

**Research Article****Relative efficiency of biparental mating, single capsule descent, selected bulk and random bulk selections in sesame (*Sesamum indicum* L.)**

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**Abstract**

A study was undertaken in sesame (*Sesamum indicum* L.) to assess the relative efficiency of biparental mating and three selection procedures in realising greater variability with desirable recombinants using  $F_2$  of two crosses viz. TMV 3  $\times$  IS 387-2 and KS 95010  $\times$  EC 343402. These  $F_2$  populations were advanced to  $F_3$  following intermating [biparental mating (BIP)] and selfing [selected bulk (SB), random bulk (RB) and single capsule descent (SCD)] approaches. The four populations thus developed in each of the two crosses were then evaluated for three earliness traits and three productive traits. BIP proved its superiority over selfing by registering high mean values in desirable direction for all the traits. Among the selfing series SCD was found superior followed by RB over SB. When compared to the  $F_3$  selfed populations, high genetic variability combined with high heritability and genetic advance was noticed in BIP of both the crosses for most of the earliness traits, except days to maturity while SCD and RB populations showed low estimates for the variability parameters. Correlation studies indicated that the undesirable strong positive associations that existed among the traits related with duration and productivity in  $F_3$  populations were converted into insignificant associations in BIP of both the crosses, thereby offering a great scope of selecting recombinants combining both earliness and productivity in BIP progenies. This possibility was limited in  $F_3$  selfed populations. Further it was inferred that in the selfed populations of both the crosses, the traits related with duration had significant positive association with seed yield primarily because of tight linkage between duration and capsule number. This tight linkage was broken in BIP as observed by the change in magnitude and direction of association in BIPs. This was attributed to breakage of undesirable linkage by forced recombinations induced by biparental mating.

**Key words:** Biparental population (BIP). Single capsule descent (SCD), Random bulk (RB), Selected bulk (SB) and Linkage

**Introduction**

India dominates the world scenario in area, production and export of sesame (*Sesamum indicum* L.). Recently, sesame has upsurged as a silver line in agri-export with its highest contribution to the export earnings among the edible oilseeds in India. Huge amount of foreign exchange eroded annually on account of the import of edible oils could be compensated through the export of larger quantities of sesame in which India has comparative advantage. Therefore, there is an urgent need to increase the sesame production by improving its productivity level, which otherwise is lower compared to other oilseeds. This necessitates the development of high yielding varieties in sesame through appropriate breeding programmes (Das and

Dasgupta, 1999; Hegde, 2002; Duhon and Singh, 2003).

The availability of variability is pre-requisite for any breeding programme. In sesame, since selection within local materials has been going on for a long time, the genetic variability for yield and its components have been exhausted (Rajan, 1981; Ashri, 1981). Further breakthrough in productivity will have to come from controlled crosses designed to create new and wide variability (Ashri, 1998). The main hybridization approach in sesame is the pedigree method. The lack of intermating beyond the initial cross restricts the variability by limiting the recombination of genes, and accumulation of undesirable linkage blocks due to continuous selfing in the segregating generations of self-pollinated crops, (Joshi, 1979; Mike, 1985). Therefore, breaking up of linkages to release the concealed variability becomes necessary for isolation of desirable superior lines. This could be achieved by subjecting the  $F_2$

generation to biparental mating, for which studies are limited in sesame. Therefore, linkage as a hindrance to the recombination stands as a barrier in effective selection in pedigree breeding approach in sesame.

Traditionally in breeding programs of sesame, selection commences right from the F<sub>2</sub> generation (selected bulk approach). One of the major disadvantages of this selection method is the uncertainty of effectiveness of early generation selection for complex quantitative traits like yield. Besides, there is a risk of missing by chance potential genotypes of earlier generations while making selection. These drawbacks of pedigree selection could be mitigated by adopting bulk method of selection, where selection of individual plants is postponed to later generations after the fixation of characters. However, as this method involves operation of natural selection in early generations, many productive recombinants may also be eliminated by natural selection because of their poor competitive ability (Suneson and Wiebe, 1962). Moreover, since only a random sample of seed of previous generation is forwarded to next generation, there is a likelihood of missing potential genotypes of early generations (Allard, 1960). The drawbacks of both pedigree and bulk methods of selection can be overcome by adopting single seed / capsule descent method (SCD) proposed by Goulde (1939), in which single seed / capsule from every F<sub>2</sub> plant is composited to raise F<sub>3</sub> and this method of selection is continued until homozygosity is reached. Theoretically SCD method is considered more effective in conserving entire variability of F<sub>2</sub> in the end population and selection is expected to be more effective than both the pedigree and bulk methods. Thus, Snape and Riggs (1975) suggested its great utility in breeding of self pollinated crops. However, in the absence of elaborative experiments, Ashri (1998) opined that it is premature to make conclusive recommendations regarding the relative merits of the above selection methods in sesame. Hence, this study was taken up to determine the merits of the two mating systems (biparental and pedigree) and three selection procedures (SSD, Random Bulk and selected bulk) in terms of release of genetic variability, heritability and changes in direction and magnitude of character associations.

### Materials and Methods

Two F<sub>2</sub> populations derived from crosses TMV 3 × IS 387-2 (C1) and KS 95010 × EC 343402 (C2) were selected for this study. The parental lines of these

crosses belonged to diverse genetic backgrounds and exhibited extremes of traits particularly in terms of maturity duration, yield potential and plant type. Hence, they were best suited for the current study. In both the crosses while the female parental lines were late maturing, high yielding and good general combiners for yield, the male parental lines were early and good general combiners for earliness but poorer in terms of yield. These F<sub>2</sub> populations were planted in a biparental mating block during the summer season of 2003 for advancing it to the next generation following selfing and intermating procedure. Four F<sub>3</sub> populations were then derived from each cross *viz.*, one intermated population *i.e.*, biparental population (BIP) and three selfed populations namely selected bulk (SB), random bulk (RB) and single capsule descent (SCD) populations. Biparental population was derived following selective intermating based on days to flowering and for which 15 early flowering and another 15 late flowering F<sub>2</sub> plants were identified. These 15 early flowering plants as males and 15 late flowering plants as females were crossed in 1:1 fashion as suggested by Kearsey (1965) and the harvested crossed seeds were bulked. The selfed capsules of the 30 F<sub>2</sub> plants used as parents for the development of the biparental progenies were harvested and bulked to form selected bulk selfed population in F<sub>3</sub> generation, while a random sample of seed obtained from the whole F<sub>2</sub> population harvested *en-masse* constituted the random bulk selfed F<sub>3</sub> population. For the development of single capsule descent selfed population, a single capsule from every F<sub>2</sub> plant was harvested and the seeds of single capsules of all the F<sub>2</sub> plants were bulked to form the SCD population in the F<sub>3</sub> generation. These populations were evaluated during the summer season of 2004 and observations were recorded on 150 plants / population for earliness traits *viz.*, days to flowering, days to maturity and height of first capsule and productive traits *viz.*, capsule number, test weight and seed yield. The data were analysed in MS excel for determining the mean performance, variability parameters and character association of these population for all the traits in both the cross combinations using the standard procedure.

### Results and Discussion

**Mean Performance:** Segregating populations with high mean are relatively effective in identifying the superior recombinants (Finkner *et al.*, 1973). In the present study a comparison of the mean performance among the population across the crosses revealed a

shift in the mean values in desirable direction for all the three earliness traits (34-35 days to flowering, 75 days to maturity and 29-30 cm for height of first capsule across both crosses) and productive traits — capsule number and seed weight (71 and 60 capsules/plant and 7.9 to 6.3g seed weight for C1 and C2, respectively) among the biparental populations as compared to selfed populations (Table 1 and 2). Desirable mean values of the BIP could largely be attributed to the predominance of additive and additive  $\times$  additive type of gene actions of the traits in the intermated populations (Sharma, 1994) or/and could also be due to creation of more variability by breakage of undesirable linkages which otherwise concealed the genetic variation in  $F_3$  population. Thus, superior performance of BIPs could mainly be attributed to the possible accumulation of favourable genes because of the breakage of undesirable linkages by intermating. Among the selfed population though not substantial differences were observed for earliness traits across the two crosses, for most of the productive traits single capsule descent performed better followed by random bulk and selected bulk. High mean performance of single capsule descent method of selection might be due to change in gene and genotypic frequency as a result of natural selection aiding in desirable direction. The relatively low mean performance of random bulk methods may be attributed to stabilized selection occurring naturally in bulk populations and loss of valuable genotype due to random selection (Khalifa and Qualset, 1975) while, genetic drift as well as the influence of environment during early generation selection would have been the reason for ineffectiveness of pedigree method over other methods (Valentine, 1984).

#### Variability parameters

The present study brought out the existence of higher genetic variability in BIPs than  $F_3$  selfed populations for most of the characters in both the crosses, except for productive trait— test weight in cross 1 (Table 1 and 2) for which SCD performed better/ on par to BIPs. The increased genetic variability not available in  $F_3$  populations was released in BIP due to intermating of  $F_2$  plants. This could be attributed to the fact that biparental mating in  $F_2$  generation caused forced recombinations, thereby undesirable linkages, especially in repulsion phase were broken down, which resulted in the release of hidden genetic variability. The overall effects produced greater genetic variability in BIP population than normal  $F_3$  selfed populations. The reduced variability in BIP

particularly for test weight could be due to presence of genes controlling this trait in coupling phase (Gardener, 1963; Pederson, 1974). Probably a few more cycles of intermating would result in breaking the linkages and thus releasing more variability (Hanson, 1959). Among the three  $F_3$  selfed populations, an increase in the amount of genetic variability was generally observed from SB-RB-SCD of both the crosses for most of the traits. These results may be attributed to the representation of each plant of  $F_2$  in the SCD population. Considering earliness and productive traits together, among the four populations studied, BIP seems to perform better, in the sense that it had high genetic variability for most of the productive traits including seed yield (35.5 and 38.9% for C1 and C2, respectively) as well as it showed an exploitable amount of variability for days to flowering ( $\sim 10\%$  across crosses), in addition to showing high variability for height of first capsule (26.3 and 27.3% in C1 and C2, respectively), another earliness trait. Whereas, all the three selfed populations exhibited very low variability for days to flowering ( $<10\%$ ) and days to maturity ( $<6\%$ ). In the selfing series, SCD population recorded high heritability coupled with high genetic advance in both the crosses for seed yield (33.5 and 48.7% for C1 and 34.8 and 55.3% for C2) and its important component traits like capsule number (30.6 and 92.5% for C1, and 25.5 and 96.4% for C2). Similar trend was also observed by RB population in cross 1 alone. In both the crosses low heritability but moderately high genetic advance for seed yield was noticed in SB population (26.6 and 25% in C1 and 33.4 and 35.5 in C2). These results reveal that in cross 1, SCD and RB  $F_3$  selfed populations would respond better for phenotypic selection, while in cross 2, SCD population alone would follow the similar trend. In both the crosses, selection would not be efficient in SB selfed population.

By considering together all the variability parameters along with the mean performance, it may be concluded that intermating in  $F_2$  segregating population is the best for throwing high variability in the biparental population for both earliness and productive traits. As this high variability is also associated with high heritability and genetic advance, this population would respond better for selecting plants with early types combining high seed yield.

**Character association:** Constellation of favourable genes and breakup of linkages associated with mating systems causes a change and direction of character

association as a result of recombination (Joshi, 1979), These associations are best measured using correlation coefficients. The present study revealed desirable shifts of correlations in the biparental progenies. Significant positive correlations established by days to flowering, days to maturity and height of first capsule with seed yield mostly because of their significant positive inter-relationships with yield component traits like plant height and capsule number in all the three  $F_3$  selfed populations were broken and changed to non-significant correlations that too in negative direction in the biparental populations of both the crosses (Figure 1). This could be possible because the forced recombination brought about by selective intermating practiced in the present study broke down the undesirable linkages between genes of earliness and productivity, thereby more number of plants having favorable combinations of genes of both earliness and productivity were produced in BIP progenies. (Murty *et al.*, 1972; Frederickson and Kronstead, 1985; Sharma, 1994). The shifts in correlations realised in the present investigation could be of immense practical value because the selective intermating in  $F_2$  population of two crosses were made with the main objective of breaking undesirable character associations existing among the traits related with earliness and productivity. These desirable shifts may be attributed to the breakage of undesirable linkages among the genes of earliness and productive traits due to forced recombinations induced by intermating of  $F_2$  plants selected based on disruptive selection for flowering.

Within the selfing series, it was found that in general, there was no change in the magnitude of these associations among the three populations across the crosses. However, significant positive correlations established by days to flowering, days to maturity and height of first capsule with seed yield in the  $F_3$  populations generally showed a reduction in their magnitude in the order of SB-RB-SCD (Figure 1). This reduction was mainly due to their corresponding reduction in the same direction in the magnitude of their positive inter-correlation with the most important yield component — capsule number (Figure 2). These results indicate that single capsule descent method would give higher response than the other two selection procedures for selection of superior plants with earliness and high seed yield. Such a chance is limited in random bulk method and it is remote in selected bulk method.

## Conclusion

In autogamous crops like sesame, the conventional breeding procedure involves hybridization between two parents having different set of desirable traits and then exercising selection in  $F_2$  and later generation to isolate desirable recombinants. If there is a linkage among the various genes which control these traits, it is expected that the majority of the linkages among the genes for different traits are in repulsion phase. In the conventional hybridization programme, after crossing the parents, the hybrid progenies are advanced through natural self pollination. Under this regime of selfing, linkage blocks are more intensified which greatly prevents the emergence of desirable gene constellations, thereby limiting genetic variability (Pederson, 1974; Bos, 1977). But these disadvantages of such unfavourable linkages and correlated response can be successfully mitigated by subjecting the  $F_2$  generation to intermating- biparental mating (Palmer, 1953; Hanson, 1959). From the results of the present study it could be inferred that biparental population developed by intermating among  $F_2$  plants selected based on disruptive selection for flowering produced higher desirable mean values for earliness as well as productive traits along with high genetic variability coupled with high heritability for these traits than the selfed populations. Further undesirable character association between earliness and capsule number was broken by selective intermating in  $F_2$ , thereby biparental populations offer a good scope for selecting recombinants combining both earliness and yield potential by exercising selection simultaneously for earliness and capsule number. Among the three selection procedures adopted in the present study to forward the  $F_2$  to  $F_3$  by selfing, single capsule descent method is found to be superior over the two methods *viz.*, random bulk and selected bulk methods, as this selection scheme produced  $F_3$  population with higher desirable mean for earliness and productivity traits combined with high variability, heritability and genetic advance. Though, the most important yield contributing trait, capsule number is positively associated with duration in selfed populations, in the population forwarded through single capsule descent method, the extent of this linkage is relatively low when compared to the other two selection procedures. Thus, a breeder facing a problem of tight linkages and undesirable character associations could resort to biparental mating involving selective intermating in  $F_2$  generation in sesame. If intermating among  $F_2$  plants is found to be a tedious process, then alternatively the  $F_2$  population could be forwarded



through single capsule descent method of selection to get a better result.

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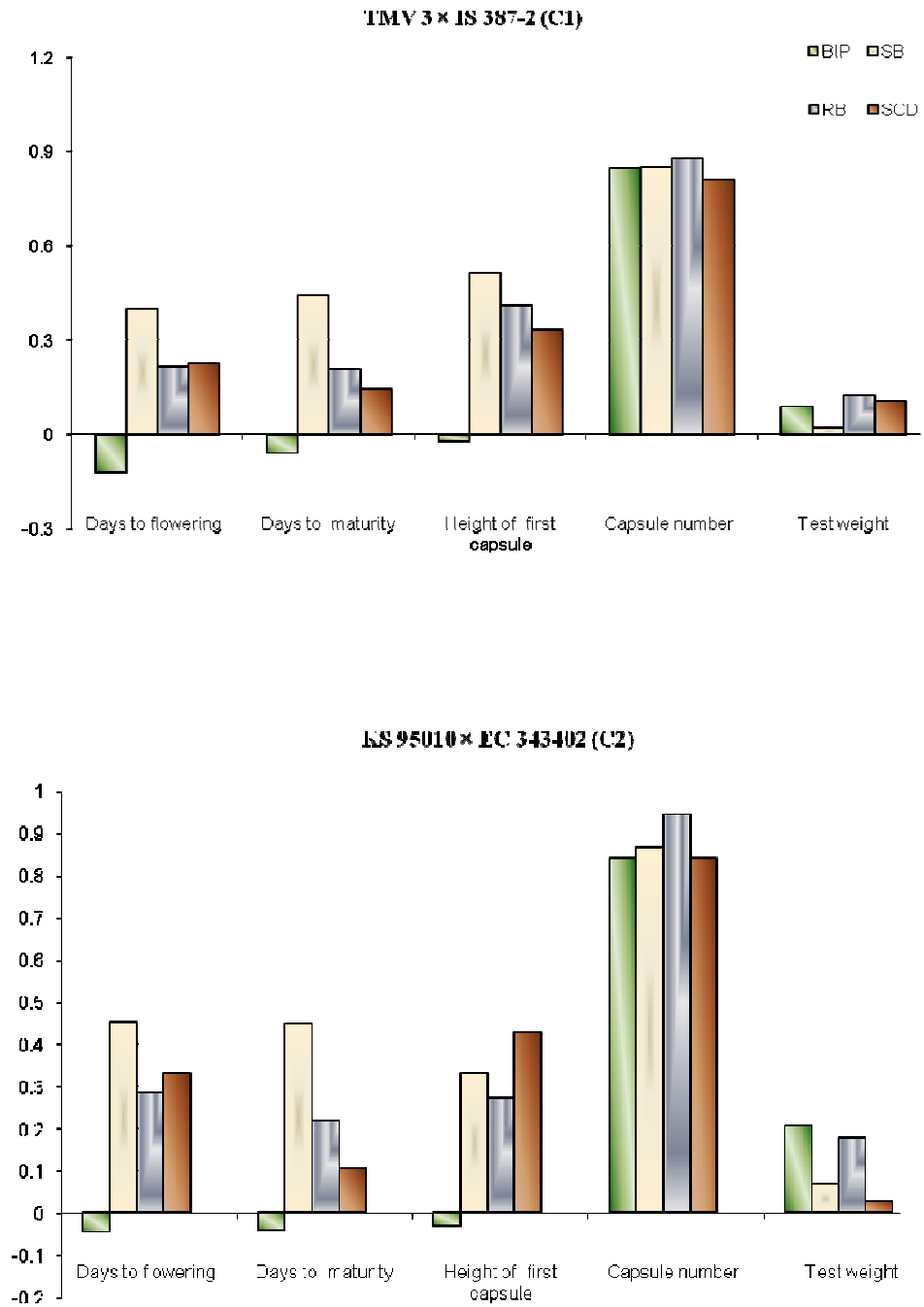
**Table 1. Mean performance and variability parameters of BIP, SB, RB and SCD populations in TMV 3 × IS 387- 2 (C1)**

Character	Population	Mean $\pm$ SE	GCV (%)	$h^2$ (%)	GA as % mean
Days to flowering	BIP	34.25 $\pm$ 0.27	10.13	84.25	20.27
	SB	37.72 $\pm$ 0.19	5.00	66.09	8.38
	RB	37.80 $\pm$ 0.24	6.92	78.93	12.67
	SCD	36.28 $\pm$ 0.26	8.10	82.54	15.16
Days to maturity	BIP	74.93 $\pm$ 0.34	5.32	91.66	9.48
	SB	77.46 $\pm$ 0.25	3.68	84.92	6.99
	RB	77.74 $\pm$ 0.30	4.46	89.29	8.69
	SCD	76.66 $\pm$ 0.30	4.60	89.58	8.96
Height of first capsule (cm)	BIP	29.67 $\pm$ 0.63	24.08	83.81	45.41
	SB	33.32 $\pm$ 0.64	21.76	84.22	41.14
	RB	32.04 $\pm$ 0.63	22.27	83.78	41.99
	SCD	32.06 $\pm$ 0.62	21.93	83.38	41.26
Capsule number	BIP	71.59 $\pm$ 2.72	32.68	91.21	64.29
	SB	50.18 $\pm$ 1.78	30.05	90.94	59.03
	RB	65.20 $\pm$ 2.33	30.26	94.50	60.61
	SCD	54.44 $\pm$ 2.01	30.59	92.45	60.58
Test weight (g)	BIP	3.05 $\pm$ 0.04	13.99	68.18	23.79
	SB	3.00 $\pm$ 0.03	10.05	53.01	13.35
	RB	3.03 $\pm$ 0.03	10.28	58.32	15.46
	SCD	3.91 $\pm$ 0.03	14.20	68.78	23.99
Seed yield (g)	BIP	7.97 $\pm$ 0.32	35.47	66.67	59.67
	SB	5.10 $\pm$ 0.19	23.54	26.55	24.99
	RB	6.56 $\pm$ 0.24	34.44	56.08	53.12
	SCD	5.82 $\pm$ 0.21	33.48	48.75	48.15

**Table 2. Mean performance and variability parameters of BIP, SB, RB and SCD populations in KS 95010 × EC 343402 (C2)**

Character	Population	Mean $\pm$ SE	GCV (%)	$h^2$ (%)	GA as % mean
Days to flowering	BIP	34.88 $\pm$ 0.30	10.49	95.05	21.07
	SB	37.57 $\pm$ 0.23	7.28	91.47	14.34
	RB	37.72 $\pm$ 0.24	7.74	92.44	15.34
	SCD	37.63 $\pm$ 0.26	8.36	93.41	16.65
Days to maturity	BIP	74.47 $\pm$ 0.34	5.22	84.20	9.86
	SB	77.36 $\pm$ 0.28	3.98	77.04	7.20
	RB	77.68 $\pm$ 0.30	4.22	79.19	7.74
	SCD	77.34 $\pm$ 0.31	4.52	81.22	8.40
Height of first capsule (cm)	BIP	29.12 $\pm$ 0.65	26.34	92.99	52.32
	SB	34.22 $\pm$ 0.58	19.97	91.33	39.32
	RB	33.38 $\pm$ 0.64	22.92	92.96	45.51
	SCD	32.67 $\pm$ 0.26	19.88	90.49	38.97
Capsule number	BIP	60.56 $\pm$ 2.38	28.26	97.61	57.51
	SB	46.43 $\pm$ 1.76	23.38	94.27	46.76
	RB	47.27 $\pm$ 1.81	25.28	95.23	50.82
	SCD	54.38 $\pm$ 1.27	25.53	96.42	51.65
Test weight (g)	BIP	3.20 $\pm$ 0.04	15.52	83.09	29.14
	SB	3.00 $\pm$ 0.03	10.73	67.29	18.13
	RB	3.10 $\pm$ 0.03	10.99	69.74	18.90
	SCD	3.18 $\pm$ 0.03	10.04	67.02	16.93
Seed yield (g)	BIP	6.30 $\pm$ 0.25	38.90	63.18	63.69
	SB	4.44 $\pm$ 0.16	29.81	33.44	35.52
	RB	4.77 $\pm$ 0.18	25.53	29.83	28.73
	SCD	5.97 $\pm$ 0.22	34.81	55.26	53.31

**Figure 1. Correlations of the traits on seed yield in the four populations of TMV 3 × IS 387-2 (C1) and KS 95010 × EC 343402 (C2)**





**Figure 2. Inter-correlation between Earliness traits and important productive trait — Capsule number**

