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Research Article

Assessment of genetic variability for capsule shattering characters in Indian sesame

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Abstract
Thirty five Indian sesame genotypes were evaluated for their genetic diversity for seed yield and yield attributing characters as well as capsule shattering characters. The genotypes were classified into eleven clusters, based on Mahalanobis D^2 statistic. Results on inter-cluster distances revealed maximum diversity between genotypes of cluster II and IV. A perusal of the results on cluster means revealed high capsule number per plant, seed weight per capsule and potential seed weight for cluster IV, the earliest genotype possessing maximum branches per plant and retained seed number for cluster VI, while maximum values for plant height, capsule width and thousand seed weight for cluster VIII indicating the desirability of genotypes from these clusters for improvement of respective traits. Further, potential seed weight has the highest contribution to total divergence followed by capsule split before drying, retained seed weight, unattached seed weight and seed weight per capsule indicating their importance in the choice of parents for developing semi shattering genotypes.

Key words
Sesamum indicum, capsule shattering characters, genetic variability, D^2 analysis

Introduction

Sesame (*Sesamum indicum* L.) is one of the oldest oilseed crops grown in India with very high quality oil. It is grown in India round the year covering an area of about 1.67 million ha with an annual production of 0.71 million ton and productivity of 426 kg/ha which is lower than the world production of 489 kg/ha. One of the major reasons for their low yield is that the Indian sesame varieties are mostly of indeterminate growth habit, which flower continuously and bear dehiscent capsules. The plant continues to flower even when the earliest set capsules at the lower portion of the plant are mature which results in non-synchronous maturity of the capsules and seed shattering in the field Weiss(1971) and Ashri(1998). This can be avoided by developing sesame genotypes with determinate growth habit. Although determinate growth habit of sesame was discovered many years ago, it has not been adopted because of many pleiotropic effects associated with the character including severe reduction of plant height, twisted stem and semi sterility Uzun *et al.(*2013). A few closed capsule mutants were developed earlier to reduce seed loss, but due to difficulty in seed release during threshing the quality of the seed decreases Uzun *et al.(*2004). On the other hand semi shattering sesame genotypes bearing capsules with higher seed retention capacity will delay opening of mature capsules in the field and release seeds easily on threshing Langham,(1998). Therefore development of semi shattering genotypes with good seed retention capacity at maturity will be useful in maintaining seed quality and help in reducing the yield loss due to capsule shattering in the field. For the development of semi shattering sesame genotypes, the capsule characters related to seed retention need to be identified and analyzed for their effect on seed yield.

Genetic improvement of seed yield alone is not possible through phenotypic selection because of its polygenic nature and low heritability. Hence, selection through correlated response entailing several contributing factors influencing seed production shall be most appropriate. Also among the several methods of multivariate analysis available to study the genetic divergence in biological population, the D^2-analysis Mahalanobis(1936) has been a perfect test in the quantitative estimation of genetic diversity amongst biological populations and assesses the relative contribution of various attributes to total divergence. Genetic diversity studies also help to determine the inherent potential of a cross for heterosis and frequency of the desirable recombinants in advanced generations Raghuwanshi and Duhoon (2005). No information on genetic divergence for capsule shattering characters in sesame is available in the literature. In this context, the present study aimed to characterize the genetic variability in Indian sesame genotypes using Mahalanobis D^2 statistic, based on seed yield and its component characters as well as capsule shattering related traits and to identify promising parental lines for their use in developing semi shattering genotypes.

Materials and Methods

Experimental material for the present investigation comprised of thirty five sesame genotypes screened for capsule shattering characters at the

experimental farm of Orissa University of Agriculture and Technology, Bhubaneswar, India during kharif season of the agricultural year 2016-17. The field lay out was done in randomized block design with three replications. Each entry was represented by 6 row plot of 2.0 m length with a line-to-line spacing of 30 cm apart. The seeds of genotypes were direct seeded in the rows and later thinned to a single seedling per hill at a distance of 10 cm approximately. All recommended practices were followed to raise a healthy crop. A total of twenty characters for yield and its components as well as capsule characters related to shattering were evaluated. Observations were recorded on ten quantitative traits, *viz.* days to maturity (DM), plant height in cm (PH), branch number per plant (B/P), capsule number per plant (C/P), capsule length in mm (CL), capsule width in mm (CW), seed number per capsule (SN/C), seed weight per capsule in mg (SW/C), 1000-seed weight in grams (TSW) and seed yield per plant in grams (SY/P). Observations were also recorded on ten capsule shattering related traits, *viz.* capsule split before drying of capsules in mm (CS-1), capsule split after drying of capsules in mm (CS-2), capsule open before drying of capsules in mm (CO-1), capsule open after drying of capsules in mm (CO-2), unattached seed weight in mg (UW), retained seed weight in mg (RW), potential seed weight in mg (PSW), unattached seed number (UN), retained seed number (RN) and potential seed number (PSN).

Days to maturity were recorded on plot basis and observations on other quantitative characters were taken from a sample of five randomly chosen plants per plot and averaged for per plant values. Capsule width was measured with the aid of a dial thickness gauge (Make: Mitutoyo no. 7301). A sample of five mature closed capsules was selected randomly from mid portion of plant and the observations on the capsule dimensions (length and width), seed number per capsule, weight of 1000 seed as well as capsule traits related to shattering were recorded. The data for capsule split before drying of capsules (CS-1) was obtained before sun drying the capsules as extent of split between the carpel exposing the membranes but not exposing the seed. This was measured from base to top of the seed chamber along the suture. Capsule split after drying of capsules (CS-2) was measured as extent of split between the carpels exposing the membrane but not exposing the seed after sun drying the capsules for 10 days after harvest. This is measured from base to top of the seed chamber along the suture for the capsules sampled for CS-1. Capsule open before drying of capsules (CO-1) was measured before sun drying the capsules as extent of opening between carpel with membranes opening enough to expose the seed and or seed chamber. This was measured from base to top of seed chamber along the placenta for capsules sampled for CS-1. Capsule open after drying of capsules (CO-2) was measured as the extent of opening between carpel with membranes opening enough to expose the seed and or seed chamber after sun drying the capsules for 10 days after harvest. This is measured from base to top of seed chamber along the placenta for capsules sampled for CS-2. The retained seed number (RN) was recorded as the total number of seeds retained in the capsule after the capsule has been inverted and twirled. This was also recorded for five mature capsules selected randomly from mid portion of plant followed by sun drying the capsules for 10 days. Retained seed weight (RW) was recorded as the total weight of seeds retained in the capsule sampled for RN. Unattached seed number (UN) was recorded as the total number of seeds released from the capsule after the capsule has been inverted and twirled. This is measured for five mature capsules sampled for RN. Unattached seed weight (UW) was recorded as the average weight of seeds released from the capsule sampled for UN. Potential seed number (PSN) was recorded as the total number of seeds for five randomly selected capsules from the mid portion of plant per observation. For this the capsules were collected between physiological maturity (the time when $3/4^{th}$ of the seed in the capsule still on the plant is mature) and harvest maturity (first dry capsules). Potential seed weight (PSW) was recorded as the total weight of seeds sampled for PSN.

The observations recorded for the capsule shattering related traits were then used to compute the following six shattering parameters, the evaluations of which are described as follows:

I. Extent of Capsule Split (ECS%) = [(CS-2) – (CS-1) / CL] × 100
II. Extent of Capsule Open (ECO%) = [(CO-2) – (CO-1) / CL] × 100
III. Upright Shatter Resistance (USR%) = [(UW + RW) / PSW] × 100
IV. Inverted Shatter Resistance (ISR%) = [RW/ PSW] ×100
V. Capsule Constriction (CCON%) = (RN /PSN) × 100
VI. Shaker Shatter Resistance (SSR%) = [(PSW - UW)/ PSW] ×100

The six shattering parameters were computed based on Langham (1998) and modified for the present study. The phenotypic and genotypic coefficient of variability was computed as per Burton and Vane, 1953. Heritability in broad sense was estimated using the components of variance as suggested by Hanson *et al.* (1956). Genetic advance was worked out as per the formula given by Johnson *et al.* (1955). Correlation coefficients for yield and yield components were evaluated utilizing the formula suggested by Aljibouri *et al.*(1958). Genetic

diversity in the material was analyzed using Mahalanobis D^2 statistic Rao(1952) and the varieties were grouped into different clusters according to Tocher's method. The genotypes were then divided into three groups for the 6 parameters, based on the index score method Singh and Chaudhary,(1977). Based on the index score the sesame genotypes under study were classified as non-shattering (NoS), semi-shattering (SeS) or super-shattering (SuS) types.

Results and Discussion

Except for branch number per plant (B/P), capsule width (CW) and 1000-seed weight (TSW), the analysis of variance revealed significant difference between the sesame genotypes for all the characters studied. This indicated the presence of wide genetic variability among the genotypes for effective selection. High magnitude of variation in the experimental material was reflected by high values of mean and range for almost all the characters (Table 1).

High values of phenotypic (PCV) and genotypic (GCV) coefficients of variation were noted for capsule number per plant (C/P), capsule split before drying (CS-1), capsule opening before drying (CO-1), unattached seed weight (UW), retained seed weight (RW), seed weight per capsule (SW/C), potential seed weight (PSW), unattached seed number (UN) and retained seed number (RN). This indicates relatively higher contribution of these characters towards genetic variability. For all characters PCV was greater than GCV estimates because former includes variation due to interactions (Table 1). The narrow difference between PCV and GCV for days to maturity (DM), capsule number per plant (CN/P), capsule length (CL), capsule width (CW), capsule split before (CS-1) and after drying (CS-2), capsule opening before (CO-1) and after drying (CO-2), unattached seed weight (UW), retained seed weight (RW), seed weight per capsule (SW/C), unattached seed number (UN), as well as potential seed weight (PSW) and seed yield per plant (SY/P) indicated that these characters were less affected by environment. Further high GCV for retained seed weight (RW) and number (RN), capsule split and opening before drying (CS-1 and CO-1), unattached seed weight (UW), seed weight per capsule (SW/C), potential seed weight (PSW), unattached and retained seed number (UN and RN) indicates presence of better scope of genetic improvement in these traits which could be achieved using simple selection procedures. None of the reports indicated higher values of PCV and GCV simultaneously for the traits state above. However higher value of both PCV and GCV for number of primary branches was reported by Narayanan and Murugan (2013)**,** Bharathi *et al.* (2014) and Gadisa *et al.*(2015). For all the characters, PCV was higher than GCV and similar type of result was reported by Ahadu (2012) and Narayanan and Murugan (2013). This implies that the characters had interacted with the environment to some extent for their expression.

The heritability estimates obtained were high for all the characters studied (Table 1). The heritability estimates ranged from 80.70 per cent in plant height to 99.87 per cent in potential seed weight indicating varied seasonal effect on character expression. High estimates of heritability (>60 per cent) was obtained for all characters indicating predominance of heritable components of variation suggesting effectiveness of selection on the basis of phenotypic expression of the traits. High heritability for one or more characters was also reported by Banerjee and Kole (2011)**,** Tripathi *et al.*(2013) and Gadisa *et al.*(2015). Contradictory results have also been found in some cases, which might be due to the number of genotypes studied, variability present in the population and the type of environment in which the varieties were evaluated. The genetic gain (as percentage of mean) was high for all the traits except DM, PH, CL, CB and CS-1 thus points to the predominance of additive effects Panse(1957) and can be taken as unit characters for effective selection Johnson *et al.(*1955) and Swarup and Chaugale(1962**)**. Estimates of heritability and genetic advance in combination are more important for selection than heritability alone. High heritability estimates coupled with high genetic advance was obtained in all the quantitative traits except for DM, PH and CW. Among the shattering related characters four traits *i.e.* capsule split before drying (CS-1), retained seed weight (RW), unattached seed number (UN) and retained seed number (RN) recorded high heritability with high genetic advance which indicated the presence of additive gene effects. This clearly indicates that phenotypic selection in the desired direction might be quite effective for these four shattering related characters. Reports of high heritability coupled with high genetic advance for one or more characters in sesame was also reported by Gadisa *et al.* (2015), Shabana *et al.* (2015) and Mahmoud and Zeinab (2015).

Yield is a complex quantitative trait, greatly influenced by environmental fluctuations. Hence, selection based on yield performance alone may indicate a biased result and lead to ambiguity. A study of nature and degree of association of component characters with yield assumes greater importance for fixing up characters that play a decisive role in influencing yield. Selection would therefore be more effective, if it is based on component characters rather than directly on yield.

Correlation coefficient analysis measures the mutual relationship between various characters and is used to determine the component character on which selection can be done for improvement in yield. In case of genotypic correlation, highest positive significant association (1.111) was found between plant height and seed yield per plant whereas lowest positive significant association (0.334) was found between capsule split before drying and capsule opening after drying. Similarly in case of phenotypic correlation highest positive significant association (0.978) was found between plant height and seed yield per plant (Table 2). At phenotypic level seed yield showed a highly significant and positive correlation with B/P, C/P, UN, RN and TSW. Capsule number per plant, the most important yield component, showed significant positive correlation with PH, UW, RW, RN and TSW. Plant height showed significant positive correlation with UW, RW and TSW. Capsule split as well as capsule open before and after drying, seed retention in the capsule, weight of retained and detached seeds are important characters that determine the shattering habit of sesame capsules. Capsule split before drying exhibited significant positive correlation with CS-2, CO-1 and CO-2. Capsule split after drying showed significant positive association with CS-1 and CO-2. Capsule opening before drying showed significant positive association only with capsule split before drying. Capsule opening after drying exhibited significant positive association with CS-1, CS-2, RW and UW. The unattached seed weight showed significant positive correlation with C/P, RW, SW/C, PW, UN, RN and PSN. Retained seed weight per capsule exhibited significant positive correlation with capsule per plant, unattached seed weight, retained seed number and seed number per capsule. Seed weight per capsule showed significant positive association with UW, PSW, UN, SN/C and PSN at both genotypic and phenotypic level. Potential seed weight exhibited positive correlation with UW, UN, SN/C and PSN. At both genotypic and phenotypic levels seed number per capsule exhibited significant positive association with unattached seed weight, seed weight per capsule, potential seed weight, unattached seed number and retained seed number. The character potential seed number exhibited significant positive correlation with UW, SW/C and PSW. At both genotypic and phenotypic levels thousand seed weight showed positive significant association with branches per plant, capsule per plant, plant height, and unattached seed number. Similar results were reported by Sumathi *et al.* (2007) and Shekhawat *et al.*(2013). SY/P showed a highly significant and positive correlation with B/P, C/P, PH, USN, RSN and TSW. Similar results of highly significant and positive correlation of SY with component traits were also obtained by Fazal *et al.* (2011) and Ismaila and Usman (2012).

The clustering method proposed by Tocher Rao (1952), using the generalized Mahalanobis distances (D^2) divided the thirty five genotypes into eleven clusters (Table 3). Genotypes of cluster three and four were the most genetically related, the distance between them being of a lesser magnitude (D^2= 476.15). The most genetically divergent genotypes were from cluster two and four, presenting greater distances (D^2= 2958.60). Among the genotypes CO-1 and Uma recorded the maximum distance (D^2= 3914). Therefore it is expected that crosses between genotypes of cluster II with genotypes of cluster IV will give rise to high yielding segregants, because of highest inter-cluster distance.

A perusal of the results on cluster means for yield and yield components (Table4) revealed considerable differences between the clusters for all characters under study. High C/P, SW/C and PSW were noticed for cluster IV comprising of 6 genotypes. However the earliest genotype possessing maximum branches per plant and retained seed number were for cluster VI, while maximum values for plant height, capsule width and thousand seed weight was noticed for cluster VIII indicating the desirability of genotypes from these clusters for improvement of respective traits.

Information on the relative contribution of various plant characters towards divergence has also been reported to aid the breeder in choice of parents for hybridization and effective selections in the advance generations (Venkatesh *et al.,* 2016). It was revealed that potential seed weight had the highest (48.91%) contribution to total divergence followed by capsule split before drying (Table 5). Contribution of the remaining characters to total divergence was, however, relatively low. Contribution of characters to divergence depends on the number of characters studied and the influence of the environment on the expression of the characters as reported by Ahadu (2012), Baraki *et al.,* (2015) and Kiranmayi *et al.,* (2016).

Capsule shattering resistance in a crop is likely to result from the combination of several characters. Among many characters contributing for shatter resistance in sesame, capsule opening and seed retention capacity of mature dry capsule is important Langham(1998). Information on six parameters of capsule shattering was recorded (Table 6), which indicated that the extent of capsule split (ECS %) along the suture ranged from 1.30% in Rama to 86.82% in Rajeswari with an overall mean of 19.74%. The extent of capsule opening (ECO %) exposing the membrane and seeds ranged from 0.87% in Nirmala to 62.70% in Thilak. The values for upright shatter resistance

(USR%) ranged from 17.07% (Phule Til-1) to 147.52% (Thilak) while inverted shatter resistance (ISR%) ranged from 1.06% in RT-362 to 60.99% in Hima. Capsule constriction (CCON%) ranged from 2% (RT-362) to 50.72% (GT-10). Shaker shatter resistance (SSR%) ranged from 1.76% (Thilak) to 98.21 % (Phule Til-1) with an overall mean of 49.81%. The genotypes were scored for these parameters following index score method (Singh and Chaudhary, 1977) and on the basis of the total score, the genotypes RT-127, Amrit and Usha recorded the minimum score of 7 while the maximum score of 15 was recorded by Thilak. Based on the total index score for these six parameters the 35 genotypes were further grouped into the Low (<10), Medium (10-12) and High (>12) score groups. The genotypes in low score group are grouped as non-shattering type, in medium group semi shattering and under high group as super shattering types. On grouping all the 35 genotypes into three groups based on the six parameters only three genotypes (Hima, Krishna and Thilak) were grouped as super shattering types. This may be due to a very low percent of capsule constriction as observed from Table 6. Nine genotypes (CO-1, CUMS-17, JLT-408, Prachi, Rama, Rajeshwari, RT-346, GT-10 and Savitri) were grouped as semi shattering types. It is observed that these genotypes recorded low to medium capsule opening and capsule constriction. This character helps in retaining the seeds within the capsule on maturity and easy release of seeds on inverting. Even though the genotypes Krishna and Thilak were grouped under the super shattering types they recorded high seed yield. This may be due to their high mean values for plant height, capsules number per plant, 1000-seed weight, seed number per capsule and capsule length. Similar observations for super shattering characters were observed by Maneekao *et al.* (2001). The rest 23 genotypes were grouped as the non shattering types.

In spite of the narrow genetic base, the characterization based on the combination of the information derived from morphological and capsule traits related to shattering was useful in the maximization of the genetic potential of the gerplasms under study, since it allowed their discrimination, with the identification of very similar and divergent genotypes. The variability found in the traits branch number per plant, capsule number per plant, unattached seed number, retained seed number and thousand seed weight and seed yield can be exploited in breeding programs for developing high yielding semi shattering sesame genotypes.

There was high genetic variability among the genotypes for seed yield and other traits as well as capsule shattering characters. The genetic gain was high for 15 traits except days to maturity, plant height, capsule length, capsule width and capsule split before drying and hence these 15 traits can be taken as unit characters for effective selection and can be exploited in breeding programs for developing high yielding sesame genotypes. Regarding contribution of characters to genetic divergence potential seed weight followed by capsule split before drying and retained seed number had the highest contribution to total divergence. The high performing non-shattering genotypes (CUHY-57, Nirmala, RT-351, Smarak, Swetha, TKG-22 and Uma) and super-shattering genotypes (Krishna and Thilak) are recommended in recombination breeding program to develop high yielding semi shattering sesame genotypes. Also the contrast groups of sesame genotypes for these capsule shattering traits form an excellent material for allele mining and can be used for QTL mapping as well as gene discovery.

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Table 1. Descriptive statistics along with genotypic and phenotypic coefficient of variation, genetic advance and genetic advance percentage over mean for 20 characters in sesame.

Characters	Range	Mean	GCV	PCV	Heritability%	GA	GA as % over Mean
DM	76.33-97.33	83.71	6.73	7.21	87.27	9.27	11.07
B/P	1.89-4.89	3.54	18.99	20.37	86.95	1.10	31.17
C/P	18.57-45.30	28.56	29.32	30.07	95.11	14.53	50.33
PH	71.63-114.37	89.37	10.88	12.12	80.70	15.38	17.21
CL	18.67-29.33	24.48	8.84	9.01	96.21	3.74	15.26
CW	5.20-8.46	6.78	9.99	10.19	96.21	1.17	17.25
CS-1	0.60-26.80	15.66	48.89	49.11	99.14	13.41	85.68
CS-2	6.60-29.40	20.62	26.71	26.96	98.10	9.60	46.55
CO-1	1.07-9.40	5.23	46.90	47.67	96.77	4.25	81.20
CO-2	4.60-19.67	9.47	34.08	34.86	95.57	5.55	58.63
UW	22.33-861.20	463.78	49.17	49.51	98.64	398.62	85.95
RW	14.60-495.57	192.96	56.32	56.98	97.69	189.06	97.98
SW/C	59.67-369.60	203.81	48.68	49.04	98.55	173.34	85.05
PSW	321.43-1832.33	1026.32	49.09	49.13	99.87	886.21	86.35
UN	10.00-278.00	142.96	50.71	51.12	98.39	126.56	88.53
RN	3.47-101.00	33.90	80.25	80.71	98.86	47.61	140.43
SN/C	13.40-67.00	40.02	33.22	35.49	87.65	21.91	54.75
PSN	67.00-339.00	201.05	34.63	36.11	91.97	117.51	58.45
TSW	1.63-3.55	2.72	15.76	17.16	84.27	0.69	25.46
SY/P	1.81-6.79	3.62	30.00	30.41	97.31	1.89	52.09

DM (Days to maturity), B/P (Branches per plant), C/P (Capsules per plant), PH (Plant height), CL (Capsule length), CW (Capsule width), CS-1(Capsule split before drying), CS-2 (Capsule split after drying), CO-1(Capsule open before drying), CO-2(Capsule open after drying), UW (Unattached seed weight), RW (Retained seed weight), SW/C (Seed weight per capsule), PSW(Potential seed weight), UN (Unattached seed number), RN (Retained seed number), SN/C (Seed number per capsule), PSN (Potential seed number), TSW (Thousand seed weight), SY/P (Seed yield per plant)

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Table 2. Phenotypic (above the diagonal) and genotypic (below the diagonal) correlation coefficients among yield and capsule shattering characters in sesame

Character	DM	B/P	C/P	PH	CL	CW	CS-1	CS-2	CO-1	CO-2	UW	RW	SW/C	PSW	UN	RN	SN/C	PSN	TSW	SY/P
DM		-0.082	-0.106	-0.178	-0.450**	-0.302	0.125	0.032	0.033	0.33	0.205	0.201	-0.031	-0.005	0.091	0.011	-0.084	-0.179	-0.193	-0.155
B/P	-0.101		0.489**	0.496**	0.219	0.07	-0.296	-0.073	-0.157	0.153	0.211	0.238	-0.102	-0.106	0.31	0.384*	-0.009	0.032	0.514**	0.518**
C/P	-0.108	0.561**		0.833**	0.028	0.185	-0.133	-0.207	-0.068	0.046	0.387*	0.366*	-0.05	-0.067	0.449**	0.412*	0.051	0.102	0.653**	0.832**
PH	-0.235	0.559**	0.964**		0.001	0.063	-0.142	-0.232	-0.095	-0.05	0.312	0.159	-0.114	-0.133	0.474**	0.381*	0.178	0.251	0.772**	0.978**
CL	-0.055	0.238	0.039	-0.014		-0.186	-0.095	0.305	-0.332	0.124	0.157	0.126	0.267	0.271	0.115	0.03	0.123	0.153	0.125	-0.007
CW	-0.347*	0.057	0.204	0.069	-0.201		0.211	0.104	0.177	0.193	0.183	0.055	0.151	0.156	0.282	0.206	0.047	0.045	-0.083	0.051
CS-1	0.137	-0.317	-0.134	-0.162	-0.099	0.221		0.636**	0.726**	0.328	0.075	0.025	0.167	0.161	0.064	-0.051	0.005	0.012	-0.314	-0.151
CS-2	0.028	-0.075	-0.214	-0.271	0.311	0.106	0.646**		0.247	0.479**	0.172	0.142	0.266	0.261	0.158	0.202	0.26	0.26	-0.207	-0.232
CO-1	0.032	-0.154	-0.076	-0.096	-0.339	0.187	0.737**	0.253		0.227	-0.146	-0.076	-0.001	-0.015	-0.098	-0.21	0.007	-0.031	-0.332	-0.11
CO-2	0.367	0.187	0.053	-0.048	0.12	0.2	0.334*	0.495**	0.24		0.305	0.373*	0.146	0.137	0.329	0.207	0.148	0.107	-0.031	-0.02
UW	0.219	0.218	0.401*	0.342*	0.163	0.187	0.078	0.175	-0.144	0.317		0.496**	0.596**	0.591**	0.891**	0.435**	0.375*	0.366*	0.291	0.312
RW	0.217	0.257	0.388*	0.178	0.125	0.055	0.027	0.146	-0.075	0.382*	0.505**		0.321	0.322	0.313	0.509**	0.315	0.289	0.156	0.213
SW/C	-0.038	-0.107	-0.057	-0.127	0.279	0.156	0.171	0.272	-0.009	0.154	0.603**	0.327		0.997**	0.449**	0.164	0.397*	0.38*	0.006	-0.105
PSW	-0.005	-0.11	-0.069	-0.145	0.277	0.159	0.162	0.263	-0.016	0.139	0.597**	0.326	1.005**		0.447**	0.182	0.407*	0.391*	-0.017	-0.121
UN	0.105	0.332	0.461**	0.522**	0.125	0.294	0.065	0.162	-0.099	0.341*	0.897**	0.325	0.455**	0.452**		0.429**	0.428**	0.448**	0.358*	0.447**
RN	0.012	0.414*	0.427**	0.427**	0.028	0.216	-0.053	0.206	-0.214	0.214	0.443**	0.515**	0.166	0.183	0.436**		0.582**	0.585**	0.261	0.435**
SN/C	-0.095	-0.008	0.072	0.199	0.141	0.065	0.005	0.284	-0.001	0.164	0.403*	0.342**	0.419*	0.435**	0.463**	0.618**		0.961**	-0.028	0.18
PSN	-0.198	0.031	0.118	0.289	0.17	0.053	0.014	0.28	-0.039	0.118	0.378*	0.307	0.393*	0.408*	0.469**	0.61**	1.001**		0.041	0.245
TSW	-0.239	0.594**	0.749**	0.906**	0.115	-0.091	-0.35	-0.237	-0.378	-0.052	0.329	0.161	0.006	-0.019	0.396*	0.284	-0.02	0.069		0.807**
SY/P	-0.161	0.579**	0.863**	1.111**	-0.006	0.053	-0.151	-0.235	-0.114	-0.018	0.317	0.219	-0.107	-0.123	0.456**	0.443**	0.195	0.26	0.911**	

* , ** significant by the t-test at 1% and 5% of probability, respectively. Values of 0.429 and 0.334 at 1% and 5 % of probability, for the phenotypic and genotypic correlation, respectively.

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Table 3. Average Intra-(Diagonal) and Inter-Cluster D^2 values for sesame genotypes

Clusters	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	Genotypes
I	261.41	661.40	1880.79	2645.03	884.92	808.25	1053.06	1508.64	1458.66	2203.19	2804.21	Subhra, Swetha, CUHY 57, Hima and Thilathara
II		281.55	1884.88	2958.60	623.77	1141.13	1039.47	1498.31	2020.29	2638.85	2600.35	CO-1, SSD-19, VRI-2, TKG-306, AKT-64 and Brijeswhari
III			337.67	476.15	1573.45	1047.38	678.51	583.80	658.38	704.67	650.29	RT-127, VRI-1, Rama, Kanak and Usha
IV				332.09	2494.97	1587.50	1078.35	982.91	710.50	671.20	754.38	Kalika, Savitri, RT-125, Amrit, Uma and TKG-22
V					245.34	653.29	1313.62	813.80	2189.70	2675.21	2030.14	GT-10, Prachi and Smarak
VI						328.53	1019.90	750.83	1346.56	1572.63	1741.42	CUMS-17, Krishna and Thilak
VII							333.96	995.78	585.57	671.45	1327.11	PT-1 and RT-346
VIII								340.11	1186.49	1460.09	859.08	Nirmala and RT-351
IX									-	582.01	1605.83	RT-362
X										-	1340.70	Rajeswari
XI											-	JLT-408

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Table 4. Cluster means for yield and yield attributing traits in sesame genotypes

CHARACTERS	CLUSTERS										
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Days to maturity	83.47	83.72	83.80	85.78	84.33	58.22	80.17	76.83	78.67	81.00	94.33
Branches per plant	4.04	3.22	3.13	3.65	3.69	4.04	3.28	3.66	1.89	4.00	4.00
Capsules per plant	30.85	21.17	23.39	303.03	38.48	36.11	21.60	44.22	19.67	21.23	35.57
Plant height (cm)	92.92	80.50	85.49	87.77	105.42	92.54	80.21	106.87	82.43	84.40	91.37
Capsule length (mm)	23.87	24.00	25.48	24.33	23.43	23.71	26.83	23.33	22.33	29.33	26.33
Capsule width (mm)	6.61	6.41	7.20	6.78	6.97	6.75	6.49	7.72	6.93	6.10	6.40
Capsule split before drying (mm)	4.57	20.77	20.59	17.48	20.65	6.15	14.50	21.30	10.00	3.93	26.80
Capsule split after drying (mm)	10.15	23.63	23.13	20.63	21.78	19.96	25.06	22.97	11.60	29.40	27.40
Capsule Open Before drying (mm)	3.32	7.07	5.85	5.38	6.60	2.89	3.76	5.30	5.50	1.07	9.40
Capsule split after drying (mm)	6.35	8.58	11.47	8.80	10.93	11.73	9.40	8.30	5.80	9.40	19.67
Unattached seed weight (mg)	318.88	198.18	618.71	657.84	363.33	618.22	146.16	712.60	345.00	540.00	861.20
Retained seed weight (mg)	155.85	109.37	184.79	277.00	213.67	282.89	182.40	168.37	16.20	75.00	449.97
seed weight per capsule (mg)	109.43	93.13	275.38	335.33	106.95	155.98	243.26	222.33	300.07	326.87	291.40
Potential seed weight (mg)	545.63	468.48	1386.84	1705.30	540.64	794.37	1227.07	1084.95	1525.87	1630.23	1432.33
Unattached seed number	100.96	55.71	197.29	168.18	156.29	193.33	50.00	237.54	115.00	180.00	250.00
Retained seed number	12.65	12.90	40.81	47.10	58.53	80.67	16.10	36.70	5.40	25.00	5.60
Seed number per capsule	22.47	33.71	45.84	45.37	47.87	51.71	31.83	33.74	54.00	60.60	40.20
Potential seed number	112.33	165.78	229.20	226.83	256.00	258.56	159.17	168.67	270.00	303.00	201.00
Thousand seed weight (g)	2.91	2.40	2.46	2.65	2.87	3.04	2.51	3.37	2.67	2.77	3.08
Seed yield per plant (g)	3.96	2.72	3.08	3.57	5.32	4.04	2.60	5.31	2.95	3.14	3.87

Table 5 . Relative contribution of characters studied towards genetic divergence in sesame genotypes

Character	Average D^2	Contribution (%)	Total rank (%)
Days to maturity	5.24	0.40	7.30
Branches per plant	5.17	0.39	7.10
Capsules per plant	17.49	1.32	5.59
Plant height (cm)	4.06	0.31	7.51
Capsule length (mm)	20.08	1.52	5.51
Capsule width (mm)	25.52	1.93	5.28
Capsule split before drying (mm)	94.47	7.14	3.32
Capsule split after drying (mm)	46.45	3.51	4.73
Capsule Open Before drying (mm)	11.77	0.89	6.04
Capsule split after drying (mm)	19.09	1.44	5.87
Unattached seed weight (mg)	62.32	4.71	3.84
Retained seed weight (mg)	40.31	3.05	4.57
seed weight per capsule (mg)	61.59	4.6	3.98
Potential seed weight (mg)	646.82	48.91	1.54
Unattached seed number	50.40	3.81	4.04
Retained seed number	92.56	7.00	3.45
Seed number per capsule	10.78	0.81	6.23
Potential seed number	37.77	2.86	4.62
Thousand seed weight (g)	23.85	1.80	5.10
Seed yield per plant (g)	46.74	3.53	4.38

Table 6. Performance of 35 sesame genotypes for six capsule shattering parameters

Variety	ECS%	ECO%	USR%	ISR%	CCON%	SSR%	Total index value
AKT-64	16.05 (1)	15.35 (1)	83.61 (2)	23.41 (2)	7.15 (1)	39.80 (2)	9
BRIJESWHARI	31.20 (2)	2.40 (1)	46.54 (1)	19.29 (1)	13.36 (1)	72.74 (3)	9
CO-1	6.36 (1)	5.45 (1)	100.45 (2)	49.08 (3)	2.77 (1)	48.63 (2)	10
CUHY 57	13.33 (1)	16.97 (1)	70.41 (2)	7.65 (1)	4.58 (1)	37.24 (2)	8
CUMS 17	46.46 (2)	22.15 (2)	98.38 (2)	19.78 (1)	29.84 (2)	21.40 (1)	10
GT-10	4.93 (1)	34.78 (2)	80.33 (2)	39.64 (2)	50.72 (3)	59.31 (2)	12
HIMA	35.25 (2)	29.25 (2)	134.44 (3)	60.99 (3)	35.82 (3)	26.55 (1)	14
JLT-408	2.28 (1)	38.99 (2)	91.53 (2)	31.40 (2)	2.79 (1)	39.87 (2)	10
KALIKA	14.81 (1)	12.21 (1)	52.41 (1)	15.45 (1)	22.47 (2)	63.04 (2)	8
KANAK	21.75 (1)	17.25 (1)	72.89 (2)	19.13 (1)	24.78 (2)	46.24 (2)	9
KRISHNA	59.47 (3)	25.07 (2)	104.20 (3)	39.31 (2)	29.44 (2)	35.12 (2)	14
NIRMALA	3.48 (1)	0.87 (1)	68.28 (2)	19.18 (1)	26.63 (2)	50.90 (2)	9
PRACHI	1.49 (1)	13.73 (1)	114.51 (3)	39.15 (2)	25.27 (2)	24.64 (1)	10
PHU1E TI1-1	6.58 (1)	8.35 (1)	17.07 (1)	15.28 (1)	3.17 (1)	98.21 (3)	8
RAJESHWARI	86.82 (3)	28.41 (2)	37.72 (1)	4.60 (1)	8.25 (1)	66.88 (3)	11
RAMA	1.30 (1)	40.52 (2)	72.57 (2)	12.12 (1)	26.52 (2)	39.55 (2)	10
RT-362	7.16 (1)	1.19 (1)	23.67 (1)	1.06 (1)	2.00 (1)	77.39 (3)	8
RT-125	2.29 (1)	22.29 (2)	52.88 (1)	17.83 (1)	19.05 (2)	64.95 (2)	9
RT-127	9.86 (1)	15.62 (1)	50.09 (1)	8.67 (1)	16.31 (1)	58.58 (2)	7
RT-346	70.98 (3)	33.17 (2)	36.81 (1)	14.43 (1)	17.87 (1)	77.62 (3)	11
RT-351	13.52 (1)	24.51 (2)	97.30 (2)	10.95 (1)	11.73 (1)	13.64 (1)	8
SAVITRI	41.14 (2)	31.71 (2)	75.22 (2)	28.67 (2)	18.94 (2)	53.45 (2)	12
SMARAK	7.73 (1)	7.73 (1)	129.06 (3)	39.81 (2)	9.46 (1)	10.74 (1)	9
SSD 19	4.44 (1)	5.08 (1)	18.99 (1)	4.03 (1)	3.45 (1)	85.04 (3)	8
SUBHRA	24.10 (1)	2.82 (1)	78.30 (2)	26.48 (2)	9.11 (1)	48.19 (2)	9
SWETHA	15.38 (1)	10.26 (1)	69.01 (2)	23.13 (2)	7.35 (1)	54.12 (2)	9
THILAK	66.76 (3)	62.70 (3)	147.52 (3)	49.28 (3)	33.56 (2)	1.76 (1)	15
THILATHARA	27.14 (1)	1.07 (1)	108.71 (3)	38.51 (2)	13.49 (1)	29.80 (1)	9
TKG-22	7.69 (1)	1.54 (1)	69.50 (2)	17.67 (1)	24.80 (2)	48.17 (2)	9
TKG-306	7.61 (1)	4.23 (1)	51.72 (1)	21.90 (2)	13.20 (1)	70.19 (3)	9
USHA	8.61 (1)	9.37 (1)	58.46 (1)	11.57 (1)	15.97 (1)	53.11 (2)	7
VRI-1	7.92 (1)	27.87 (2)	38.49 (1)	15.44 (1)	4.68 (1)	76.95 (3)	9
VRI-2	2.82 (1)	3.38 (1)	110.23 (3)	23.85 (2)	8.11 (1)	13.62 (1)	9
AMRIT	9.43 (1)	17.14 (1)	38.36 (1)	3.85 (1)	10.66 (1)	65.49 (2)	7
UMA	4.66 (1)	1.64 (1)	43.78 (1)	14.23 (1)	28.81 (2)	70.44 (3)	9
Mean	**19.74**	**17.07**	**72.67**	**22.48**	**16.63**	**49.81**	
Range	**1.30 - 6.82**	**0.87 - 62.70**	**17.07 -147.52**	**1.06 - 60.99**	**2.0 -50.72**	**1.76 - 98.21**	

The values in the parenthesis indicates the index score.