Pak. J. Bot., 43(6): 2737-2744, 2011.

GENETIC DIVERGENCE IN SESAME (*SESAMUM INDICUM* L.) LANDRACES BASED ON QUALITATIVE AND QUANTITATIVE TRAITS

FAZAL AKBAR[1], M. ASHIQ RABBANI[2], ZABTA KHAN SHINWARI[1*] AND SHAH JEHAN KHAN[3]

[1]*Department of Biotechnology, Quaid-i-Azam University, Islamabad, Pakistan*
[2]*Institute of Agri-Biotechnology & Genetic Resources, NARC, Islamabad, Pakistan*
[3]*Plant Breeding & Genetics Department, Faculty of Agriculture, Gomal University, D.I. Khan, Pakistan*
**Corresponding author's E-mail:* shinwari@qau.edu.pk

Abstract

Sesame (*Sesamum indicum* L.) is one of the world's oldest oil crops and has been cultivated in Asia since ancient times. The breeding potential of the germplasm accessions held in PGRP gene-bank has hardly been exploited to date. This study was carried out to evaluate the phenotypic variability in the local sesame genotypes using 16 qualitative and quantitative traits. A total of 105 sesame accessions collected from diverse ecologies of Pakistan were used. A considerable level of variation was recorded for a number of morphologic and agronomic traits, while limited diversity for observed among the accessions for characters like stem hairiness, flower color (white with purple shading), seed color and to some extent phyllody disease. The correlation coefficient analysis indicated that plant height, capsules plant^{-1}, capsule length and 1000-seed weight had the significant positive effect on seed yield. The characters related to maturity, days to flower initiation and days to 50% flowering showed negative correlation with seed yield. Multivariate analysis was performed in order to establish similarity and dissimilarity patterns. Principal component (PC) analysis revealed that first three PC axes explained 54.21% of the total multivariate variation, while the first four PC axes explaining 63.64%. Plant height, days to maturity, capsules plant^{-1} and seed yield plant^{-1} were the major determinants of the genetic diversity in the collection. Cluster analysis places all the accessions into seven groups. Clustering was not associated with the geographical distribution instead accessions were mainly grouped due to their morphological differences. Elite sesame germplasm has been selected on the basis of best agro-morphological performance from 105 sesame collections. These results have an important suggestion for sesame germplasm agro-morphological assessment, enhancement, categorization and conservation in Pakistan.

Introduction

Sesame (*Sesamum indicum* L.) is one of the oldest cultivated plants in the world and the most important ancient oilseeds crop known to mankind. It belongs to family Pedaliaceae. The crop is grown throughout the tropical and subtropical countries of the world (Ashri, 1994). It is a warm weather crop and often grown by small landholders under marginal or stressed conditions. Sesame is an important source of edible oil and is widely used one of the ingredients in food products especially in bakery foods and animal feed. Sesame seed contains 50-60% oil and 25% protein with antioxidants lignans such as sesamolin, sesamin and has been used as active ingredients in antiseptics, bactericides, viricides, disinfectants, moth repellants, anti-tubercular agents (Bedigian *et al*., 1985) and considerable source of calcium, tryptophan, methionine and many minerals (Johnson *et al*., 1979). Its oil has also medicinal and pharmaceutical value and is being used in many health cure products.

Plant germplasm of a particular crop collected from the local sources provides greater genetic variability and can furnish useful traits to broaden the genetic base of crop species. The success in genetic improvement of the crop and the development of a species needs the availability and accessibility of genetic variability (Pervaiz *et al*., 2010). Recognition of duplicates, organization of core set of a particular population and the option of selection of parents for the breeding program are directly linked to the genetic variability. Sesame is considered a self-pollinating crop but varying degrees (5 to 60%) of cross pollination may occur depending on insect activity, environmental conditions and availability of other vegetation (Yermamos, 1980). According to Hamrick & Godt (1989) out-crossing plant species have a tendency to present between 10 and 20% of the genetic variation between populations. Genetic advance can easily be achieved after selection for a few generations because of the combination of this autogamy and heterogeneity in sesame species.

Sesame is an important conventional oilseed crop of Pakistan. In 2008-09, around 41,000 tonnes were produced on an area of 90,700 hectares (Anon., 2009). Its average yield (452 kg/ha) is near to the ground as compared to other principal sesame producing countries of the world such as Egypt, Honduras and China which are generating 1143, 1133 and 1185 kg seed yield per hectare, respectively (Anon., 2000). The key problems in its cultivation are seed shattering at maturity preventing combine-harvest, indeterminate growth habit causing non-uniform capsule maturation and susceptibility to wilting under irrigation. Genetic improvement of local sesame has the potential to overcome these production limitations. Pakistan is worthy of sesame genetic variability due to the absence of genetically improved sesame breeding varieties and the cultivation of local heterogynous landraces throughout the country. There are numerous ecotypes of sesame adapted to various ecological conditions. However, the cultivation of modern varieties is limited due to insufficient genetic information. Many farmers continue to grow local sesame populations with low yields. Over 172 sesame accessions collected from different parts of our country have been conserved in national gene-bank (Masood *et al*., 2003). These local landraces can be used as a raw material for agricultural improvement (Ali *et al*., 2009).

Genetic diversity in crop plants is essential to sustain level of high productivity (Rabbani *et al*., 2010). Genetic variation survives for agronomically vital characters in sesame but its production is still very low in our country. Although Pakistan is rich of sesame variability, but the value of categorization and preserving of this precious natural variation in sesame is not reported in Pakistan so for, like other researchers in the world (Demir, 1962; Bisht *et al*., 1998; Bhat *et al*., 1999; Baydar *et al*., 1999; Xiurong *et al*., 2000). Like Brazil (Arriel *et al*., 2000) the categorization of sesame is still in the premature stage in Pakistan. As a general rule the breeding program needs a large amount of evaluated traits based on agronomic and morphological descriptors. Traditionally studies on genetic diversity are based on morphological and quantitative characters. No doubt the genetic variability present in the Pakistani sesame germplasms needs protection from the continuous genetic erosions. That's why, this study was carried out to recognize and categorize genetic variability of 105 sesame accessions collected from diverse environmental conditions throughout Pakistan and to choose sesame germplasms with diverse agronomic performances and yield potential from these important assets. Knowledge of genetic diversity among landraces will help in the selection and breeding of high yielding, good quality cultivars that will increase production (Mumtaz *et al*., 2010).

Materials and Methods

The research was carried out in the field area of Institute of Agri-Biotechnology & Genetic Resources (IABGR), National Agricultural Research Centre, Islamabad, Pakistan (33° 33' N and 73° 06'E) during 2009. Annual average rainfall in this region ranges from 500-900mm with 70% in summer and 30% in winter. A total of 105 diverse sesame accessions collected from various ecological regions of Pakistan were used as experimental material. The sesame accessions were sown on silty clay loam soils with a pH 7.5. All the accessions were sown in 2009. The experiment was laid out in an augmented design. Each plot has a size of 1.5 x 3.5 m^2 with 2 lines per accession. Length of the row was 3.5 m, path between beds was 2.5 m and row to row distance was kept as 0.75 m. An improved cultivar, 'TS3' was repeated as check after every 20 accessions. For seed bed preparation presowing irrigation was applied to plant experiment under optimum moisture condition. Planting of the experiment was done with hand drill. Thinning was done to maintain most favorable plant population. Weeds were prohibited by hand once 30 days after planting.

Quantitative observations were recorded for days to flowering initiation, days to 50% flowering, days to maturity, plant height, primary branches plant^{-1}, secondary branches plant^{-1}, capsules plant^{-1}, capsule length, capsule width, 1000-seed weight and seed yield plant^{-1}. Trait selection and measurement techniques were based on IPGRI descriptors of sesame (Table 1). Analysis of variance was carried out on mean values of accessions observed in each block. The correlation coefficients were calculated by using the formulae suggested by Kwon & Torrie (1964). Principal component analysis (PCA) was also carried out with Eigenvalues > 1.0 were chosen, as proposed by Jeffers (1967). Correlations between the characters and the relevant PCs were acquired. In addition, cluster analysis was also carried out to evaluate the level of dissimilarity among the sesame germplasm. A dendrogram was constructed with Euclidian distance.

Table 1. Morphological and seed traits recorded for sesame germplasm from Pakistan.

Trait	Scale	Description of the trait
Qualitative traits:		
Stem hairiness (SH)	-	1 = Glabrous (no hairs); 2 = Weak or sparse; 3 = Hairy; 4 = Very hairy.
Flower color (FC)	-	1 = Deep violet/purple; 2 = White with deep violet/purple shading; 3 = White with light violet/purple shading; 4 = White.
Seed color (SC)	-	1 = White; 2 = Black; 3 = Brown; 4 = Red; 5 = Grey; 6 = Others.
Phyllody disease incidence (Ph)	-	1 = Very low; 3 = Low; 5 = Intermediate; 7 = High; 9 = Very high.
Quantitative traits:		
Days to flower initiation (DFI)	Days	Number of days from seed sowing until 50% of plants have first flower in each accession.
Days to 50% flowering (50%DF)	Days	Numbers of days from seed sowing until 50% plants have at least one flower in each accession.
Days to maturity (DM)	Days	Number of days from seed sowing until 75% of plants reaching physiological maturity.
Plant height (PH)	cm	Mean height of five random plants from ground level to the apex of the main stem.
Primary branches plant^{-1} (PB/P)	No.	Total number of branches originating from main stem which gives rise to other capsule-bearing branches.
Secondary branches plant^{-1} (SB/P)	No.	Total number of branches originating from primary branches which gives rise to other capsule-bearing branches.
Capsules plant^{-1} (C/P)	No.	Total number of capsules on both primary and secondary branches. Mean of five randomly selected plants.
Capsule length (CL)	mm	Distance from the base to the tip of five randomly selected capsules.
Capsule width (CW)	mm	Distance across the widest point of the same capsule used for length.
Seeds capsule^{-1} (S/P)	No.	Mean number of seeds from five randomly selected capsules from five different plants.
1000-seed weight (TSW)	g	Weight of 100 random dried seeds was calculated and then converted to 1000-seed weight by multiplying 10.
Seed yield plant^{-1} (SY/P)	g	Average seed weight of five randomly selected plants for each accession was recorded at 13% moisture content.

Results and Discussion

The range of variation observed among the accessions for all qualitative and quantitative descriptors are presented in Table 2. Variation for stem hairiness, seed color and phyllody disease was recorded. However, variation did not exist for flower color among the accessions. Besides the above mentioned traits, most of the sesame accessions were observed with shattering and indeterminate growth habit. Our results were in agreement with the findings of Uzun & Cagirgan (2001), Uzun & Cagirgan (2006) and Uzun *et al*., (2003). There was mostly white flower color with light pink shading, which is the common characteristic of Indian sesame collection with somewhat deep purple shading. A mycoplasma like organism (MLO) is considered to be the causative agent of phyllody or green flowers disease. Phyllody disease is transmitted by means of *Orosius albicinctus* Dist. Some time the disease incidence ranged from 90 to 100% which result the total loss of yield. It has been investigated that if the disease intensity increased to 1% seed yield reduced to 8.36 kg hectare^{-1} (Maiti *et al*., 1988). Although phyllody disease was considered as a monomorphic trait but most of the accessions were investigated for phyllody disease which may be one of the main factors for low yield in Pakistani sesame germplasm. Hairiness is distinctive trait of sesame which present in various parts of the plant like stem, capsules, leaves, corolla (Weiss, 1983). In case of our study mostly hairs were present on the stem, while other plant parts such as leaves, corolla and capsules were without hairs. Accession '21661' collected from Sialkot (Punjab province) showed strong leaves, stem and capsules hairiness. This accession showed earliness in flowering and maturity with low seed yield potential as compared to other sesame accessions.

Table 2. Variation in quantitative traits of 105 local sesame accessions from Pakistan.

Trait	Mean	Minimum	Maximum	SD	CV (%)	Variance
Days to flower initiation	44.2	36.0	54.0	3.6	8.2	13.1
Days to 50% flowering	49.2	40.0	59.0	3.7	7.6	14.0
Days to maturity	122.4	110.0	130.0	4.6	3.8	21.3
Plant height	121.7	76.2	150.2	16.0	13.1	254.7
Primary branches plant^{-1}	10.6	4.4	19.6	4.0	37.9	16.3
Secondary branches plant^{-1}	10.4	0.6	25.8	5.3	51.1	28.3
Capsules plant^{-1}	106.5	17.0	234.0	55.9	52.5	3125.0
Capsule length	25.9	20.2	35.2	2.2	8.4	4.7
Capsule width	4.9	4.3	6.1	0.3	5.6	0.1
Seeds capsule^{-1}	63.7	23.2	84.2	10.4	16.4	108.6
1000-seed weight	2.6	1.2	3.9	0.5	21.2	0.3
Seed yield plant^{-1}	32.4	2.8	112.5	26.0	80.3	674.2

A considerable level of polymorphism was observed among the 105 sesame accessions for most of the quantitative traits measured (Table 2). Pattern of variation among the landraces was different for different agro-morphological traits. The largest variation was observed for plant height, capsules plant^{-1}, seeds capsule^{-1} and grain yield plant^{-1}. The variances for the said traits were 254.7, 3125.0, 108.6 and 674.2, respectively. Relatively, a low level of variability was detected in days to flowering, capsule length and width, 1000-seed weight, etc. The mean values of the sesame accessions for days to flower initiation, days to 50% flowering and days to maturity were 44.2, 49.2 and 122.4 with a range of 36 to 54, 40 to 59 and 110 to 130 days, respectively. These traits could be assessed to recognize for both early and late maturity. The sesame cultivar TS3 showed high values for these three traits, while many other germplasm accessions showed earliness in our study. Both earliness and late in maturity 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 (Suddihiyam *et al*., 1992; Ashri, 1995; Rehman *et al*., 2009). The average for plant height, primary branches plant^{-1}, capsules plant^{-1}, seeds capsule^{-1} and 1000-seed weight among the accessions were 121.7, 10.6, 106.5, 63.7 and 2.6, respectively. The range for plant height was 76.2 and 150.2cm, primary branches plant^{-1} varied from 4.4 and 19.6, capsules plant^{-1} ranged between 17 and 234, seeds capsule^{-1} ranged from 23.2 to 84.2 and 1000-seed weight was 1.2 and 3.9. These traits showed extensive genetic variation and accessions with such a large level of genetic diversity often used for the determination of best genotypes for diverse ecological conditions. There was a great deal of seed yield variation observed among all the sesame germplasm. The mean seed yield was observed as 32.4g with a range of 2.8 and 112.5g. This variation can be contributed to the cultivation conditions and strongly supported the idea that local sesame germplasm still commonly sustained by the farmers due to the absence of improved breeding cultivars for diverse environmental conditions (Furat & Uzun, 2010).

Correlation coefficients of seed yield and yield components are given in Table 3. Data revealed that number of capsules plant^{-1}, days of maturity, plant height, capsule length and 1000-seed weight had the significant positive contribution with seed yield plant^{-1}. Our results agreed with similar positive correlation observed by Khan *et al*., (2001), Uzun & Cagirgan (2001) and Sumathi *et al*., (2007). Positive but not statistically significant correlation was observed in primary branches plant^{-1}, secondary branches plant^{-1}, capsule width, and seeds capsule^{-1}. Two related traits, days to flower initiation (-0.06) and 50% flowering (-0.02) revealed negative and significant correlation with seed yield plant^{-1}. These traits are highly associated to days to maturity, as early flower initiation in sesame gives early capsule rising. Similar negative effect of DFI and 50%DF on seed yield were investigated by Gnanasekaran *et al*., (2008) and Yol *et al*., (2010).

Table 3. Correlation coefficients among 12 quantitative traits in sesame germplasm.

Trait*	DFI	50%DF	DM	PH	PB/P	SB/P	C/P	CL	CW	S/C	TSW	SY/P
DFI	1.00											
50 % DF	0.56**	1.00										
DM	-0.04	0.04	1.00									
PH	-0.33**	-0.35**	0.23*	1.00								
PB/P	0.04	-0.05	-0.09	0.27**	1.00							
SB/P	0.01	-0.13	-0.05	0.34**	0.63**	1.00						
C/P	-0.05	-0.08	0.22*	0.43**	0.47**	0.49**	1.00					
CL	0.16	0.08	0.16	0.21*	-0.04	-0.01	-0.03	1.00				
CW	-0.01	-0.08	0.12	0.18	0.07	0.05	0.10	0.19*	1.00			
S/C	-0.10	-0.20*	0.19	0.17	-0.02	0.17	0.01	0.15	0.14	1.00		
TSW	-0.20*	-0.17	0.23*	0.17	-0.38**	-0.22*	0.03	0.14	0.06	0.02	1.00	
SY/P	-0.06	-0.02	0.41**	0.52**	0.03	0.19	0.33**	0.23*	0.09	0.18	0.23*	1.00

*DFI (days to flower initiation), 50%DF (days to 50% flowering), DM (days to maturity), PH (plant height), PB/P (primary branches plant^{-1}), SB/P (secondary branches plant^{-1}), C/P (capsules plant^{-1}), CL (capsule length), CW (capsule width), S/C (seeds capsule^{-1}), TSW (1000-seed weight), SY/P (seed yield plant^{-1}).

Multivariate analysis of the accessions showed that the first four PCs (PC1 to PC4) having eigenvalues > 1.0 and cumulatively accounted for 63.64% of the total variation (Table 4). The first PC axes accounted for 23.39% of the total variation, whereas the second PC explained 17.13% and the third PC accounted for 13.68% of variation. The cumulative proportion of the variation reached 54.21% in the first three PC axes, and 63.64% in the all four axes. The high level of variation in all four PC axes showed a high level of variation for these characters. According to Düzyaman (2005) there are no procedures to find out the significance of a coefficient, that is eigenvector. On the other hand higher coefficients for some traits designated the relatedness of that character to relevant PC axes (Sneath & Sokal, 1973). The variation in PC1 was largely correlated with days to flower initiation, days to 50% flowering, plant height, and secondary branches plant^{-1}; in PC2 with primary branches plant^{-1}, 1000-seed weigh, seed yield plant^{-1}; PC3 was mainly associated with days to flower initiation, days to 50% flowering, days to maturity, capsule length and seed yield plant^{-1}, and in the fourth PC variation was mainly correlated with days to maturity and capsules plant^{-1}. First two principal components were also plotted to observe the relationship between sesame accessions (Fig. 1). Traits with high coefficients in the PC1 to PC3 should be considered as more significant because these axes explain more than 50% of the whole variation. Principal component analysis indicated that days to flower initiation, days to 50% flowering, secondary branches plant^{-1} and seed yield plant^{-1} were among the most important traits which accounted for more than half of the all phenotypic variation revealed in this sesame germplasm collection. It is suggested that research on these trait will save a lot of time for the identification of best sesame germplasm in Pakistan.

Table 4. Eigenvalues, proportion of variability and quantitative traits that contributed to the first four principal components of sesame germplasm from Pakistan.

	PC1	PC2	PC3	PC4
Eigenvalue	2.81	2.06	1.64	1.13
Cumulative Eigenvalue	2.81	4.86	6.50	7.64
Variance (%)	23.39	17.13	13.68	9.43
Cumulative Variance	23.39	40.52	54.21	63.64
Trait	**Eigenvectors**			
Days to flower initiation	0.193	-0.230	0.567	-0.044
Days to 50% flowering	0.241	-0.155	0.560	0.176
Days to maturity	-0.227	0.295	0.308	0.206
Plant height	-0.486	0.100	-0.056	0.044
Primary branches plant^{-1}	-0.286	-0.515	-0.013	-0.036
Secondary branches plant^{-1}	-0.366	-0.408	-0.014	-0.062
Capsules plant^{-1}	-0.411	-0.210	0.081	0.322
Capsule length	-0.124	0.188	0.404	-0.370
Capsule width	-0.171	0.089	0.135	-0.516
Seeds capsule^{-1}	-0.203	0.146	0.009	-0.540
1000-seed weight	-0.084	0.493	-0.021	0.246
Seed yield plant^{-1}	-0.373	0.204	0.279	0.241

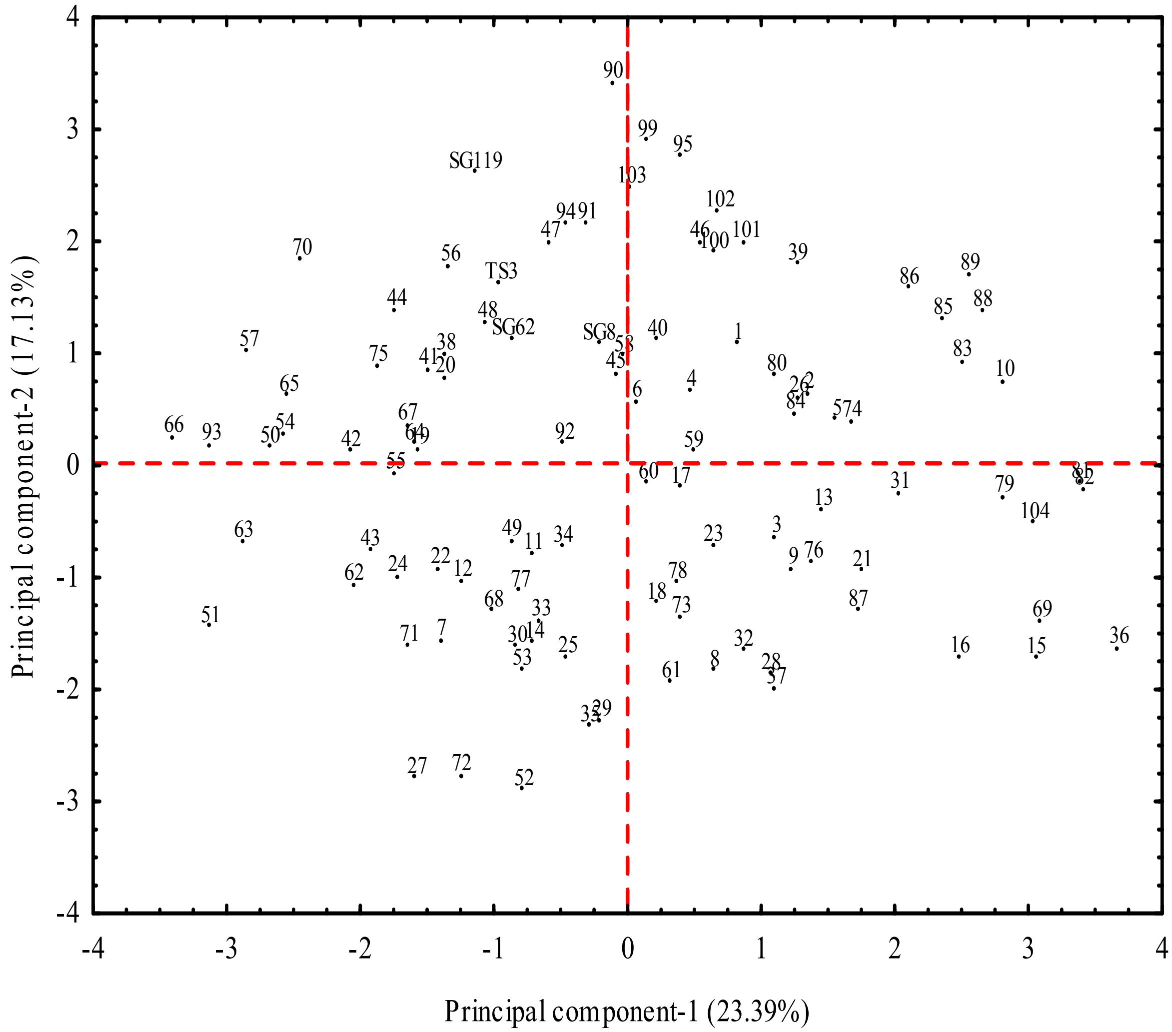

Fig. 2. Scatter diagram of first two principal components based on mean values of quantitative traits in 105 accessions of sesame germplasm.

Hierarchical cluster analysis based on agro-morphological traits allocated the 105 sesame accessions into seven clusters (Fig. 2). Critical assessment of clusters exposed that clusters were heterogeneous within themselves and between each others based on major character relations. Third cluster contained maximum accessions (26) followed by cluster-1 (24), cluster-2 (20), cluster-7 (17), cluster-4 (10), cluster-5 (6) and cluster-6 (5). Cluster means for different quantitative characters stated for each cluster are presented in Table 5. The seven clusters were characterized as follows: Cluster-1 was mainly characterized by late maturity, tall stature, high primary and secondary branches, higher number of capsules plant^{-1}, high number of seeds capsule^{-1}, predominantly white in flower color and low incidence of phyllody disease. Cluster-2 comprised accessions with low yield, medium to tall plant height, high branching habit, early in maturity, stem hairiness sparse, and medium to high phyllody disease incidence. Cluster-3 was primarily characterized by high seed yield, higher number of capsules plant^{-1}, more capsule length and width, flower with white deep purple shading and white seed coat. Accessions in cluster-4 were characterized by tall plant height, capsule width and length, glabrous stem hairiness, black and white seed coat with low phyllody disease. Accessions in cluster-5 were associated with higher number of seeds capsule^{-1}, high number of primary and secondary branches plant^{-1}, early in maturity, better capsule size, medium to high in yield potential, with black seed coat and low phyllody disease incidence. Cluster-6 consisted accessions with higher seed weight, high number of capsules plant^{-1} with more length and width, low number of branches plant^{-1}, medium to tall plant height, low number of seeds capsule^{-1} with black color and low phyllody disease incidence. Cluster-7 was mainly characterized by short plant stature, early in maturity, lower capsules plant^{-1}, and low seeds capsule^{-1} with white seed coat, the lowest seed yield, sparse stem hairiness, and white flowers with deep purple shading. Clustering of landraces was not associated with the geographical distribution instead accessions were mainly grouped due to their morphological differences. Our results are in agreement with investigations of Dixit & Swain (2000) and Gupta *et al.*, (2001). This may be the movement of sesame genotypes from one area to another in compilation sites. A few ecological conditions could also direct the gene flow between populations from diverse geographical origins. Although sesame has been described as a self-pollinated plant, recent indication raises the option of natural out-crossing in sesame (Pathirana, 1994; Baydar & Gurel, 1999).

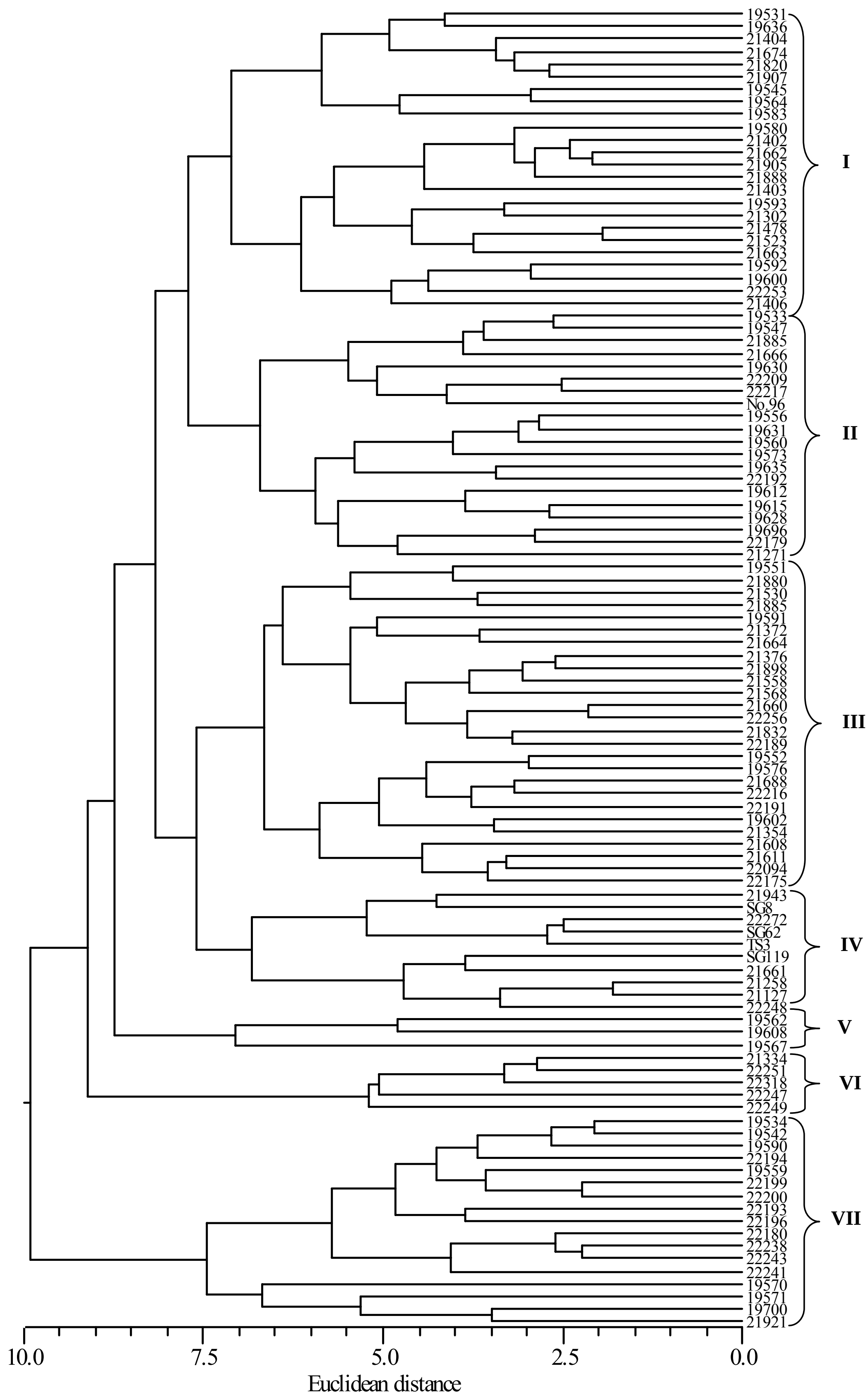

Fig. 2. Scatter diagram of first two principal components based on mean values of quantitative traits in 105 accessions of sesame germplasm.

Table 5. Means of different quantitative traits and predominance of qualitative descriptor states for different clusters of 105 sesame landraces.

Trait*	Cluster-1	Cluster-2	Cluster-3	Cluster-4	Cluster-5	Cluster-6	Cluster-7
SH	glabrous	sparse	medium	glabrous	medium	medium	sparse
FC	white-purple	white-purple	white-purple	white-purple	white-purple	white-purple	white-purple
SC	white	white-black	white	white-black	black	black	white
Ph	low	med to high	high	low to med	low	low	low
DF	41.95	43.95	44.85	43.34	44.82	43.83	48.23
DM	123.38	118.50	123.92	126.85	119.23	125.36	121.88
PH	127.38	118.86	128.89	132.28	125.43	115.76	102.92
PB/P	10.95	10.92	13.80	6.11	17.23	6.46	8.64
SB/P	10.45	10.10	12.25	5.99	18.20	4.48	4.24
C/P	100.28	87.22	115.56	61.94	90.75	57.66	71.78
S/C	66.81	64.89	60.70	70.47	71.57	57.52	59.11
CL	25.52	25.73	26.29	27.15	28.56	25.26	25.44
CW	4.81	4.77	4.89	4.95	5.71	5.17	4.76
TSW	2.34	2.26	2.58	2.84	2.06	3.39	2.42
SY/P	33.65	17.59	65.58	61.83	17.36	28.82	13.57

*SH (stem hairiness), FC (flower color), SC (seed color), Ph (phyllody incidence), DFI (days to flower initiation), 50%DF (days to 50% flowering), DM (days to maturity), PH (plant height), PB/P (primary branches plant^{-1}), SB/P (secondary branches plant^{-1}), C/P (capsules plant^{-1}), CL (capsule length), CW (capsule width), S/C (seeds capsule^{-1}), TSW (1000-seed weight), SY/P (seed yield plant^{-1}).

Table 6. Elite sesame genotypes identified for some of important agro-morphological traits.

Trait of interest	Range	Accessions identified
Days of maturity	< 115	19533, 19612, 19615, 19630, 21666, 21885, 22191, No.96
Capsules per plant	≥ 200	21354, 21608, 21664, 21832, 21880, 22094, 22189, 22256
Seeds per capsule	≥ 70	19542, 19573, 19608, 19631, 21663, 21880, SG119, TS3
1000-seed weight	≥ 3.5g	19630, 21663, 21664, 21885, 22189, 22249, 22251, 22318
Seed yield per plant	≥ 80g	21372, 21660, 21888, 21943, 22256, 22272, SG62, TS3

Elite sesame germplasm selection was carried out on the basis of important agro-morphological traits such as days to maturity, capsules plant^{-1}, seeds capsule^{-1}, 1000-seed weight and seed yield plant^{-1} (Table 6). Germplasm accessions which tended to have comparatively short statured plants (19533, 19612,19615,19630,21666, 21885, 22191), higher number of capsules plant^{-1} (21354, 21608, 21664, 21832, 21880, 22094, 22189, 22256), more seeds capsule^{-1} (19542, 19573, 19608, 19631, 21663, 21880), heavier seeds (19630, 21663, 21664, 21885, 22189, 22249, 22251, 22318) and higher seed yield (21372, 21660, 21888, 21943, 22256, 22272,) as compared to check variety (TS3) were being identified for future utilization in breeding programs. Our results indicated that the genetic material studied had a considerable level of variability that could be exploited in future breeding programs. Further research on these selected accessions will save a lot of time for the breeder in future.

Conclusions

A high level of genetic diversity based on agro-morphological traits was observed in our study. 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 Pakistani sesame.

Acknowledgements

The authors gratefully acknowledge the financial support from a PSDP funded project on “Production of Medicinal Herbs in Collaboration with Private Sector (PMHPS)” for this study. We are also obliged to Dr. M. Shahid Masood, Senior Director, Institute of Agri-Biotechnology & Genetic Resources (IABGR), National Agricultural Research Centre (NARC), Islamabad for providing the seed material of local sesame germplasm and extending field/laboratory facilities for the conduct of given study.

References

Ali, M.A., S. Niaz, A. Abbas, W. Sabir and K. Jabran. 2009. Genetic diversity and assessment of drought tolerant sorghum landraces based on morph-physiological traits at different growth stages. *POJ*, 2: 214-227.

Anonymous. 2000. FAO Production Year Book. 54: 123.

Anonymous. 2009. Agricultural statistics of Pakistan. Economic wing, Ministry of food & agriculture, Government of Pakistan. pp. 63-64.

Arriel, N.H.C., J.W. Santos, J.A.N. Moreira, M.B.M. Nóbrega and F.P. Andrade. 2000. Avaliação de descritores quantitativos Na caracterização preliminar de germoplasma de gergelim (*Sesamum indicum* L.). *Revista de Oleaginosas e Fibrosas*, 4: 45-54.

Ashri, A. 1994. Genetic resources of sesame: present and future perspectives. In: *Sesame Biodiversity in Asia: Conservation, Evaluation and Improvement*. (Eds.): R.K. Arora and K.W. Riley. IPGRI Office for South Asia, New Delhi, India. pp. 25-39.

Ashri, A. 1995. Sesame research overview: current status, perspectives and priorities. In: *Proc. Sesame Work*. (Eds.): M.R. Bennett and I.M. Wood. NT Dept. Primary Industry and Fisheries, Darwin. pp. 1-17.

Baydar, H. and F. Gurel. 1999. The effects of honey bees on cross-pollination and hybrid seed production in sesame (*Sesamum indicum* L.). *Turk. J. Field Crops*, 4: 21-24.

Bedigian, D., D.S. Seigler and J.R. Harlan. 1985. Sesamin, sesamolin and the origin of sesame. *Biochem. Sys. Ecol.*, 13: 133-139.

Bhat, K.V., P.B. Prashant and S. Lakhanpaul. 1999. Study of genetic diversity in Indian and exotic sesame (*Sesamum indicum* L.) germplasm using random amplified polymorphic DNA (RAPD) markers. *Euphytica*, 110: 21-33.

Bisht, I.S., R.K. Mahajan, T.R. Loknathan and R.C. Agrawal. 1998. Diversity in Indian sesame collection and stratification of germplasm accessions in different diversity groups. *Genet. Resour. Crop Evol*., 45: 325-335.

Çağırgan, M.İ. 2006. Selection and morphologic characterization of induced determinate mutants in sesame. *Field Crops Res*., 96: 19-24.

Demir, I. 1962. Türkiye'de yetiştirilen önemli susam çeşitlerinin başlıca morfolojik, biyolojik ve sitolojik vasıfları üzerinde araştırmalar (in Turkish with German abstract). Ege Üniversitesi Ziraat Fakültesi Yayınları: 53, s. 160, İzmir.

Dixit, U.N. and D. Swain. 2000. Genetic divergence and heterosis in sesame. *Indian J. Genet. Plant Breed*., 60: 213-219.

Düzyaman, E. 2005. Phenotypic diversity within a collection of distinct okra (*Abelmoschus esculentus*) cultivars derived from Turkish landraces. *Genet. Resour. Crop Evol*., 52: 1019-1030.

Furat, S. and B. Uzun. 2010. The use of agro-morphological characters for the assessment of genetic diversity in sesame (*Sesamum indicum* L.). *POJ*, 3: 85-91.

Gnanasekaran, M., S. Jebaraj and S. Muthuramu. 2008. Correlation and Path co-efficient analysis in sesame (*Sesamum indicum* L.). *Plant Archives*, 8: 167-169.

Gupta, R.R., B.M.S. Parihar and P.K. Gupta. 2001. Genetic diversity for some metric characters in sesame (*Sesamum indicum* L.). *Crop Res*., 21: 350-354.

Hamrick, J.L. and M.J.W. Godt. 1989. In: *Allozyme diversity in plants*. (Eds.): A.H.D. Brown, M.T. Clegg, A.L. Kahler, B.S. Wei. Plant Population Genetics: Breeding and Genetic Resources. Sinauer, Sunderland. pp. 43-63.

Jeffers, J.N.R. 1967. Two case studies in the application of principal component analysis. *Appl. Stat*., 16: 225-236.

Johnson, L.A., T.M. Suleiman and E.W. Lusas. 1979. Sesame protein: a review and prospectus. *J. Amer. Oil Chem. Soc.,* 56: 463-468.

Khan, N.I., M. Akbar, K.M. Sabir and S. Iqbal. 2001. Characters association and path coefficient analysis in sesame (*Sesamum indicum* L.). *J. Biol. Sci*., 1: 99-100.

Kwon, S.H. and J.H. Torrie. 1964. Heritability and interrelationship of traits of soybean populations. *Crop Sci*., 4: 196-198.

Maiti, S., M.R. Hegde and S.B. Chattopadhyay. 1988. *Handbook of Oil Seed Crops*. Oxford and IBH Publishing Co. (Pvt.). Ltd., New Delhi. 317p.

Masood, S., A. Ghafoor and A. Javaid. 2003. Characterization and evaluation of plant genetic resources. Plant Genetic Resources Institute, NARC, Islamabad.

Mumtaz, SA; M. Naveed and Z. K. Shinwari. 2010. Assessment Of Genetic Diversity And Germination Pattern In Selected Cotton Genotypes Of Pakistan." *Pak. J. Bot*., 42(6): 3949-3956

Pathirana, R. 1994. Natural cross-pollination in sesame (*Sesamum indicum* L.). *Plant Breed*., 112: 167-170.

Pervaiz, Z.H., M.A. Rabbani, I. Khaliq, S.R. Pearce and S.A. Malik. 2010. Genetic diversity associated with agronomic traits using microsatellite markers in Pakistani rice landraces. *Elect. J. Biotech.*, 13: 1-12.

Rabbani, M.A., M.S. Masood, Z.K. Shinwari and K.Y. Shinozaki. 2010. Genetic Analysis of basmati and non-basmati Pakistani Rice (*Oryza Sativa* L.) cultivars using microsatellite markers. *Pak. J. Bot*., 42(4): 2551-2564.

Rehman, A.U., I. Habib, N. Ahmad, M. Hussain, M.A. Khan, J. Farooq and M.A. Ali. 2009. Screening wheat germplasm for heat tolerance at terminal growth stage. *POJ*, 2: 9-19.

Sneath, P.H.A. and R.R. Sokal. 1973. *Numerical Taxonomy*. W.H. Freeman and Company, San Francisco.

Suddihiyam, P., B.T. Steer and D.W. Turner. 1992. The flowering of sesame (*Sesamum indicum* L.) in response to temperature and photoperiod. *Aus. J. Agric. Res*., 43: 1101-116.

Sumathi, P., V. Muralidharan and N. Manivannan. 2007. Trait association and path coefficient analysis for yield and yield attributing traits in sesame (*Sesamum indicum* L). *Madras Agric. J*., 94: 174-178.

Uzun, B. and M.I. Cagirgan. 2001. Path-coefficient analysis for seed yield and related characters in a population of determinate and indeterminate types of sesame (*Sesamum indicum* L.). *Turk. J. Field Crops*, 6: 76-80.

Uzun, B. and M.I. Cagirgan. 2006. Comparison of determinate and indeterminate lines of sesame for agronomic traits. *Field Crops Res*., 96: 13-18.

Uzun, B., D. Lee, P. Donini and M.I. Cagirgan. 2003. Identification of an AFLP marker linked to the closed capsule mutant trait in sesame. *Plant Breed*., 122 : 95-97.

Weiss, E.A. 1983. *Oilseed Crops*. Longman, NY.

Xiurong, Z., Z. Yingzhong, C. Yong, F. Xiangyun, G. Qingyuan, Z. Mingde and T. Hodgkin. 2000. Establishment of sesame germplasm core collection in China. *Genet. Resour. Crop Evol*., 47: 273-279.

Yermamos, D.M. 1980. Sesame. In: *Hybridization of Crop Plants*. (Eds.): W.R. Fehr and H.H. Hadley. *Amer. Soc. Agron*,, CSSA, Madison.

Yol, E., E. Karaman, Ş. Furat and B. Uzun. 2010. Assessment of selection criteria in sesame by using correlation coefficients, path and factor analysis. *AJCS*, 4: 598-602.

(Received for publication 17 January 2011)