (PML), plant height (PHT), number of capsules per plant (NCP), mean capsule length (MCL), mean capsule width (MCW), seeds per capsule (SPC), 1000-seed weight (TSW), seed yield per plant (YLD)

Association between quantitative traits

The assessed traits were subjected to principal component analysis (PCA), which revealed that the first three most important PCs, with Eigen value > 1 explain 81.15% of the total variation, (Table 5). Most of the assessed traits are correlated to the first PCs which explain 59.43% of the total variation. This PCs associate negatively the mean capsule length, 1000 seed weight and seed yield per plant. However, it associates positively plant cycle related traits, primary branch, plant height, middle leaf width and petiole length at middle leaf. The second PCs accounted 12,49% of the total variation. It was positively associated to middle leaf length, and seeds per capsule.

Table 5. Principal component analysis (PCA) of different quantitative traits.

Principal component	PC1	PC2	PC3
Eigen value	7.725	1.624	1.200
Variance (%)	59.427	12.493	9.232
Cumulative	59.427	71.920	81.152
DFI	0.944	0.015	-0.058
DF50	0.950	-0.109	-0.096
DPM	0.932	0.055	0.028
PBR	0.849	-0.169	0.181
LML	0.032	0.823	0.022
WML	0.774	0.477	0.067
PML	0.854	0.281	0.034
PTH	0.899	-0.053	-0.139
NCP	-0.195	0.313	0.886
MCL	-0.677	0.221	-0.217
SPC	-0.091	0.644	-0.486
TSW	-0.949	-0.021	-0.163
YLD	-0.895	0.175	0.185

Days to flower initiation (DFI), days to 50% flowering (DF50), days to physiological maturity (DPM), primary branch (PBR), length of middle leaf (LML), width of middle leaf (WML), petiole length at middle leaf (PML), plant height (PHT), number of capsules per plant (NCP), mean capsule length (MCL), seeds per capsule (SPC), 1000-seed weight (TSW), seed yield per plant (YLD).

The third PCs with 9.23 of the total variation was mainly associated positively to the number of capsules per plant.

Organization of agro-morphological diversity

Hierarchized Ascending Classification (HAC) was performed using Euclidean distances with the Ward method and automatic truncation at the inertial 2703 level allowed the 37 sesame landraces to be clustered into three very distinct phenotypic groups in the dendrogram (fig. 1).

Group I and III comprised landraces from all the five provinces of collection. Whereas, group II comprised landraces from only three provinces. Group I contained most of the landraces (19), compared to group III (11 landraces) and group II (7 landraces). Analysis of Fisher distances between groups (Table 6), obtained from discriminant function analysis (DFA) showed that the distances were higher between group I and group III (32.34) and lower between group I and group II (16.59), then between group II and group III (9.52). There were significant differences (P < 0.001) between all the groups.

Table 6. Fisher distances and significant difference between groups.

Group	1	2
2	9.529***	
3	32.340***	16.597***

***Indicates significance at 0.1% probability

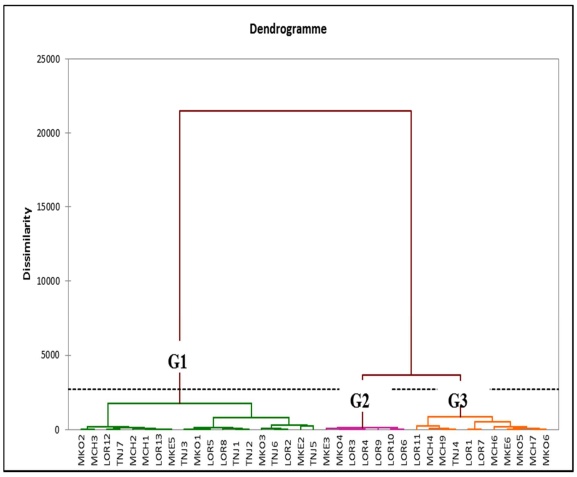

Fig. 1. Dendrogram showing clustering pattern of 37 landraces of Chadian sesame; (G1: group 1; G2: group 2; G3: group 3).

Characteristics of phenotypic groups

Discriminant function analysis (DFA) showed the position of individual groups on the 1/2 axis with a total inertia of 100 % (Fig. 2).

Axis 1 with inertia of 84.59% was defined by plant height, plant cycle and primary branch. Axis 2 with 15.41 % inertia was defined by number of seed per capsule.

The Wilks Lambda test (Rao approximation) gave observed F of 15.231 while the critical F was 1.873 The groups were therefore, different entities from each other. The position of the individual landrace on the DFA 1/2 axes made it possible to characterize the groups. Group I was composed of the tallest and latest landraces, with high number of primary branches.

Group III consisted of landraces with short height, earlier cycle and a few numbers of primary branches. Group II consisted of medium height landraces with medium cycle and a few numbers of seed per capsule.

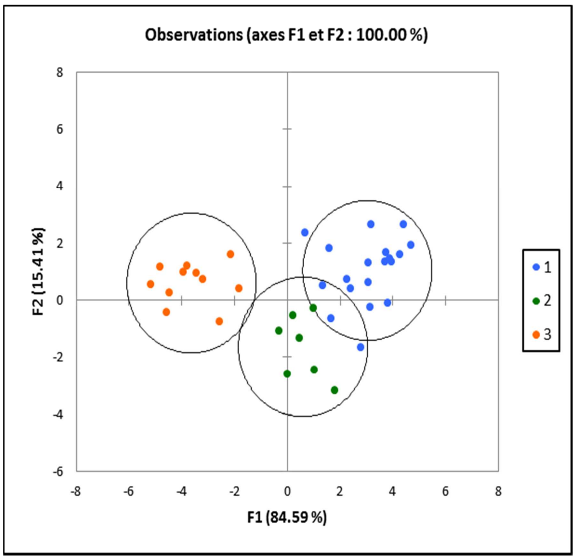

Fig. 2. Discriminant factor analysis showing four major groupings of Chadian sesame.

The analysis of the average performance of the groups by analysis of variance showed that there were high significant differences between groups for most of the assessed traits at the 0.01% probability. Only number of seed per capsules showed non-significant differences between the groups (Table 7).

Table 7. average performance of the groups.

Group	DFI	DF50	DPM	PBR	WML	PML	PTH	MCL	SPC	TSW	YLD
1	55.882 a	62.235 a	120.451 a	10.184 a	13.217 a	11.123 a	213.189 a	3.373 b		1.336 c	8.813 c
2	52.394 b	58.939 b	115.727 b	10.170 a	13.732 a	10.312 a	181.535 b	3.355 b		1.524 b	11.837 b
3	41.815 c	48.185 c	100.037 c	3.667 b	8.114 b	7.417 b	154.102 c	3.644 a		2.898 a	20.425 a
Pr > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.585	0.000	0.000

Days to flower initiation (DFI), days to 50% flowering (DF50), days to physiological maturity (DPM), primary branch (PBR), width of middle leaf (WML), petiole length at middle leaf (PML), plant height (PHT), mean capsule length (MCL), seeds per capsule (SPC), 1000-seed weight (TSW), seed yield per plant (YLD).

Discussion

The study showed that sesame landraces from the Sudanian zone of Chad were all branched with shattering capsule and indeterminate growth habit, which are the typical characteristics of cultivated sesame (Bedigian, 2003; Furat & Uzun, 2010). Hairiness is a typical character of sesame and can be seen in many parts of the plant such as stem, leaf, corolla, and capsule. Indeed, leaf hairiness has a positive effect in terms of preventing water loss, a desirable trait in plant breeding. Capsule hairiness is a desired feature as it increases tolerance against plant diseases, pests and drought (Koitilio, 2018; Ozcinar & Sogut, 2017; Tesfaye *et al.*, 2021). therefore, landraces with strong or profuse hair could be potential genitors for breading insect tolerant varieties. It was also found that these landraces had dominantly white or cream seed color. According to Bedigian (2010) , sesame seed color varies from brown to white, and reflect the farmer preferences. White and cream sesame coat seed are also the most desired in the local and international market. Indeed, most of the Chadian production is suggested to the international trade (FAO, 2021). The study showed that some landraces had tetracarpellate capsules. This type of capsules potentially enlarges the space for more seeds to fit and a structural modification converting the two extra-floral nectaries to capsule (Bedigian, 2003).

Both earliness and lateness in maturity of sesame landraces are important for plant breeding programs trying for adaptation of sesame germplasms to various ecological regions as well as for researches on photoperiod and thermo-sensitivity (Akbar *et al.*, 2011). This study, showed that there were very valuable sources for plant breeding programs aiming for adaptation of sesame to different environments.

The coefficients of variation for most of the quantitative traits were below 30%, which indicated small amplitude of variation in the traits relative to the mean value. This would show a relatively low genetic diversity of sesame from the sudanian zone of Chad. However, great coefficient of variation was found for seed yield, primary branch and number of capsules per plant. This explains the importance of these traits for the Chadian farmers. Indeed, according to Bedigian (2010), Farmers choose the cultivars they grow according to local geographic adaptation, length of growing cycle, seed color, uniformity in maturity, shattering behavior, responses to diseases and pests.

Multivariate analysis of the landraces revealed that the first three PCs gave Eigen-values > 1.0 and cumulatively accounted for 81.15% of the total variation. Traits with high coefficients in the first two PCs should be considered as more important since theses axes explain more than 70% of the total variation. PCA indicated that 1000 seed weight, seed yield per plant, plant cycle related traits, primary branch, plant height, petiole length at middle leaf and seed per capsule were among the most important characters which accounted for more than 70 % of the phenotypic variation expressed in these sesame landraces. These characters were therefore found to be most useful for distinguishing sesame genotypes.

Through seven less correlated quantitative traits, the structuring of diversity allowed the landraces to be clustered into three statistically distinct groups. The cluster analysis did not separate the studied landraces based on their geographical origins. This suggest that there have been migration of the sesame materials from one province to another in the collection area throw seed exchange and marketing (Forsberg *et al.*, 2015; Bandila *et al.*, 2011). Group 3 landraces were shorter with early flowerings and early maturing. Also, they had low number of primary branches and high seed yield per plant. The combinability of high productivity and precocity which contribute to sesame performance, suggest that landraces of this group could be of highest interest for the breeding program.

Conclusion

Agronomic and morphological evaluation of germplasm can be useful for characterization, conservation and maintenance of genetic resources. This study revealed a large agro-morphological diversity of qualitative and quantitative traits of the sesame from the sudation zone of Chad. As the success in genetic improvement of the crop needs the availability of genetic variability and there is a great deal of genetic variability present in the Chadian sesame. Structuring of diversity clustered the cultivars into three groups, of which in group three were found landraces with interesting traits for sesame breading. Landraces in this group combined precocity and high productivity which are the main traits of breeding for the climate change adaptation.

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