



Source-Sink Relationship Studies in Multicapsule Genotypes of Sesame

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i113147

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/107428>

Original Research Article

Received: 21/07/2023

Accepted: 28/09/2023

Published: 04/10/2023

ABSTRACT

A study was conducted to determine the source and sink relationship in multicapsule genotypes of sesame. Thirty-six multicapsule genotypes along with two single capsule genotypes as checks were used in this study. Data on source characters such as number of leaf axils, leaf area, SPAD chlorophyll, photosynthetic rate, plant height, stem girth was recorded at capsule formation stage. Similarly, data on sink related characters such as number of flowers per axil, number of capsules per axil, capsule length, breadth, seed weight, seed yield per plant, and oil content were recorded. There were 1 to 3 capsules per axil, genotypes, SC-500-1, PI-154298, JCS-1020, exhibited 3 capsules at every axil. The results indicated the source characters such as number of leaf axils per plant was significantly positively correlated with seed yield per plant, leaf area was significantly positively correlated with number of flowers per main stem, total capsule number per main stem and seed weight of the right capsule in the bunch of the capsules. SPAD chlorophyll was positively associated with, number of flowers per axil, number of capsules per axil and seed yield per plant. Photosynthetic rate was significantly associated with total number of capsules per main stem of the

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plant, oil content and test weight. There were 7 principal components which explained 80 of the variation presents in the genotypes. Characters such as number of flowers per axil, number of leaf axils per plant, number of capsules per axil in the main stem and capsule length, weight, seed weight of left and right capsules contributed for the variation. Variation in these characters distributed the genotypes across the axis in the PCA biplot. Genotypes such as SC-500, PI-154298 exhibited high capsules number per plant, capsules per axil, capsule length and capsule seed weight. This study indicated that the genotypes showing more than 1 capsules per axil have high leaf area, stem girth. These genotypes are potential source for utilization in yield improvement programmes.

Keywords: Sink relationship; sesame; genotypes; seed crop.

1. INTRODUCTION

Sesame (*Sesamum indicum* L., $2n=26$) is a major oil seed crop worldwide, with more than 96% of seed production accounted for by Africa and Asia [1]. Sesame is being cultivated and consumed in India since time immemorial for its the seeds have high nutritional value, due to protein quality and oil, and are also an important source of anti-oxidants compounds, like sesamol and sesamol, both with anti-hypertensive and anti-cancerous properties [2]. At present, Myanmar is the largest producer of sesame seeds in the world followed by India, China, Turkey, and Pakistan in Asia. In India, during 2020-21, sesame has been cultivated in an area of 17.50 lakh ha with a production of 9.58 lakh tones annually and productivity of 478 kg/ha. Being the fourth most important oilseeds crop in Indian agriculture, it is widely cultivated in the states of Uttar Pradesh, Rajasthan, Orissa, Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, West Bengal, Bihar, and Assam. In Telangana state, the crop is grown to an extent of 3899.4 ha with a total production of 7.62 lakh tonnes and productivity of 4.16 kg ha^{-1} [3]. It is mainly grown in Jagtial, Nirmal, Warangal and Nizamabad districts of Telangana state [3]. In sesame, flowers are produced in the leaf axils and later develop into capsules. Maximum number of flowers found at the leaf axil is 3, but all 3 flower may or may not form into capsules at an axil. However, genotypes from China, Isreal, Turkey have 3 capsules per leaf axil at each leaf axil over the length of the main stem. These genotypes are mostly have single stem with any branches. Indian genotypes have large extant of variation for capsule number per axil. Maximum number of capsules per leaf axil is 3 but may not be uniform at all the leaf axil along the length of the plant due to environmental variation linked to nutrition of the plant. Theoretically, a greater number of capsules/leaf axils per plant would result in a higher seed yield. The character

association studies in multicapsule genotypes of sesame are pivotal for understanding the genetic basis underlying this trait's variability. Such studies not only shed light on the complex interactions among different characteristics of the plant but also aid in the development of improved cultivars with superior capsule attributes. By identifying the correlations between capsule number and other source-sink significant traits, we can unravel the genetic factors responsible for enhanced seed production and formulate targeted breeding strategies. The correlation coefficient analysis indicated that plant height, number of branches, number of capsules per plant and 1000 seed weight had the significant positive effect on seed yield [4]. One of the approaches to increase the number of capsules is by promoting additional capsules at each axil. The number of capsules at each node (2 leaf axil in each node) may vary from two to six [5]. Genotypes bearing a greater number of capsules at each axil have a yield advantage compared to genotypes with single capsules. Cultivated varieties in China, Korea, and elsewhere are predominated by multi capsules at each leaf axils on single stem plants [5]. Genotypes with additional capsules per leaf axil are needed since theoretically, plants bearing more than one capsule at each axil will add a greater number of capsules per plant than one capsule in each leaf axil, which consequently would result in more seed yield. Yield is the end product of multiplicative interaction between various yield components and source characters such as leaf number, leaf area, SPAD chlorophyll content, photosynthetic rate and stem girth. This necessitates a thorough understanding of character association by each character on seed yield [6-8]. This research paper aims to comprehensively investigate source characters of multicapsule genotypes of sesame, unraveling the character associations that can influence yield. The knowledge generated through this study will not only enhance our understanding of

sesame genetics but also pave the way for the development of high-yielding, resilient cultivars that can meet the growing demands of the global sesame industry, ensuring food security and economic prosperity for regions dependent on this remarkable crop. With this background, the present study was taken up with the main objective to analyze the character association analysis for seed yield and its related traits in a collection of 36 genotypes through correlations, path coefficient analysis and principal component analysis.

2. MATERIALS AND METHODS

Experimental site: The experiment was carried out at ICAR-Indian Institute of Oilseeds Research, Narkhoda farm, Hyderabad (17° 15' 30. 1608" N longitude, 78° 19' 11. 1324" E and altitude 569 meters above sea level) during summer, 2023.

Experimental materials and design: The experimental material consisted of 36 sesame genotypes including four checks that were collected from ICAR-Indian Institute of Oilseeds Research (IIOR). The trial was laid out in Randomized Block Design (RBD) with three replications. Seeds of each genotype was sown in rows by hand on a separate plot size of 6.75 m² (2 rows x 5m row length x 45cm between rows and 15cm between plants within

rows). Other cultural practices were followed as recommended for the area and fertilizers are applied at the rate of 30:30:20 NPK (kg/ha).

Data collection: The source characters which help in indirect estimation of photosynthates are number of leaf axils per plant, leaf area, SPAD chlorophyll, photosynthates assimilation rate, stem girth and plant height. Five plants per plot were randomly selected and labelled to record the values of the all the traits during capsule formation stage (approximately 50 days after sowing).

Sink characters such as number of flowers per axil in the main stem (NFAMS), number of capsules per axil in the main stem (NCAMS), total number of capsules per plant in the main stem (TCMS), capsule length, breadth, and seed weight per capsule of middle capsule (MSMCL, MSMCB, MSMCW) and adjacent capsules of multicapsule bunch at axil designated as left capsule (MSLCL, MSLCB, MSLCW) and right capsule (MSRCL, MSRCB, MSRCW) as represented in the Fig. 1 were recorded for main stem from the r andomly selected plants. Seeds yield per plant was recorded by harvesting 5 selected plants and harvest index, oil content and test weight were estimated. Phenological traits such as days to flowering, days to maturity were recorded over the plot by observation.

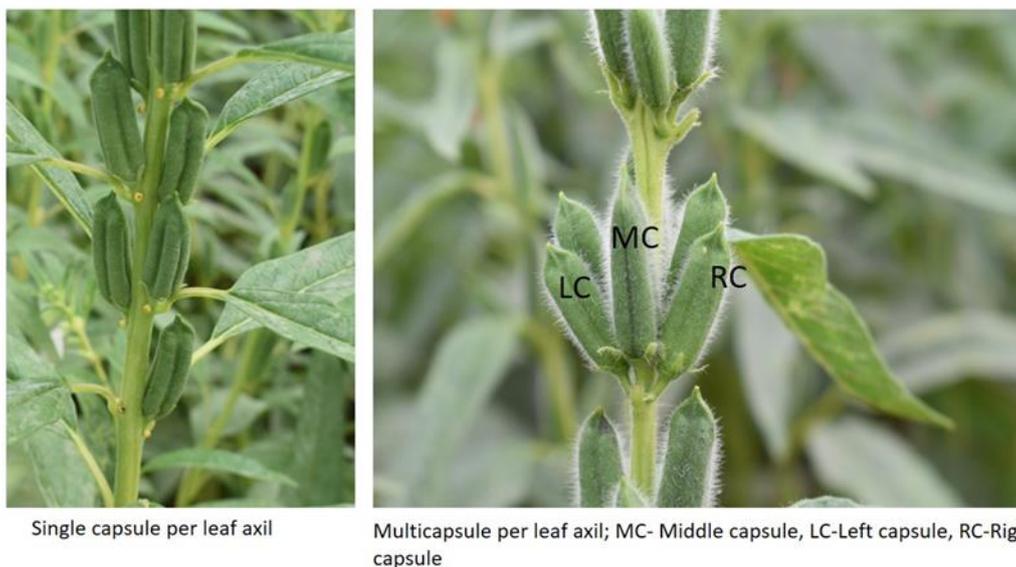


Fig. 1. Pictorial representation of genotypes with single capsules per axil, genotypes with multicapsules per axil, middle caspsule at the node (MC), left capsule at the node (LC) and right capsule at the node (RC)

Data analysis:

Correlation analysis: Estimation of the phenotypic and genotypic correlation coefficients were computed following the procedures suggested by Falconer [9] from corresponding variance and covariance components. The significance of phenotypic correlation coefficients was tested by comparison of estimated values with the tables of correlation coefficients [10] at 5 per cent and 1 per cent level of significance with $n-2$ degrees of freedom where 'n' is the number of genotypes used in the experiment.

Principal component analysis: The principal component analysis (PCA) was carried out according to Banfield's approach (1978). Principal component analysis (PCA) was used to find out the characters, which accounted more to the total variation. The eigen values and eigen vectors were computed from data matrix. Eigen values define the amount of total variation that is displayed on principal components. The proportion of variation accounted for each principal component (PC) is expressed as the eigen value divided by the sum of the eigen values.

3. RESULTS AND DISCUSSION

Correlation analysis: Correlation between the source- sink characters were studied using Pearson's correlation coefficient (Table 1.). Number of leaf axils in the main stem per plant (NLAMS) are the major source for production of photosynthates which gets accumulated in the capsules formed at that axil. A significant positive association was found between NLAMS and seed yield per plant. Higher the number of leaves per plant resulted in higher seed yield per plant. However, NLAMS was negatively but significantly associated with capsule length, breadth and capsule seed weight. Leaf area was significantly positively associated with number of flowers per axil, total number of capsules per plant, seed weight per capsule (right capsule) and test weight. SPAD chlorophyll was positively correlated with number of flowers per axil and number of capsules per axil. Higher the chlorophyll content, there is high probability of capsule formation from each flower at the axils without any flower drop. Chlorophyll content is positively associated capsule breadth and seed yield per plant [11]. Photosynthates assimilation rate is positively associated total number of capsules per plant, test weight and oil content. Higher SPAD chlorophyll content in the leaves

leads to higher photosynthetic assimilation rate in the genotypes. The photosynthetic assimilates are drawn towards development of sink s (capsules). Number of capsules per plant including branches is directly and significantly correlated with the seed yield per plant than *per se* number of capsules per plant from the main stem (Fig. 2). These results significantly indicated that more than one capsules at axil resulted in higher seed yield per plant. Gopika *et al.* 2022 also concluded that physiological characters are directly associated with number of capsules per plant and seed yield per plant.

Seed yield per plant was significantly positively correlated with number of leaf axils per plant and photosynthetic rate. Pandey *et al.* [12] studied correlation between physiological characters and yield characters in normal sesame genotypes and concluded with similar result. Number of leaf axils per plant was significantly positively correlated with seed yield per plant and negatively correlated with leaf area which indicates that genotypes with more number of leaves have smaller leaves and low seed yield per plant. Similar observation was reported by Fang *et al.* [13]. Capsule length positively correlated with capsule breadth of left and right capsule only but there was no significant relation in the middle capsule. Capsule weight was significantly positively correlated with capsule length in the middle capsules, however in adjacent capsules, both length and breadth are positively correlated with higher seed weight of the capsule. Similar observations were made by Ozcinar *et al.* [14], Teklu *et al.* [15]. Seed yield per plant was positively and significantly associated with capsule seed weight of middle capsule only and negatively but non significant association was found between capsule seed weight of adjacent capsules. In the present experiment, it was noted that middle flower at the axil open first (1-2 days earlier) over the adjacent flowers and would probably draw more photosynthates to develop into capsule. Middle capsule is bigger in terms of length and breadth over the adjacent capsules was recorded in the present study. Therefore middle capsule at the axil is the primary capsule which contributes towards seed yield per plant [16,17].

Principal component analysis: The principal component analysis (Table 2) revealed that seven principal components, have accounted for 80.50% of the total variation. The first two principal components PC1 and PC2 contributed more to 50 % of the total variation. Therefore, in

this study, differentiation of the genotypes into different cluster was because of a cumulative effect of a number of characters rather than the contribution of specific few characters (Fig. 3).

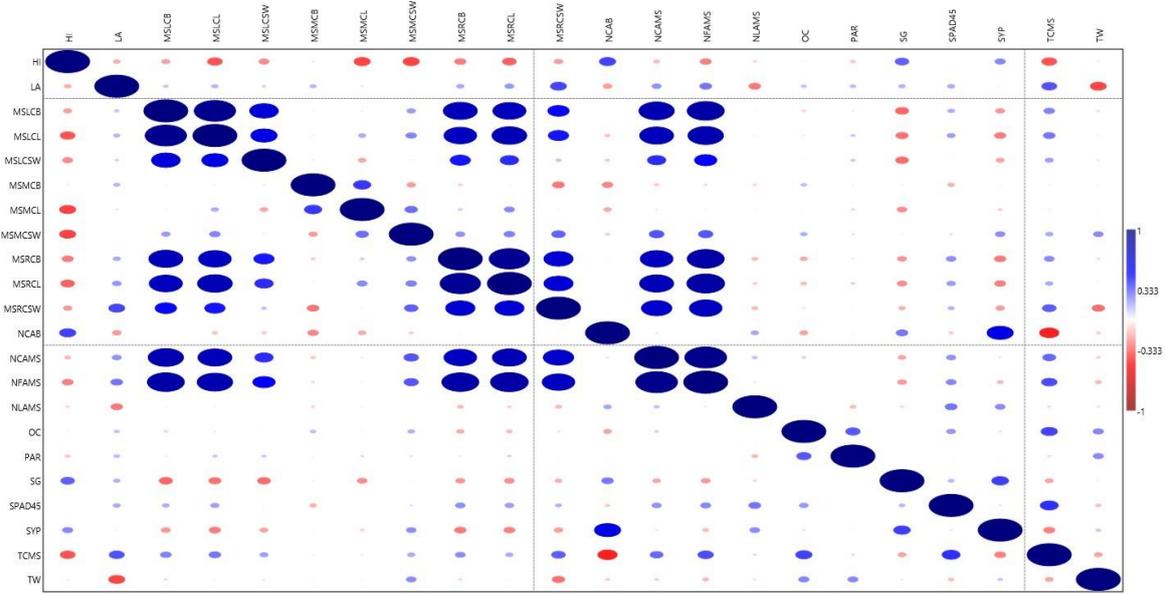


Fig. 2. Heatmap of correlation coefficient of the between the yield and yield components comprising of source and sink characters

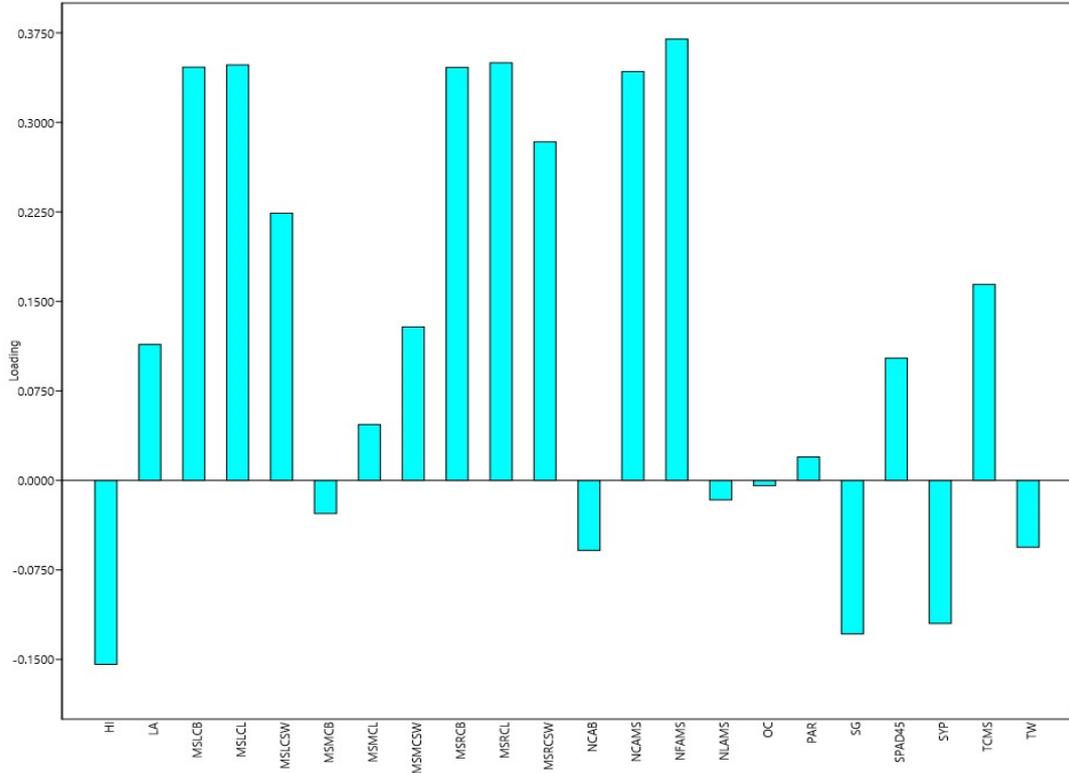


Fig. 3. Characters contribution for the PCA loading values

Table 1. Correlation coefficient (r) between source and sink characters in multicapsular sesame

Source-Sink characters	NLAMS	LA	SPAD Chlorophyll	PAR	SG
NFAMS	0.048	0.269**	0.231*	0.009	-0.204
NCAMS	0.119	0.210	0.213*	-0.014	-0.178
NCAB	0.173	-0.198	-0.110	-0.029	0.266**
TCMS	0.073	0.339**	-0.183	0.370**	-0.080
MSMCB	-0.084	0.145	-0.152	0.032	0.032
MSMCL	-0.035	0.049	0.002	0.076	-0.224*
MSMCSW	-0.012	0.015	0.065	-0.072	0.030
MSRCB	-0.136	0.167	0.221*	0.045	-0.209
MSRCL	-0.094	0.202	0.197	0.088	-0.222*
MSRCSW	-0.137	0.363**	0.143	-0.023	-0.157
MSLCB	-0.030	0.112	0.157	0.039	-0.301**
MSLCL	-0.035	0.146	0.188	0.105	-0.277**
MSLCSW	-0.014	0.087	0.022	0.103	-0.290**
SYP	0.226**	-0.034	0.378**	0.061	0.021
TW	-0.068	-0.362**	0.042	0.236*	0.232*
HI	-0.084	-0.156	-0.017	-0.117	0.311**
OC	0.000	0.120	0.202	0.327**	0.014

** Significant at 0.01: *Significant at 0.05 NLAMS =Number of leaf axils/main stem, NLAB= Number of leaf axils/branches, NFAMS= Number of flowers/axil in main stem, NFAB= Number of flowers/axil in branches, NCAMS= Number of capsules/axil in main stem, NCAB= Number of capsules per plant including branches, TCMS= Total number of capsule/main stem, TCPB= Total number of capsule/branches, MSMCL(mm) = Capsule character length /middle capsule, MSRCL(mm) = Capsule character length /right capsule, MSLCL(mm) = Capsule characters length /left capsule, MSMCW(mm) = Capsule characters width /middle capsule, MSRCW(mm) = Capsule characters width / right capsule (main stem), MSLCW(mm) = Capsule characters width / left capsule , MSMCSW(mg) = Capsule seed weight / middle capsule, MSRCSW(mg) = Capsule seed weight /right Capsule, MSLCSW(mg) = Capsule seed weight /left Capsule, SG= Stem girth (cm), SPAD= SPAD chlorophyll, PAR= Photosynthetic assimilation rate, LA= Leaf area, TW= Test weight (g), HI= Harvest index(%), SYP= Seed yield/plant (g).

Table 2. Eigen values and factor lodgings of the principal components analysis

PC	Eigen value (%)	% Variance	Cummulative % variance				
1	6.54	29.75	40.66				
2	2.40	10.91	49.07				
3	1.85	8.40	57.00				
4	1.74	7.93	63.94				
5	1.52	6.94	70.60				
6	1.46	6.66	76.25				
7	1.24	5.64	80.51				
PC Loadings							
CHARACTERS	PC1	PC2	PC3	PC4	PC5	PC6	PC7
NLAMS	-0.016	0.129	0.149	0.118	-0.564	-0.052	0.402
LA	0.114	-0.145	0.350	-0.203	0.452	-0.053	0.083
SPAD45	0.102	-0.019	0.454	-0.011	-0.206	0.053	0.147
PAR	0.020	-0.123	-0.034	0.285	0.318	0.357	-0.019
SG	-0.129	0.217	0.304	0.089	0.350	0.002	0.048
NFAMS	0.370	0.129	0.061	0.028	0.016	0.019	0.032
NCAMS	0.343	0.169	0.092	0.084	-0.015	0.040	0.044
NCAB	-0.059	0.533	-0.027	0.100	0.085	-0.044	0.183
TCMS	0.164	-0.288	0.415	-0.092	-0.191	0.073	-0.017
MSMCB	-0.028	-0.284	-0.139	0.011	0.261	0.019	0.599
MSMCL	0.047	-0.286	-0.173	0.200	0.118	-0.490	0.308
MSMCSW	0.129	-0.021	0.131	0.463	-0.042	-0.369	-0.246
MSLCB	0.346	0.098	-0.139	0.009	-0.027	0.150	0.116
MSLCL	0.348	0.002	-0.136	0.064	-0.005	0.094	0.131
MSLCSW	0.224	-0.012	-0.171	-0.032	-0.095	0.396	0.135
MSRCB	0.346	0.105	-0.091	-0.026	0.083	-0.027	-0.046
MSRCL	0.350	0.069	-0.115	0.045	0.115	-0.084	0.018
MSRCSW	0.284	0.095	0.161	-0.112	0.135	-0.227	-0.271
SYP	-0.120	0.343	0.180	0.367	0.109	-0.090	0.248
TW	-0.056	-0.064	-0.189	0.524	-0.032	0.222	-0.260
HI	-0.154	0.332	0.054	-0.173	0.143	0.251	0.036
OC	-0.004	-0.243	0.343	0.339	0.039	0.333	0.020

The characters having relatively higher value in the first principal component (PC1) were number of flowers per axil of main stem (NFAMS), number of capsules at axil in the main stem (NCAMS), main stem left capsule breadth (MSLCB), main stem left capsule length (MSLCL), main stem right capsule breadth (MSRCB) and main stem right capsule length (MSRCL) had more contribution to the total variation and they were responsible for the differentiation of the genotypes [18,19]. Second principal component was dominated by number of capsules per plant including branches (NCAB), seed yield per plant (SYP) and harvest index (Table 2). A biplot (Fig.4) representing the ordination of genotypes and the morphological traits with PC1 in the abscissa and PC2 in the ordinate depicted a clear pattern of grouping of genotypes in the factor plane [20-22]. All the genotypes were widely scattered across different quarters (Fig.4).

Genotypes with monostem and multicapsule per axil were grouped together. These genotypes can be selected for higher total capsules in main stem (TCMS), main stem main capsule length (MSMCL), oil content (OC) and photosynthetic assimilation rate (PAR). Most promising genotypes for these traits are PI-154298, SC-500-1, PI-158040, PI-158056 along with a multicapsule variety of Telangana JCS-1020 (check). Characters such as test weight (TW), main stem left capsule length (MSLCL), main stem left capsule breadth (MSLCB), main stem left capsule weight MSLCW showed low variation across the genotypes. Two checks genotypes GT-10 and Swetha Til were grouped together and were outliers since they were the only genotypes with single capsules per axil (Pandey et al 2021). In multicapsule genotypes, IC-500811, G-44, IC-500779, variation for number of capsules per axil over the length of the main stem was found, and hence they must be rejected since they are unstable for production of multicapsules at every axil. The prominent characters identified in a particular principal component are prime contributors to total variability and have the tendency to hang together and can be used effectively for selection in crop breeding programmes. Such biplots based on PCA analysis were used by Furat and Uzan, [23].

4. CONCLUSIONS

The contribution of seed weight main capsule and left capsule influence the seed yield per

plant. Sesame genotypes with multicapsules at every leaf axil in the main stem and branches serve as source for enhancing seed yield in sesame. Source character such as number of leaf axil, leaf area and stem girth are limiting factors in relation to sink characters (number of capsules per plant). Therefore there is a need to improvement in the directions of increased leaf area, enhanced physiological performance increased stem girth (source characters) in multicapsule genotypes.

ACKNOWLEDGEMENT

This is part of the author's post-graduate thesis work at Professor Jayashankar Telangana State Agricultural University. The author is highly grateful for the research facilities provided by the ICAR-Indian Institute of Oilseeds Research, Hyderabad, and Professor Jayashankar Telangana State Agricultural University.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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