Multivariate Analysis for Yield and Yield Attributes in Sesame Germplasm (*Sesamum indicum* L.)

MAHALINGAM ANGAMUTHU[1]*, RAGHUL SUBRAMANIYAN[2], THALAPATHIRAJA TAMILMATHI[1], KASIRAJAN SUBRAHMANIYAN[3] and GAYATHRI PANDURANGAN[4]

[1]Regional Research Station, Tamil Nadu Agricultural University, Vriddhachalam, Tamil Nadu, India.
[2]Protection of Plant Varieties & Farmers' Rights Authority, New Delhi.
[3]Tamil Nadu Rice Research Institute, Tamil Nadu Agricultural University, Aduthurai, Tamil Nadu, India.
[4]Adhiparasakthi Agricultural college, Kalavai, Vellore, Tamil Nadu, India.

Abstract

Sesame is one of the important oilseed crops grown in India. Sesame is one of the oldest crops known to mankind because of its nutritious nature. The aim of the study is to determine the most diverse genotypes and important traits influencing sesame seed yield for the crop improvement. Hence, 57 sesame germplasm accessions were used to understand the variation and association among them based on the results of cluster analysis, correlation and principal component analysis (PCA). Cluster analysis showed that, all the 57 accessions were grouped into six clusters among which cluster I had more number of genotypes followed by cluster II and cluster IV. The correlation analysis, showed that single plant yield was positively correlated to days to first flowering and days to 50% flowering. The trait number of capsules per plant had positive correlation with plant height and number of branches per plant. The principal component analysis (PCA) revealed that traits plant height, days to 1st flowering, number of branches per plant and days to 50% flowering are the major principal component traits contributing to the 40 % of total variation among the cumulative variation of 77% from the yield contributing traits. Thus, overall multivariate analysis results reveals that the trait number of capsules per plant, capsule length and number of seeds per capsule were the major trait contributing to the seed yield in sesame. Thus, selection of heterotic parents would be highly useful in sesame hybridization programme.

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Introduction

Sesame (*Sesamum indicum* L.) is one the most ancient oilseed crop known to mankind, belongs to the family *Pedaliaceae* with chromosome number of 2n=26 and containing 16 genera with 60 species. The genus *Sesamum* consists of 36 species and *Sesamum indicum* L. is the most utilized species for seed and oil.[1] Sesame is called as "Queen of Oilseed crop" due to its stability and quality of oil. The excellent quality of oil is due to the presence of high amount of unsaturated fatty acid content i.e., Linoleic acid (35-45%) and Oleic acid (35-42%), low amount of saturated fatty acid content i.e., Palmitic acid (10-12%) and Stearic acid (5-7%). The stability of the sesame oil is due to the presence of antioxidants lignans (sesamin, sesamolin and sesaminol). Sesame consists of rich source of oil (45-60%), protein (18-25%), carbohydrate (12-14%), minerals and polyunsaturated fatty acid due to thus benefits, sesame is considered as nutritious oilseed crop.[2] The health benefits compounds viz., antioxidant, antiaging, antihypertensive, anticancer, cholesterol lowering and antimutagenic properties were present in the sesame.[3,4] The world sesame was cultivated under 14 million hectares area with production and productivity of about 7.2 million tons and 0.79 tons per hectare, respectively. In India, sesame was cultivated under 1.5 million hectares area, about 0.65 million tons of production and 0.43 tons per hectare productivity. In India, states cultivating sesame were Tamil Nadu, Telangana, Andhra Pradesh, West Bengal, Madhya Pradesh, Gujarat and Rajasthan. In worldwide, currently more than 50 countries were growing sesame and among them 30% was contributed by India. Despite of its quality and nutritional benefits, sesame was not preferred by many of the developed countries due to peculiar reasons viz., indeterminate growth habit, low harvest index, seed shattering effect and susceptible to diseases.[5]

In Tamil Nadu, more than 30 sesame varieties were released and notified for cultivation. Though most of the varieties were low yielding, indeterminate growth, seed shattering, susceptible to biotic and abiotic stress.6 Sesame breeding aims high yielding with resistance to biotic and abiotic stresses coupled with other traits would be preferred to achieve the goal. Thus, among the available germplasm or cultivar or advance breeding lines might be used as parents for hybridization programme to attain the desired outcome. Statistical analysis like variability, correlation, diversity and principal component analysis might be used to identify the variation and diversity among the genotypes. Thus, sesame breeding programme would be successful only when unraveling the true diversity and variability among the germplasms available. Further, based on the results the selection of parents would be effective for the crop improvement programme. Thus, the present study aims to reveal the diversity, association, variability and to identify the principal component responsible for the variation among set of 57 sesame germplasm for the selection of parents to involve in the hybridization programme.

Material and methods

The field experiment was conducted in Regional Research Station, Tamil Nadu Agricultural University, Vridhachalam, Tamil Nadu, India. A total of 57 Sesame germplasms were evaluated during *Kharif* 2022. The details of 57 sesame germplasm were presented in the Table 1. Each germplasm was grown as a separate row with the spacing of 30 x 10 cm and followed all the standard agronomic practices as per Tamil Nadu condition. Observation was recorded for eight traits viz., days to first flowering, days to 50% flowering, plant height (cm), number of branches per plant, number of capsules per plant, capsule length (cm), number of seeds per capsule and single plant yield (g). The obtained data was subjected to statistical analysis.

Table 1: Details of the sesame germplasm involved in the study

S.No	Genotype	S. No	Genotype
1	AT 375	30	EC 370541
2	AT 377	31	EC 370556
3	DS 10	32	EC 370727
4	DS 28	33	EC 370934
5	DS 35	34	EC 370992
6	DS 45	35	EC 542304

7	DS 51	36	GT 10
8	DS 56	37	IC 208652D
9	DS S4	38	IS 1162- B
10	EC 334968	39	JCS - DT-26
11	EC 34615	40	NPGR 10
12	EC 346158	41	NPGR 11
13	EC 346244	42	RMT 430
14	EC 346313	43	RMT 485
15	EC 346319	44	RMT 496
16	EC 346357	45	RMT 498
17	EC 346362	46	RMT 504
18	EC 346392	47	RMT 541
19	EC 346414	48	RMT 544
20	EC 346481	49	RMT 545
21	EC 346569	50	RMT 977
22	EC 346678	51	TBS 11
23	EC 346867	52	TBS 6
24	EC 351554	53	TKG 22
25	EC 351852	54	TMV 3
26	EC 358036	55	TMV 7
27	EC 359017	56	VRI (Sv) 2
28	EC 361730	57	VRI 3
29	EC 370540		

The observed data was subjected to statistical analysis like descriptive statistics including range, mean and standard deviation, cluster analysis, correlation analysis and principal component analysis (PCA). Grouping of sesame germplasm into various cluster was performed by using Tochers method as suggested.[7] Simple correlation analysis was done as per the standard method suggested.[8] The correlation among the traits was used to determine the magnitude of associations among the observed traits. Principal component analysis (PCA) was done as suggested.[9] Principal component analysis (PCA) was used to find out the characters which accounted more to the total variance. The statistical analysis like cluster analysis and principal component analysis (PCA) were carried out in R statistical software. The simple correlation was performed using software PYTHON programming language.

Results

A successful breeding program relies mainly on the magnitude of variability present and investigating the extent of diversity is vital for its conservation and utilization in crop improvement program.[10] The descriptive data of various yield related traits of 57 sesame germplasm were presented in Table 2.

Table 2: Descriptive statistics on sesame germplasm for yield and yield component traits.

Sl. No.	Traits observed	Mean	Std Dev	Min	Max
1	Days to 1st flowering	32.28	3.41	27.00	39.00
2	Days to 50% flowering	35.25	3.43	29.00	42.00
3	Plant height (cm)	102.38	18.61	67.00	132.80
4	No. of branches / plant	4.37	1.40	2.00	7.50
5	No. of capsules / plant	58.77	17.13	23.00	101.00
6	Capsule length (cm)	2.60	0.22	2.00	3.30
7	No. of seeds / capsule	64.16	7.25	34.00	95.00
8	Single plant yield (g.)	5.86	2.06	0.92	10.92

The trait days to first flowering ranged from 27 to 39 days with mean value of 32.23 days. The trait days to 50% flowering ranged from 29 to 42 days with mean value of 35.25 days. Plant height had ranged from 67 to 132.80 cm with mean value of 102.38 cm. The trait number of branches per plant ranged from 2 to 7.5 with the mean value of 4.37. Number of capsules per plant trait ranged from 23 to 101 with mean value of 58.77. The trait capsule length ranged from 2 to 3.30 cm with mean value of 2.60 cm. Number of seeds per capsule ranged from 34 to 95 with mean value of 64.16 and the trait single plant yield ranged from 0.92 to 10.92 g with mean value of 5.86 g. The cluster analysis was commonly used multivariant analysis to group the genotypes based on their similarities. In this study, 57 sesame germplasm were grouped into six clusters based on the Tochers method and presented in Table 3 and Fig 1.

Table 3: Clustering pattern among sesame germplasm for yield and yield component traits.

Cluster number	Number of genotypes	Constituent genotypes
I	35	AT 375, TBS 11, TBS 6, DS 51, DS 10, DS 28, DS 54, DS 56, EC 542304, DS 35, EC 334968, EC 346319, DS 45, JCS – DT- 26, EC 346481, EC 370992, IC 208652D, EC 361730, EC 346678, RMT 504, RMT 496, EC 346158, TMV 3, EC 370541, TMV 7, VRI 3, EC 346392, EC 351852, VRI (Sv) 2.
II	10	AT 377, EC 370934, RMT 977, TKG 22, IS 1162-B, RMT 430, RMT 544, RMT 545, RMT 485, EC 34615, RMT 541, RMT 498, EC 346867, EC 370540, EC 346313, EC 346357.
III	1	NPGR 11
IV	9	EC 370727, EC 346414, EC 370556, EC 346244, EC 351554, EC 346362, EC 358036, EC 346569, EC 359017.
V	1	GT 10
VI	1	NPGR 10

Among the clusters, cluster I was the major one with 35 genotypes, followed by cluster II with 10 genotypes, cluster IV with 9 genotypes and cluster III, V and VI had one genotype in each cluster.
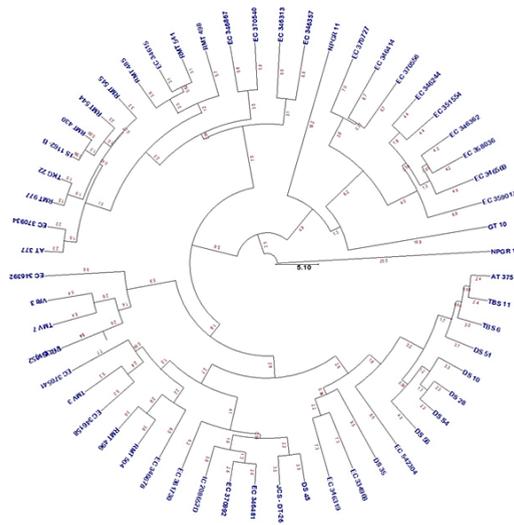
Fig. 1: Cluster analysis on sesame germplasm

Correlation analysis used to measure the genetic association between two or more traits and helps in indirect selection in plant breeding programme. The correlation estimate was presented in the Table 4.

Table 4: Correlation analysis on sesame germplasm for yield and yield component traits.

	Days to 50% flowering	Plant height (cm)	No. of branches / plant	No. of capsules / plant	Capsule length (cm)	No. of seeds / capsule	Single plant yield (g.)
Days to 1st flowering	0.92*	0.50*	0.39*	0.10	-0.37*	-0.06	0.32*
Days to 50% flowering		0.49*	0.28*	0.02	-0.34*	-0.09	0.32*
Plant height (cm)			0.60*	0.55*	-0.29*	-0.23	0.09
No. of branches / plant				0.68*	-0.41*	-0.16	0.00
No. of capsules / plant					-0.11	-0.01	0.08
Capsule length (cm)						0.51	0.10
No. of seeds / capsule							0.16

*Significant at 5% probability

The trait single plant yield had positive and significant correlation with days to first flowering (0.32) and days to 50% flowering (0.32). The trait capsule length had negative and significant correlation with days to first flowering (-0.37), days to 50% flowering (-0.34), plant height (-0.29) and number of branches per plant (-0.41). Trait number of capsules per plant recorded positive and significant correlation with plant height (0.55) and number of branches per plant (0.68). Number of branches per plant recorded positive and significant correlation with days to first flowering (0.39), days to 50% flowering (0.28) and plant height (0.60). The trait plant height had positive and significant correlation with days to first flowering (0.50) and days to 50% flowering (0.49).

Principal component analysis (PCA) is one of the multivariate method used to measure the contribution of each component to the total variance. The results of PCA were presented in Table 5.

Table 5: Principal component analysis on sesame germplasm for yield and yield component traits.

S.No	Traits observed	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
1	Days to 1st flowering	0.45	-0.40	-0.11	0.23	-0.04	0.23	0.15	-0.71
2	Days to 50% flowering	0.42	-0.44	-0.16	0.22	0.12	0.13	0.23	0.69
3	Plant height (cm)	0.45	0.12	0.17	0.07	0.56	-0.57	-0.32	-0.07
4	No. of branches / plant	0.42	0.31	0.25	0.08	-0.31	0.48	-0.56	0.13
5	No. of capsules / plant	0.29	0.37	0.53	-0.14	-0.04	0.02	0.69	0.00
6	Capsule length (cm)	-0.33	-0.21	0.47	0.10	0.61	0.49	-0.07	-0.02
7	No. of seeds / capsule	-0.18	-0.34	0.55	0.49	-0.42	-0.37	-0.08	0.04
8	Single plant yield (g.)	0.13	-0.49	0.26	-0.79	-0.14	-0.07	-0.16	0.01
	Eigen Values	3.19	1.60	1.39	0.71	0.54	0.27	0.21	0.07
	Proportion of Variance	0.40	0.20	0.17	0.09	0.07	0.03	0.03	0.01
	Cumulative Proportion	0.40	0.60	0.77	0.86	0.93	0.96	0.99	1.00

The principal component analysis (PCA) showed that PC1, PC2 and PC3 accounted for 77% of the cumulative proportion of variation. The eigen values of the principal components PC1, PC2 and PC3

were found to be greater than one and presented in the Scree plot (Fig. 2). In PC1, the traits viz., days to first flowering (0.45), days to 50% flowering (0.42), plant height (0.45) and number of branches per plant (0.42) were positively contributed for 40% of variation. The trait number of capsules per plant (0.37) had positive contribution in PC2 with 20% of variation. In PC3, the traits viz., capsule length (0.47) and number of seeds per capsule (0.55) were positive contribution with 17% of variation.

Discussion

Multivariate analysis using 57 sesame germplasm revealed that grouping of genotypes into various clusters, relationship of association among various yield attributing traits and major contributing traits for the total variance. The descriptive statistics indicates the presence of greater range among the traits indicates the presence of diverse genotypes in the sesame germplasm. Cluster analysis showed that 57 sesame germplasm was grouped into 6 clusters. Among the 6 clusters, cluster I, II and IV were the major cluster consisting of 35, 10 and 9 germplasm in each cluster, respectively. The other clusters, cluster III, V and VI are solitary (Fig. 1). Similar pattern of clustering was reported.[1,5,6]

Correlation analysis revealed that the trait single plant yield had positive associated with days to first flowering and days to 50% flowering. Similar results were reported.[1,2,11] [11]reported negative correlation for single plant yield with days to 50% flowering. All other traits had no significant correlation with single plant yield. The trait capsule length had negative association with days to first flowering, days to 50% flowering, plant height and number of branches per plant. Similar results were reported by[9] and trait capsule length with positive correlation with plant height and number of branches per plant was reported.[10-12] The trait number of capsules per plant had recorded positive correlation with plant height and number of branches per plant. Similar results were reported.[1,12-14] Trait number of branches per plant had positive association with days to first flowering, days to 50% flowering and plant height. The trait plant height recorded significant association with days to first flowering and days to 50% flowering. Similar results were reported.[1,2,12] The trait days to first flowering had positive correlation with days to 50% flowering.

Principal component analysis (PCA) is one of the multivariate statistical tools for investigating the factors majorly contributing to the total variation. The principal component analysis (PCA) revealed that three principal component PC1, PC2 and PC3 have accounted for 77% of total variation. The eigen value of all the three principal components had greater than one. The principal component traits in PC1 viz., days to first flowering, days to 50% flowering, plant height and number of branches per plant and contributed 40% of variation. The principal components traits in PC2 number of capsules per plant had major contribution of 20% of variation. The traits viz., capsule length and number of seeds per capsule had contributed of about 17% of variation. Similar results were reported.[5,13,15,16] Hence, importance has to be given to those traits which has more contribution towards variation while framing the crop improvement programme. Further, the identified diverse set of germplasm can be utilized in hybridization breeding program to obtain desirable traits and to develop high yielding genotypes.

Conclusion

Though high yielding sesame varieties were not much popular, because yield is a complex trait controlled by polygenic in nature. The results from multivariate analysis revealed that the trait number of capsules per plant, capsule length and number of seeds per capsule must be included in the selection criteria for the improvement of yield. The selection of heterotic parent was also one of the important objectives for hybridization breeding in sesame.

Conflict of Interest

The authors do not have any conflict of interest.

Data Availability Statement

This statement does not apply to this article

Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

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Author Contributions

- **Mahalingam Angamuthu and Raghul Subramaniyan:** Experiment, analysis, writing, and original draft preparation.
- **Mahalingam Angamuthu, Raghul Subramaniyan and Thalapathiraja Tamilmathi:** conceptualization, resources, validation and supervision.
- **Mahalingam Angamuthu and Kasirajan Subrahmaniyan:** Reviewing, and editing.

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