CHAPTER II
REVIEW OF LITERATURE

The literature pertaining to heterosis and inbreeding depression, combining ability and gene action, components of genetic variances (Hayman’s numerical approach) and phenotypic stability in sesame (*Sesamum indicum* L.) has been reviewed under the following sub-headings:

2.1 Heterosis and inbreeding depression
2.2 Combining ability and gene action
2.3 Genetic components of variances (Hayman’s numerical approach)
2.4 Genotype x environment interactions and stability analysis

2.1 Heterosis and inbreeding depression

Heterosis or hybrid vigour indicates the superiority of hybrid over its parents. It was first reported in plants by Koelreuter (1763) and noted that vigour in crosses increased with the increase in dissimilarity of parents. The term “heterosis” as is now widely used, was coined by Shull (1908). It refers to the phenomenon in which the F₁ hybrid obtained by crossing two dissimilar individuals shows the increased or decreased vigour over the better or mid-parental value. Later on Fonseca and Patterson (1968) used a new term “heterobeltiosis” to describe improvement of heterozygotes in relation to better parent.

The heterosis is increased vigour, which is confined to only F₁ generation. From the F₁ to F₂ and in later generations, there is considerable depression as a consequence of inbreeding. The extent of this depression in the same crop varies from character to character, generation to generation and also with the genotypes themselves. East (1908) observed that the genes for plant height were fixed after five generations of inbreeding, while yield continued to decline for 20 generations. Wright (1921) symbolized coefficient of inbreeding of F₁ and defined as the correlation between uniting gametes. Generally, the depression is rapid in first few generations and is slowed down in later generations.

Murty (1975) examined the extent of heterosis for six agronomic and two chemical characters in a complete diallel set of ten self-pollinated varieties of sesame (*Sesamum indicum* L.) of diverse ecogeographic origin. Heterosis was, on an average,
the highest for seed yield (33 %) followed by number of capsules per plant (16 %). Mean per cent heterosis was small for earliness, plant height and number of primary branches, while it was non-significant for number of secondary branches and percentage of oil. Per cent heterosis was generally higher in Indian x exotic crosses than in Indian x Indian and exotic x exotic crosses. The exotic lines appeared to be useful in Indian sesame breeding programmes, particularly in the improvement of earliness, number of secondary branches, seed yield and protein content.

Dixit (1976) observed inbreeding depression in the F₂ population of sesame for plant height, number of capsules, number of branches and yield per plant in some of the crosses.

Chavan et al. (1982) evaluated F₁ and F₂ generations of six intervarietal crosses derived from eight varieties for plant height, capsules per plant, number of days for maturity and yield per plant and reported significant positive heterosis for number of capsules per plant, number of days for maturity and yield per plant. Low value for inbreeding depression was found to be associated with plant height and capsules per plant allows the selection for crop improvement.

Sharma and Chauhan (1983) studied the performance of F₁ hybrids involving 10 varieties of sesame to investigate heterosis for seed yield and eight other component characters. The mid-parent and better parent heterosis for seed yield ranged from -16.76 to 105.70 per cent, and -34.99 to 60.27 per cent, respectively. The hybrids JT 66-173 x SH 50 and T 12 x SN 62 exhibited the maximum heterosis and heterobeltiosis to the tune of 105.70 and 60.27 per cent for seed yield, respectively. The heterosis for seed yield appeared to be due to high manifestation of heterosis for number of capsules per plant. Inbreeding depression was also reported for plant height and oil content in F₂ generation.

Godawat and Gupta (1985) studied inbreeding depression for seed yield per plant and three related characters for which the parents, F₁, F₂, BC₁ and BC₂ of five crosses were grown at four locations. Inbreeding depression was reported in all the crosses, indicating the involvement of non-additive gene action in the control of seed yield, number of capsules per plant and plant height.

Shivaprakash (1986) studied 10 quantitative characters in five crosses of sesame. High heterosis was observed for plant height in JE x Local and for capsule length and number of branches in RE x Local cross combination. Inbreeding
depression was significant for plant height in JE x Local; and for capsule length and number of primary branches in RE x E 8.

Singh et al. (1986) studied inbreeding depression in F$_2$ with respect to 13 traits in 30 crosses of white seeded Sesamum orientale. Number of branches per plant, capsules per plant, harvest index, yield per plant, protein content and oil content exhibited significantly the high values for heterosis. Till x Pb.1 recorded the highest heterosis for yield (327.94 %) over the better parent. It also showed the highest yield superiority (108.36 %) over the standard variety T 12. The capsules per plant contributed most to heterosis for yield. Characters like number of capsules per plant, days for flowering, days for maturity, yield per plant, plant height and length and breadth of capsule showed significant inbreeding depression.

While studying heterosis and inbreeding depression for nine characters in two crosses of sesame involving single stemmed varieties, Pathak and Dixit (1988) reported that the extent of heterosis was low in sesame due to mutual cancellation of gene effects for the characters studied. Inbreeding depression was noted the highest for capsules per plant in both the crosses.

While evaluating 17 hybrids of sesame involving 8 diverse parents, Sasikumar and Sardana (1990) observed significant and positive heterobeltiosis for yield and its important attributes in 6 hybrids viz., B 67 x Pb MT 82-2-6, B 67 x AT 6, Pb MT 82-2-6 x VS 16, Pb MT 82-2-6 x Ahuti, Ahuti x VS 16 and OMT 3 x BS 5-18-6. Further, it was noted that there is a good scope for commercial exploitation of heterosis as well as isolation of homozygous lines among the progenies of other heterotic F$_1$s.

In a ten-parent diallel analysis of sesame (Sesamum indicum L.), Sodani and Bhatnagar (1990) observed significant heterosis for seed yield for 21 cross combinations. Mean heterosis was high for number of capsules and branches per plant and low for plant height and capsule length. Heterosis for grain yield and its component characters was highly correlated. In general, crosses with significant heterosis also showed significant inbreeding depression in F$_2$.

Zhan et al. (1990) found that the heterosis of yield and its components have been expressed by F$_1$ hybrids: yield per plant > capsules per plant > 100 seed weight > seeds per capsule. Despite F$_2$ hybrids showed inbreeding depression, still maintaining a definite vigour for these traits.

Reddy et al. (1992) evaluated diallel crosses involving nine diverse lines of sesame for heterosis study and found significant heterosis for seed yield. The cross
A combination R 84-4-2 x VS 16 gave the highest seed yield, while RT 54 x R 84-4-2 noticed significant heterosis in for oil content.

In a 6 x 6 diallel analysis of sesame, Susmita and Sen (1992) reported high magnitude of heterosis over better and mid-parents for plant height, days to 50 per cent flowering, 1000 seed weight and seed yield.

Brindha and Sivasubramaniam (1993) evaluated six genotypes and their F1 hybrids of sesame through diallel analysis for different traits. High heterosis was observed in crosses BS 6-1-1 x TSS 11, TS 11 x SI 1730 and Madhavi x SI 1730 for days to first flowering, plant height, number of branches per plant and seed yield per plant.

Patel (1993) evaluated 8 x 8 diallel crosses of sesame and found that heterosis over better parent was high for number of effective branches per plant, number of capsules and yield per plant, whereas heterosis over mid-parent was high for plant height, number of seeds per capsule and 1000 seed weight.

While studying diallel analysis in sesame, Fatteh et al. (1995) reported that, the magnitudes of heterosis and heterobeltiosis were higher for number of branches per plant (154.12 % and 54.50 %) followed by number of capsules per plant (108.14 % and 88.65 %) and seed yield per plant (86.81 % and 68.94 %). The range of heterosis and heterobeltiosis for seed yield was from -54.28 to 86.81 per cent and -56.02 to 68.94 per cent, respectively. The crosses TMV 3 x HT 1 and PT 64 x TC 25 showed the maximum heterosis over better parent.

In a study of 10 x 10 diallel crosses excluding reciprocals, Navadiya et al. (1995) recorded high heterosis for yield per plant, plant height, number of effective branches per plant and number of capsules per plant, while days to flowering, days to maturity, 1000 seed weight and oil content had low heterosis. Hybrid RT 126 x OMT 3 manifested the highest heterobeltiosis (101.6 %) for yield per plant.

In a line x tester analysis involving six lines and three testers in sesame, Kumar (1996) reported superior performance of TNAU 12 x TMV 3 hybrid for various characters viz., plant height, number of capsules per main stem, capsules per branch, shoot weight, root weight, oil content and seed yield based on standard heterosis and per se performance. The heterosis for seed yield ranged from -4.9 to 169.9 per cent.

During their study of heterosis in sesame, Mishra and Yadav (1996) observed standard heterosis in both the direction for all the characters. Negative heterosis was
observed for days to 50 per cent flowering and days to 80 per cent maturity. Significant and positive heterosis, heterobeltiosis and standard heterosis was recorded for number of capsules per plant, number of seeds per capsule and seed yield per plant in crosses TC 289 x Phule 1 and JF 7 x TC 25.

Padmavathi (1998) reported heterotic potential of sesame crosses in F1 and F2 generations. The heterosis over better parent for plant height ranged from -16.7 to 33.8 per cent with 13 crosses showing significant positive heterosis. The heterobeltiosis for capsule length was very low. Negative heterosis was predominant for days to maturity indicating possibility of developing early maturing types. The heterobeltiosis for seed yield ranged from -44.1 to 16.2 per cent. Nineteen hybrids showed significant and positive heterosis over better parent for seed yield.

Sakhare et al. (1998) crossed 12 sesame genotypes and evaluated progenies for 10 yield components. The maximum heterosis was noted for seed yield per plant followed by harvest index and capsules per plant. Phule Til 1 x IC 41930 exhibited 98.2 per cent increase in seed yield over the check variety and was found promising for exploitation of heterosis at commercial level.

Alam et al. (1999) carried out heterosis study in sesame and recorded significant and negative heterobeltiosis for days to 50 per cent flowering. Two F1’s viz., B 14 x IS 5 and TSS 130 x IS 5, produced significant and positive heterobeltiosis for seed yield per plant, number of primary branches per plant and number of capsules per plant. Significant positive heterobeltiosis was also observed for oil content in two crosses viz., B 9 x B 14 and B 67 x TSS 6.

Govindarasu et al. (1999) carried out line x tester analysis using three lines and three testers and reported that the cross TMV 3 x RJS 199 expressed the significant and the highest desirable heterosis, heterobeltiosis and standard heterosis for seed yield per plant. It also exhibited similar heterotic expressions for number of branches per plant and number of capsules per plant.

Das et al. (2000) reported heterosis for yield and yield components in 10 F1 hybrids obtained by 5 x 5 diallel crosses. All the hybrids showed significant and positive heterosis and heterobeltiosis for seed yield per plant. The heterosis for seed yield per plant ranged from 25.4 to 58.2 per cent over mid-parent and from 14.3 to 55.2 per cent over better parent. The cross JS 1 x JS 3 exhibited the maximum heterobeltiosis for seed yield per plant (55.2%) followed by JS 2 x JS 3 (44.3%).
Dikshit and Swain (2000) found that heterosis in seed yield was very much associated with heterosis in number of capsules per plant and branches per plant. The range of relative heterosis and heterobeltiosis for seed yield was -36.8 to 83.5 per cent and -42.5 to 66.0 per cent, respectively.

Kavitha et al. (2000) studied heterosis using cytoplasmic male sterile lines in sesame and observed 5.83 per cent heterosis for number of capsules per plant, 22.32 per cent for 1000 seed weight and high heterosis (103.41 %) for seed yield with 40 per cent heterobeltiosis. Significant positive heterobeltiosis was also recorded for oil content (5.29 %), number of primary branches (13.13 %) and secondary branches (78.07 %). Cross CMS T6 x Si 1525 recorded the maximum heterosis as well as heterobeltiosis for seed yield. It also recorded significant positive heterobeltiosis for oil content. CMS T4 x Paiyur 1 recorded significant positive heterobeltiosis for number of capsules per plant.

Ragiba and Reddy (2000) assessed the heterosis and inbreeding depression by evaluating 10 parents, 45 single crosses excluding reciprocals (F₁) and 45 single crosses (F₂) of sesame. Estimates of mean squares were highly significant for all 12 characters investigated, indicating large diversity among the parents. The highest range of mean performance was recorded for the number of capsules per plant in both parents (46.0 to 72.96) and crosses (31.6 to 106.6). Ranges of MP and BP heterosis were high for number of secondary branches (-65.24 to 270.14% and -100.32 to 188.36%, respectively), number of capsules on primary branches (-49.75 to 182.64% and -88.99 to 157.97%, respectively), number of capsules on secondary branches (-82.89 to 335.75% and -86.98 to 149.77%, respectively) and seed yield per plant (-92.26 to 137.81% and -42.37 to 146.98%, respectively). The hybrids VS 16 × JLT 6 (high potential for grain yield), X 198 × R 84-4-2 (high potential for number of capsules on primary branches and number of capsules per plant), RT 54 × X 198 (very high negative heterosis for days to 50% flowering and days to maturity), V 16 × Madhavi (highest performance for number of primary branches), and X 198 × R 84-4-2 (high heterosis for number of capsules on secondary branches and number of capsules per plant) showed higher heterosis over MP and BP for most of the characters. Most crosses showing non-allelic interaction demonstrated high inbreeding depression for number of capsules on the main stem, number of capsules on primary branches and number of capsules on secondary branches.
Durga and Raghunatham (2001) studied heterosis in 18 sesame hybrids developed by crossing six lines with three cultivars. The maximum heterosis was observed for number of secondary flowers, productive capsules on main stem, seed yield per plant, harvest index and oil yield per plant. Negative but desirable heterotic effects were observed for days to first flowering, height to first branch and first capsule, plant height and abortive capsules per plant. Low to moderate heterotic effects were exhibited by nodes to first flower, petiole length, laminal length and width, number of primary branches, days to maturity and oil percentage.

Hoballah (2001) evaluated a half diallel set of crosses involving seven parents in sesame to study heterosis in the F1 generation. The expressions of heterosis varied with the crosses and characters investigated. The maximal significant positive useful heterosis was observed for branches per plant (52.9 %) followed by seed yield per plant (38%), capsules per plant (33.6%), capsule length (19.0%), 100 seed weight (18.6%) and plant height (12.1%).

While studying heterosis and inbreeding depression in sesame, Karuppatyam and Ramasamy (2001) found that two hybrids, Si 3214 x SVPR 1 and TMV 6 x SVPR 1 recorded significant heterosis over standard check Co 1. In general, crosses with significant heterosis expressed significant inbreeding depression in F2. The F2 progenies of cross Si 3214 x SVPR 1 showed high heterosis with non-significant inbreeding depression for seed yield.

Mishra and Sikarwar (2001) analyzed five lines and three testers to estimate the magnitude of heterosis for six characters using a line x tester analysis and found that the cross combinations JTS 13 x TKG 22, TKG 81 x TC 25, EC 132856 x TC 25 and EC 132834 x TKG 22 manifested negative and the maximum heterobeltiosis for days to maturity. Among crosses, only three cross combinations, JTS 13 x TKG 22, EC 138527 x OMT 3 and TKG 81 x TC 25 exhibited significant and positive heterobeltiosis for plant height. For the number of branches per plant, majority of the cross combinations showed positive and significant heterobeltiosis and some of them were negative. For seed yield, the cross combinations JTS 13 x TKG 22, EC 132856 x TKG 22 and EC 132834 x TKG 22 exhibited the maximum significant and positive heterosis over better parent.

Reddy et al. (2001) estimated heterosis for 11 traits in 36 F1 hybrids of sesame. The cross combination TKG 64 x E 8 showed significant heterosis over better parent for number branches per plant, number of capsules per plant, capsule length,
number of seeds per capsule, test weight, plant height, capsule yield per plant, seed yield per plant and oil content. TC 397 x E 8 also exhibited significant heterosis over better parent for number of branches per plant, number of capsules per plant and number seeds per capsule.

Sankar and Kumar (2001) evaluated 32 crosses derived from 8 x 4 line x tester analysis in sesame to measure the extent of heterosis for days to 50 per cent flowering, plant height, number of primary branches per plant, number of capsules per plant, oil per cent and single plant yield. Combinations TNAU 120 x CO 1 and DCH 25-1 x TMV 6 manifested highly significant relative heterosis, heterobeltiosis and standard heterosis for most of the traits including single plant yield and hence, could be exploited for developing superior varieties. The best heterotic combinations for seed yield were DCH 25-1 x TMV 6, TNAU 118 x CO 1 and DCH 25-1 x SVPR 1, which recorded 200.20, 172.17 and 164.83 per cent standard heterosis over CO 1, respectively, and can be utilized for hybrid development.

Karuppaiyan and Sundaresan (2002) evaluated 80 F1 hybrids of sesame developed through line x tester mating design and reported standard heterosis for seed yield in between -79.2 to 68.5 per cent. Out of 80 crosses, 52 crosses exhibited significant and negative heterosis. Only 7 crosses exhibited positively significant standard heterosis for seed yield. The hybrid S 0626NL-4 x Co 1 registered 68.5 per cent economic heterosis followed by Si 102 x TMV 6 and S 0626NL-4 x TMV 3 with 38.3 and 34.5 per cent, respectively.

Saravanan and Nandrajan (2002) crossed eight parents of different geographical origin viz., CO 1, VRI 1, TMV 3, SI 3216, YLM 123, SI 42, SVPR 1 and AHT 123) in half diallel fashion to study the heterosis for days to flowering, plant height, number of primary branches per plant, number of seeds per capsule, 1000 seed weight, oil content, harvest index and seed yield per plant. Six hybrids viz., VRI 1 x AHT 123, SI 3216 x YLM 123, SI 3216 x SI 42, YLM 123 x AHT 123, CO 1 x VRI 1 and CO 1 x SI 42 were identified as the best crosses expressed high standard heterosis over the standard cultivar for yield and its components.

Singh (2002) observed non-significant and negative inbreeding depression for days to maturity in most of the crosses indicating the importance of additive gene action, while high heterosis and high inbreeding depression for seed yield and many other traits for most of the crosses reflected the importance of non-additive gene action.
Krishnaiah et al. (2003) evaluated 28 F₁’s obtained through a diallel crosses of 8 parents for 13 characters viz., days to 50 per cent flowering, days to maturity, plant height, number of primary branches, number of secondary branches, capsules on the main stem, capsules on the primary branches, capsules on the secondary branches, capsule length, seeds per capsule, 1000 seed weight, seed yield per plant and harvest index. The results revealed that crosses YLM 11 x T brown, Rajeswari x YLM 17 and Rajeswari x Krishna were the best combinations for yield based on heterosis and per se performance. The heterosis was ranged from -32.35 to 23.24 per cent for seed yield per plant, -16.13 to 10.10 per cent for days to maturity, -12.14 to 4.64 per cent for 1000 seed weight, -16.27 to 17.34 per cent for seeds per capsule, -15.13 to 11.00 per cent for capsule length, -18.57 to 19.43 per cent for harvest index and -42.78 to 35.70 per cent for plant height.

Kumaresan and Nadarajan (2003) evaluated 48 hybrids of sesame derived from crossing 12 lines and 4 testers in a line x tester mating design. The hybrid OMT 30 x VRI 1 had higher per se performance and significant standard heterosis for single plant yield and oil content. Among 48 hybrids studied, on the basis of per se performance and standard heterosis, the cross OMT 30 x SVPR 1 was also to be the superior cross combination in terms of number of days to 50 per cent flowering, number of capsules and single plant yield.

Kumar and Ganesan (2004) evaluated 15 hybrids produced by crossing five lines and three testers of sesame for nine characters. Among the hybrids, the crosses TMV 6 x T 6 and TMV 3 x T 6 showed significant and positive standard heterosis for plant height, number of branches per plant, number of capsules on main stem, number of capsules on branches, total number of capsules, capsule length, number of seeds per capsule, 1000 seed weight and seed yield per plant.

Mothilal and Ganesan (2005) evaluated 21 crosses developed through 7 x 7 diallel mating design to study the heterosis in sesame. Among the crosses, Vinayak x Madhavi recorded significant positive heterosis over mid-parent for plant height, number of branches per plant, number of capsules on main stem, number of capsules on branches, number of seeds per capsule, 1000 seed weight and seed yield per plant. Vinayak x Si 3012 exhibited significant heterosis over mid-parent and better parent for plant height and seed yield per plant, while Padma x Si 97 recorded significant positive heterosis over mid-parent and better parent for seed yield per plant. The
higher estimate of heterosis in these traits may be due to dominance or epistasis or both.

Patel et al. (2005) stated that the heterosis varied in intra and inter seasonal cross combinations. High heterosis was observed for number of branches per plant and seed yield per plant, moderate heterosis for plant height and number of capsules per plant and low heterosis for number of capsules on main stem, length of capsules, 1000 seed weight and oil content. Desired heterosis was not observed for days to flower initiation and days to maturity.

Prajapati et al. (2006a) studied heterosis in a set of 10 x 10 diallel crosses excluding reciprocals. The magnitude of heterosis varied from trait to trait. The amount of heterosis was high for seed yield per plant and number of branches per plant, whereas for days to flowering, days to maturity, plant height, number of capsules per plant, capsule length, seeds per capsule, 1000 seed weight and oil content had low magnitude of heterosis. The hybrid TMV 3 x C 103 manifested the highest economic heterosis (116.4 %) and relative heterosis (71.6%) for seed yield per plant.

Singh (2007) studied heterosis in relation to combining ability for yield and its components in sesame through line x tester analysis using four lines and three testers. The range of standard heterosis for seed yield per plant was from -11.74 to 29.78 per cent. The maximum heterosis was noted in the cross TC 289 x ES 3 for seed yield per plant along with four other traits viz., number of capsules on main axis, number of capsules per plant, number of seeds per capsule and 1000 seed weight. Five crosses viz., TC 25 x ES 3, TC 25 x GT 1, TC 25 x JLT 8, T 4 x GT 1 and T 4 x ES 3 recorded significant and negative heterosis, heterobeltiosis and standard heterosis for maturity.

Thiyagu et al. (2007a) estimated the extent of heterosis in 36 F1 hybrids derived through line x tester fashion for nine traits including seed yield. Heterosis for yield was generally accompanied by heterosis for component traits. The extent of heterosis for days to 50 per cent flowering and days to maturity varied from -15.31 to 8.42 per cent and -13.09 to 13.53 per cent, respectively. The cross Uma x ORM 17 (-15.31%) for days to 50 per cent flowering and SVPR 1 x ORM 17 (-13.09%) for days to maturity recorded significant and negative heterosis. Out of 36 crosses, 12, 16 and 5 crosses showed significant positive and standard heterosis for the characters plant height, number of primary branches per plant and number of capsules per plant, in which heterosis ranged from -23.62 to 23.74 per cent, -35.92 to 38.57 per cent and
-50.89 to 35.87 per cent, respectively. The hybrid vigour for seed yield and oil yield varied from -51.60 to 46.85 per cent and -54.09 to 63.11 per cent, respectively and cross CO 1 x ORM 14 showed the highest value of heterosis.

While studying heterosis and inbreeding depression in sesame, Anuradha and Reddy (2008a) observed the maximum relative heterosis in NKD 1110 x Gowri (89.48%) and minimum in DCB 1799 x Gowri (-64.20%) for seed yield, while heterobeltiosis ranged from –66.72 per cent (K5 188 x YLM 17) to 83.67 per cent (NKD 1110 x Gowri). Five crosses viz., Tanuku brown x Vinayak, NKD 1110 x Gowri, NKD 1110 x Madhavi, DCB 1799 x Vinayak and SI 320 x Gowri registered significant and positive values for both heterosis and heterobeltiosis for seed yield. Non-significant and negative inbreeding depression was observed for days to maturity in most of the crosses.

Misra et al. (2008) studied heterosis and combining ability in sesame for five traits viz., number of branches per plant, capsules per plant, seeds per capsule, 1000 seed weight and yield per plant in F$_1$S of a 12 parent half diallel crosses. Among the crosses, cross Pragati x AKT 64 exhibited the highest significant and positive heterosis for branches per plant (56.36%) and 1000-seed weight (5.92%), whereas the cross Prachi x TC 25 exhibited the highest significant and positive heterosis for number of capsules per plant (51.28%) and number of seeds per capsule (15.32%).

Sharmila and Ganesh (2008) found that hybrid NIC 7937 x VRI 1 expressed desirable negative heterosis over better parent for days to maturity. A large number of crosses exhibited positive and significant standard heterosis for seed yield. NIC 7937 x SVPR 1 recorded 29.10 per cent for capsule length and Si 1115/1 x TMV3 recorded 47.10 per cent for seed yield per plant. Si 1115/1 x TMV 3 was also manifested high standard heterosis for number of branches per plant, number of capsules per plant, capsule length and 1000 seed weight. Except VS 9510 x CO 1, all other tested hybrids recorded negative heterosis for oil content. VS 9510 x CO 1 had high heterotic vigour for plant height, number of branches per plant, number of capsules per plant, capsule length, 1000 seed weight, oil content and seed yield per plant.

Sumathi and Muralidharan (2008) worked out heterosis over mid parent, better parent and standard parent, CO 1. The cross Paiyur 1 x Cordebergea was early in flowering duration, while the cross TMV 5 x Cordebergea was having superior heterosis for mono stem/shy branching nature with desirable seed yield per plant. TMV 3 x KS 990813 was superior for number of capsules per plant and seed yield per
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plant. Paiyur 1 x MT 34 showed good performance for number of seeds per capsule and oil content with desirable heterosis for seed yield per plant.

Gaikwad et al. (2009) estimated the heterosis and inbreeding depression in ten F₁ hybrids for seed yield and its component traits. Among the hybrids, JLT 8 x ES 3 recorded the highest relative heterosis (38.85%), heterobeltiosls (20.57%) and standard heterosis (54.05%) for seed yield per plant. Cross GT 1 x ESS found to be superior in terms of number of capsules per plant, length of capsule and number of seeds per capsule. Negative inbreeding depression was observed for days to 50 per cent flowering and days to maturity. Yield per plant and number of capsules per plant showed considerable inbreeding depression in F₂ generation.

Khan et al. (2009) evaluated half diallel set of crosses produced from five sesame parents and reported that heterosis ranged from -40.35 to 41.46 per cent, -4.14 to 69.67 per cent and -19.22 to 255.12 per cent for number of branches per plant, number of capsules per plant and seed yield per plant, respectively. Based on average heterotic effects for mid parents, the number of capsules per plant (39.56%) was the main yield component contributing towards heterosis for seed yield per plant followed by branches per plant (12.14%), days to maturity (9.67%), days to flower initiation (3.07%) and plant height (2.97%). Three crosses viz., TS 3 x SG 27, SG 27 x SG 43 and SG 27 x Til 89 were considered as elite crosses.

Toprope (2009) noted significant differences for yield and yield components, indicating the presence of genetic variability in F₁, F₂ and F₃ under study. The maximum limit for the residual heterosis of F₂ and F₃ was lower than that of heterosis in F₁, however, the presence of an appreciable amount of heterosis in F₂ and F₃ was recorded. The crosses that exhibited a substantial amount of heterosis also had high amounts of residual heterosis in F₂ and F₃. The crosses Punjab Til 1 x RT 46, JLT 26 x RT 46 and Uma x RT 46 had low inbreeding depression.

Yamanura et al. (2009) evaluated 19 parents and their 90 crosses in sesame developed by crossing 10 females with 9 males in line x tester fashion. Cross combinations DS 13 x Western recorded the highest significant positive heterosis (113.99 %) followed by DS 16 x TSES 2 (112.44 %), DS 16 x E 8 (107.77 %) and DS 16 x DS 1 (105.18) for seed yield per hectare. These hybrids also recorded significant positive heterosis for seed yield per plant.

Banerjee and Kole (2010) studied heterosis and inbreeding depression for seven important yield contributing characters and reported the maximum heterosis for
seed yield per plant over the mid and better parent in the crosses CST 2002 x TKG 22 (43.30%) and MT 34 x B 67 (27.22%), respectively. Mid parent heterosis for seed yield per plant was due to cumulative heterosis for various important component traits, such as capsules per plant, seeds per capsule and 1000 seed weight. Inbreeding depression was the highest for seed yield followed by 1000 seed weight, capsules per plant, number of branches per plant and plant height, indicating the predominance of non-additive genetic effects. B 67 x Rama exhibited significant positive heterosis in F₁, but non-significant inbreeding depression in F₂ for seed yield.

Durai et al. (2010) performed line x tester analysis with 8 lines and 4 testers to estimate the heterosis for 10 traits viz., days to 50 per cent flowering, plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, seed weight, oil content, chlorophyll content, leaf area index and single plant yield. A total of twenty one hybrids were found to be positively significant for seed yield, of which S-9-1-84 x Paiyur 1 and ES-9-1-84 x CO 1 were the two best crosses.

Prajapati et al. (2010a) studied heterosis in 45 F₁s of sesame resulting from 10 x 10 diallel, excluding reciprocals in four environments. The results revealed pronounced hybrid vigour for yield and most of the yield components. The hybrid ABT 23 x ABT 26 expressed the highest heterobeltiosis for seed yield per plant (26.95%). The cross Mrug 1 x PT 64 also manifested high heterobeltiosis for yield contributing traits viz., number of capsules per plant, length of main branch, number of effective branches per plant, number of seeds per capsule, capsule length and harvest index on pooled basis. None of the hybrid exhibited significant heterobeltiosis for earliness and dwarfness.

Banerjee and Kole (2011) evaluated seven genotypes of sesame, their 21 F₁s and 21 F₂s and reported that, cross CST 2002 x MT 34 exhibited highest positive heterosis for oil yield per plant over mid-parent (43.6%) and better parent (28.4%). Other hybrids showing high, positive and significant heterosis for oil yield per plant over both mid- and better parent were MT 34 x B67, TKG 22 x Rama, MT 34 x Rama and CST 2002 x TKG 22. In general, heterosis for oil yield in sesame might be the result of combined heterotic effects of different physiological traits. In case of oil yield, majority of the crosses expressing significant heterosis also exhibited positive and significant inbreeding depression. However, cross CST 2002 x TKG 22, which showed positive and significant heterosis over both the parents for oil yield per plant, also exhibited non-significant inbreeding depression in F₂.
Gaikwad and Lal (2011) determined heterosis and inbreeding depression in sesame and reported that among the hybrids, JLT 8 x ES 3 recorded the highest relative heterosis (38.85%), heterobeltiosis (20.57%) and standard heterosis (54.05%) for seed yield per plant. Next best hybrid GT 1 x ES 3 was superior in terms of number of capsules per plant, length of capsule and number of seeds per capsule. Negative inbreeding depression was observed for days to 50 per cent flowering and days to maturity. Yield per plant and number of capsules per plant showed considerable inbreeding depression in F₂ generation.

Padmasundari and Kamala (2012) evaluated five parents and its 10 F₁, F₂ and F₃ populations. All ten crosses realized positive, highly significant and relatively high standard heterosis compared to mid-parent and better parent heterosis in seed yield and yield components with desirable earliness in maturity. The cross X 79-1 x EC 351887 appeared to be the best with highest heterosis for seed yield, branches and 1000 seed weight over standard parent, TC 25. Genetic gain for this cross was negative in F₂ for branches, pods per plant and 1000 seed weight and seed yield and it was positive and highly significant in F₃ for these characters. Vm x X 79-1 is the next best cross gained desirable earliness and highly significant positive, high heterosis for seed yield, short stature, pods per plant and primary branches. Heterobeltiosis was highly significant for these characters. Genetic gain for this cross was highest and highly significant in F₃, but it was negative in F₂ for almost all the characters except seeds per pod. Crosses Vm x EC 351887, Vm x EZ 351881 and Vm x EC 359007 also gained highly significant and very high desirable heterosis for seed yield.

Praveenkumar et al. (2012) carried out diallel analysis in sesame using 10 mutant lines to study the heterosis in inter-mutant hybrids for various quantitative traits viz. plant height, days to 50 per cent flowering, days to maturity, number of capsules per plant, capsule length, number of seeds per capsule, 1000 seed weight, oil content and seed yield per plant. The highest magnitude of standard heterosis was recorded in the cross Mutant 9 x Mutant 699 (45.2 % over CC1 and 108.77 % over CC2) followed by Mutant 181 x Mutant 699 (42.68 % over CC1 and 105.26 % over CC2) and Mutant 51 x Mutant 699 (48.78 % over CC1 and 114.04 % over CC2).

Jadhav and Mohrir (2013) studied the heterosis for quantitative traits in sesame. Analysis of variance revealed significant differences among the crosses for all the traits except days to 50 per cent flowering, days to maturity and number of seeds per capsule. Crosses SI 3218 x S 0434, SI 3218 x Lalguda local, GSM-22 x
SI 331517 and GSM 22 x Lalguda local were the best heterotic combinations for seed yield, which recorded 193.10, 191.38, 191.38 and 170.69 per cent standard heterosis, respectively, and could be utilized for hybrid development. Four hybrids namely, GSM 22 x SI 331517, IC 413204 x S 0434, IC 413204 x KMS 5- 873 and IC 413202 x S 0434 manifested desirable relative heterosis for seed yield per plant along with yield components.

Jatothu et al. (2013) studied standard heterosis for eleven characters of sixty hybrids of sesame developed by crossing 10 lines and 6 testers in line x tester fashion. The lines x testers interactions contributed up to 79.55 per cent for capsule length followed by number of seeds per capsule (77.98%), seed yield per plant (77.15%) and number of effective primaries per plant (75.75%). The highest percentage of average heterosis was observed for seed yield per plant and number of effective primary branches per plant. Five crosses viz., PKDS 62 x IS 562 B, S I7818 x SI 3171, KKS 98049 x SI 3171, KKS 98049 x KMR 78 and CST 2001-5 x TKG 22 were identified as potential hybrids with high standard heterosis for seed yield over better yielding commercial hybrid check Swetha til.

Parimala et al. (2013) found that, all the characters showed in variable crosses depicted heterosis in both positive and negative directions indicating that genes with negative as well as positive effects were dominant. The cross JCS 596 x Swetha recorded the highest positive heterosis for number of branches per plant over mid parent. The range of heterosis for number of capsules per plant was -74.27 to 50.74 per cent over better parent. Maximum positive heterosis for number of capsules per plant was exhibited by NIC 8283 x KMR-74 over mid parent and better parent. The hybrids Rajeswari x Swetha, Chandana x Swetha, JCS 596 x KMR 74, JCS 596 x Swetha and NIC 8283 x KMR 74 recorded highly significant positive standard heterosis for plant height. Maximum significant standard heterosis for number of capsules per plant was found in the crosses NIC 8283 x KMR 74, Chandana x Swetha and NIC 8392 x Swetha. The magnitude of heterosis was 103.62 per cent and 98.53 per cent over mid and better parent for seed yield per plant, respectively. The crosses Chandana x Swetha (36.63%) and NIC 8283 x KMR 74 (18.26%) exhibited the highest standard heterosis for seed yield per plant.

Salunke et al. (2013) studied hybrid vigour through diallel analysis for yield and its components in sesame. Seven genotypes were crossed in a diallel fashion, including reciprocals. Out of 42 hybrids, 23 hybrids showed significant and positive
heterosis over their mid-parental value, 16 over corresponding better parent value, 17 over commercial check variety DSS 9 and 12 over commercial check variety CO 1 for seed yield. The hybrid combinations Dhauri Local x DSS 9 and DSS 9 x Dhauri Local exhibited significant positive heterosis for seed yield per plant.

Vavdiya et al. (2013) assessed the extent of heterosis for 15 quantitative traits including seed yield per plant in a set of 48 F₁s developed from twelve lines and four testers crossed in a line x tester fashion. The analysis of variance revealed highly significant differences among the parents and hybrids for all the characters. The standard heterosis for seed yield per plant ranged from -12.32 to 137.39 per cent. The crosses NIC 75 x G.Til 10, IC 81564 x G.Til 10, NIC 75 x G.Til 4, AT 238 x G.Til 10 and Borda 1 x G.Til 10 were good heterotic combinations for seed yield per plant, which recorded 137.39, 128.74, 111.34, 100.42 and 90.84 per cent standard heterosis, respectively. The heterosis for seed yield per plant was associated with the heterosis expressed by its component characters.

Joshi et al. (2014) assessed the extent of the heterosis in sesame for eleven quantitative traits including seed yield per plant in 40 crosses of sesame developed by crossing ten lines and four testers. Analysis of variance revealed the significant differences among the crosses for all the traits. Among the crosses evaluated, Timbi 3 x Guj. Til 10, BAVJ 1 x RT 125 and ES 246 x RT 125 were found to be most heterotic hybrids for yield per plant in terms of heterobeltiosis. These hybrids may be tested in large scale trials to confirm the superiority in heterosis. Crosses BAVJ 1 x RT 125, BAVJ 1 x Guj.Til 1 and Timbi 3 x Guj. Til 10 were the best heterotic combinations for seed yield, which recorded 24.35, 23.31 and 22.27 per cent standard heterosis, respectively over standard check Gujarat Til 2, and could be utilized for hybrid development.

Chaudhari et al. (2015a) worked out the heterosis over better parent and standard varieties Gujarat Til 4 and TKG 22 for 11 quantitative traits in sesame. Five hybrids viz., Gujarat Til 1 x JLS 116, Gujarat Til 2 x JLS 116, Gujarat Til 3 x AKT 64, Patan 64 x JLS 9707-2 and Patan 64 x JLT 408 manifested desirable heterobeltiosis for seed yield per plant along with other six major yield contributing characters. The crosses Gujarat Til 3 x AKT 64, Gujarat Til 3 x PKV NT-11, Gujarat Til 3 x JLS 9707-2 and Gujarat Til 3 x JLS 116 were the best heterotic combinations for seed yield, which recorded 85.81 and 98.08 per cent, 63.38 and
74.13 per cent, 63.38 and 74.13 per cent and 54.28 and 64.43 per cent standard heterosis over Gujarat Til 4 and TKG 22, respectively.

Hassan and Sedeck (2015) observed highly significant differences among genotypes, parents, crosses and parents vs. crosses for all the traits studied, indicating wide diversity among the parents used in this study. The F₁ cross Sohag 78 x Intro 640 exhibited the maximum heterosis percentage for seed yield per plant over the better parent.

Kumar et al. (2015) studied the extent of heterosis under four different environments for yield and its component traits in sesame. Diallel mating design excluding reciprocals was used to develop 28 F₁ crosses from eight parents. Analysis of variance revealed highly significant differences among the parents vs. hybrids under four environments for all the characters, indicating the presence of significant amount of genetic variability for all the traits studied. Heterosis was worked out over mid parent, better parent and standard check, GT-2. For seed yield, crosses Pbt 1 × AT 124, GT 10 × Pbt 1 and GT 2 × PT 64 in E₁; crosses GT 10 × TMV 3, GT 2 × PT 64 and GT 10 × Pbt 1 in E₂; and crosses TMV 3 × C 1013, TMV 3 × Pbt 1 and GT 10 × Pbt 1 in E₃ environment having high per se performance along with significant mid-parent, better parent and standard heterosis. None of the cross in E₄ environment exhibited significant standard heterosis.

Reddy et al. (2015) studied heterosis in a set of 21 hybrids. The crosses KMR 74 x Patan 64, KMR 24 x G.Til 3, G.Til 3 x G.Til 10, KMR 74 x KMR 77 and KMR 77 x G.Til 3 recorded highly significant and positive standard heterosis (over check variety Patan 64) for seed yield per plant. The hybrids, KMR 77 x G.Til 3, KMR 24 x KMR 74, KMR 24 x Patan 64, G.Til 3 x G.Til 10, KMR 74 x Patan 64 and KMR 24 x G.Til 3 showed highly significant standard heterosis for number of capsules per plant. The hybrids KMR 24 x G.Til 3, KMR 74 x Patan 64, KMR 74 x KMR 77, G.Til 3 x G.Til 10 and KMR 77 x G.Til 3 were found to have high heterosis for number of seeds per capsule. None of the crosses exhibited significant positive standard heterosis for number of branches per plant and capsule length. The cross KMR 77 x G.Til 10 had shown highly significant and positive standard heterosis for test weight. Among the crosses studied, two crosses (KMR 77 x G 20 and KMR 77 x G.Til 3) exhibited significant positive heterosis for plant height.

While studying heterosis, Shobha Rani et al. (2015) recorded highly significant differences among sesame hybrids for all the traits studied. Two hybrids
Swethathil x VS 07-023 and Swethathil x JL SEL 05-3 recorded the highest standard heterosis of 13.40 per cent and 10.70 per cent, respectively, with significantly higher seed yield per plant i.e., 28.7 g and 28.0 g, respectively.

Monpara and Pawar (2016) evaluated 8 x 8 half diallel sesame hybrids for their performance of yield and component traits. Average heterosis was the highest for primary branches followed by seed yield, biological yield and plant height. Substantial amount of better parent and standard parent heterosis was observed for majority of the characters studied. The hybrids RT 54 x ABT 33, AT 158 x ABT 33, AT 158 x AT192, AT 192 x G.Til 1and AT 158 x AT 177 were the best heterotic hybrids recorded 70.43, 62.61, 61.74, 53.04 and 48.70 per cent standard heterosis, respectively. These hybrids also showed significant standard or better or mid parent heterosis for some of the important component traits like, early maturity, capsule length, seeds per capsule and biological yield in desirable direction.

Patel et al. (2016) estimated the extent of heterosis for days to flowering, days to maturity, plant height, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, oil per cent and single plant yield by evaluating 36 crosses derived from a 9 x 9 diallel mating design in sesame. A total eighteen crosses exhibited significant positive standard heterosis over check GT 10 for seed yield per plant. Priya x Vianyak, PB Til 1 x TMV 6 and TC 25 x Vinayak showed a highly significant relative heterosis and heterobeltiosis for single plant yield and some of its yield components.

Abd El-Kader et al. (2017) evaluated six parental sesame genotypes and their 15 F₁ crosses to study the extent of heterosis. The results revealed that genotypes and its components (parents, hybrids and parents vs. hybrids) mean squares were highly significant for all the traits studied. The highest heterotic effects over mid and better parents were detected in F₁ hybrids, NA 80 x NA 35 and NA 80 x NA 40 for seed yield per plant and seed yield per plot and one or more of its attributes.

Chaudhari et al. (2017) evaluated 7 parents and their 21 crosses to study the magnitude of heterosis for seed yield and its components in sesame. Analysis of variance revealed significant differences among the genotypes, hybrids and parents for all the traits studied except for harvest index for parents. Several crosses exhibited significantly desirable heterobeltiosis and economic heterosis for seed yield per plant and other characters. On the basis of per se performance and estimates of heterobeltiosis, the crosses AT 242 x AT 255 (17.58%) and AT 242 x GT 3 (17.19%)
were found to be most promising for seed yield per plant, hence could be evaluated further to exploit the heterosis or utilized in future breeding programme to obtain desirable segregants for the development of superior genotypes.

Ghule *et al.* (2017) evaluated 32 hybrids of sesame obtained by crossing 4 x 8 genotypes in ‘L x T’ fashion along with their 12 parents and 2 standard checks to measure the extent of heterosis. The cross GT 3 x AT 255 (32.10%, 22.79 %, 23.00% and 21.72 %) and the cross RT 54 x MT 10-8-1 (19.23%, 18.95%, 17.63% and 16.41%) showed the highest magnitude of significantly positive heterosis over mid parent, better parent and over both standard checks JLT 408 and Phule Til-1, respectively for seed yield per plant.

Karthickeyan *et al.* (2017) evaluated 24 hybrids (6 lines and 4 testers) along with their 10 parents and standard check TMV 5. The hybrids viz., TMV 4 x SVPR 1 and TMV 4 x TMV 6 were found to be best for exploitation, as they manifested significant and positive standard heterosis for seed yield per plant.

Nayak *et al.* (2017) studied heterosis for yield and yield components in a set of 28 crosses developed through half diallel mating design in sesame. Analysis of variance revealed significant differences among the genotypes, hybrids and parents for all the traits except harvest index for parent studied. Several crosses exhibited significantly desirable heterobeltiosis and economic heterosis for seed yield per plant and other characters. On the basis of *per se* performance and estimates of heterobeltiosis, the crosses ASRT 10 x AT 324 (41.88%) and ASRT 10 x Patan 64 (41.88 %) were found to be most promising for seed yield per plant.

Tripathy *et al.* (2017) studied heterosis in sesame in cross combinations using 12 x 12 diallel matting based on morpho-economic traits including seed yield and oil content. Cross combinations, T 13 x E 8 (156.3 %), Pratap x RT 103 (138.4 %), CST 785 x E 8 (127.0 %), BS 5-18-6 x T 13 (125.5 %) and BS 5-18-6 x T 13 (125.5 %) were the best crosses with respect to seed yield per plant on the basis of significant desirable relative heterosis, while T 13 x E 8 (224.6 %), Pratap x RT 103 (131.5 %), BS 5-18-6 x T 13 (119.1 %), T 13 x Madhabi (118.5 %) and CST 785 x E 8 (116.7 %) were the best crosses with respect to seed yield per plant on the basis of significant desirable heterobeltiosis.

Virani *et al.* (2017) studied heterosis for seed yield and its components in a set of line x tester crosses of 10 lines and 5 testers. The analysis of variance revealed highly significant differences among the genotypes for all the characters indicating
that the genotypes exhibited significant differences for all the characters studied. The differences among the parents were highly significant for all the characters except days to 50 per cent flowering, width of capsule and oil content. The differences among the hybrids were also found highly significant for all the characters. The differences among the parents vs. hybrids were also found significant for six characters viz., days to 50 per cent flowering, days to maturity, number of internodes per plant, length of capsule, number of capsules per plant and seed yield per plant. High heterosis was observed for days to 50 per cent flowering, days to maturity, number of branches per plant, number of internodes per plant, length of capsule, number of capsules per plant, number of seeds per capsule, 1000 seed weight and seed yield per plant, whereas the magnitude of heterosis was moderate for plant height, height to first capsule, width of capsule, number of capsules per leaf axil and oil content. The range of heterobeltiosis for seed yield per plant was from -44.14 to 50.9 per cent, while the standard heterosis ranged from 42.01 to 54.9 per cent. The cross Borda 2 x GT 1-9-4 had recorded the highest standard heterosis for seed yield per plant followed by ES 246 x GT 4, RMT 180 x GT 3 and ES 246 x GT 2.

Karande et al. (2018) estimated the heterosis for seed yield and yield contributing traits in sesame through line x tester analysis consists of seven female lines and three testers. The highest magnitude of heterosis over mid-parent (90.44%) and better parent (68.07%) for seed yield per plant was registered in the cross BSG 5 x LT 8. The crosses BSG 5 x LT 8 and BSG 5 x LT 5 manifested the highest magnitude of standard heterosis of 125.19 per cent and 109.36 per cent over standard check Phule til and JLT 7, respectively.

Pandey et al. (2018) made an attempt to estimate the associations of genetic distances using agro-morphological traits with hybrid performance. Seven parents and 21 crosses generated from using half diallel mating design were evaluated at two environments. Compared with the average parents yield (12.57 g/plant), eight hybrids had a significant (P < 0.01) yield advantage across the environments, with averages of 26.94 and 29.99 per cent for better-parent heterosis (BPH) and mid-parent heterosis (MPH), respectively. UMA x NIC 8316 is the top most heterotic cross combination with 47.70 and 55.84 per cent better parent heterosis and mid-parent heterosis, respectively.
2.2 Combining ability and gene action

Selection of appropriate parents which nick well in hybridization and produce superior off springs is an important practical problem encountered by plant breeder. The usual approach is to choose the parents on the basis of per se performance. However, it does not provide always a good indication of the superiority of its hybrids. It is of common experience that certain combinations nick well to produce superior hybrids, whereas others involving equally promising parents produce poor hybrids. Therefore, combining ability study is more reliable, as it provides useful information for the selection of parents in terms of performance of hybrids and also elucidates the nature and magnitude of gene action involved in the expression of quantitative traits and developing suitable breeding methodology for the crop.

The concept of combining ability has become very popular in the discipline of plant breeding since Davis (1927) suggested the use of inbred variety cross (top cross) as a method of evaluating inbred lines of maize. Later on Sprague and Tatum (1942) elaborated it by proposing the concept of general and specific combining ability. Information on relative importance of general and specific combining ability is of value in the formulation of efficient breeding programme particularly in those species which are amenable to commercial production of F₁ hybrid seed. As such the information is useful in selecting superior parents for particular traits.

The general combining ability is defined as the average performance of a line in a series of crosses and is considered as a measure of additive gene action, whereas specific combining ability is the deviation in performance of a cross combination from that predicted on the basis of the general combining ability of the parents involved in the cross. It is considered as a measure of non-additive gene action.

General combining ability is controlled by additive gene action and additive x additive interaction as suggested by Rojas and Sprague (1952). Griffing (1956a) suggested a model to show that variance for GCA involved mostly additive genetic effects, whereas SCA resulted from dominance and epistatic components of genetic variance. Hayman (1960) proposed that in the absence of epistatis, general combining ability consists of both additive and dominance portions, while specific combining ability involved over-dominance. Griffing (1956b) described two models, each with a four methods, for working out general combining ability and specific combining ability estimates in a set of diallel cross and showed relationship of diallel crossing
method to Fisher (1918 & 1930) method of covariance between relatives and expressed in terms of additive and non-additive genetic variance.

Diallel analysis is the quickest method of understanding the genetic nature of quantitatively inherited traits and it helps to ascertain the prepotency of parents and their F2. A recent review of literature available on combining ability and gene action in sesame is briefly described as under in subsequent paragraphs.

Murty (1975) investigated the magnitude of general and specific combining ability variances and differences in reciprocal F1 hybrids. Additive as well as non-additive gene action seemed to govern the expression of the various characters studied. General combining ability variances were predominant for days to flowering, plant height, number of primary branches and number of secondary branches, while specific combining ability variances were in moderate to high proportions for seed yield, percentage of oil and percentage of protein. TMV 2 and SI 770 were the best general combiners for many of the characters, while SI 1783 and Sel. R were found to be the best for earliness and oil content, respectively. Significant variances due to reciprocal effects were also detected for some of the characters.

While studying gene effects for nine characters in two crosses of sesame involving single stemmed varieties, Pathak and Dixit (1988) proclaimed that additive as well as non-additive gene effects were operative for the expression of most of the characters under study, except days to flowering where additive gene action was important.

Goyal and Kumar (1991) analyzed 8 x 8 diallel set of F1 generation without reciprocals in sesame and reported that, the variances due to gca and sca were highly significant denoting importance of additive and nonadditive gene actions for all the eight traits. The estimated components of sca variances were higher in magnitude for all the traits, indicating the predominance of non-additive or dominant gene action for the traits. The parents Vinayak and SP 1162 were good general combiners for most of the characters, Type 12 for seeds per capsule, oil content and number of branches, and Pratap for number of capsules, plant height, oil content, days to flowering and maturity, and number of branches, which could be utilized in hybridization programme. The specific crosses Pratap x Vinayak, Pratap x TC 25, Type 12 x N 32, Vinayak x SP 1162, Type 12 x SP 1162 and N 32 x ES 22 appeared to be good for seed yield and most of the seed yield contributing characters.
While evaluating 9 x 9 diallel crosses of sesame, Reddy et al. (1992) observed that gca and sca effects were highly significant for oil content and seed yield per plant. Higher magnitude of GCA variance than SCA variance and higher GCA/SCA variance ratio for oil content indicated that its inheritance was predominantly under the control of additive gene action, while seed yield was predominantly under the control of non-additive type of gene action.

Patel (1993) carried out combining ability analysis in sesame and reported that variances due to GCA, SCA and reciprocals were significant for days to initial flowering, days to maturity, plant height, length of capsule and number of seeds per capsule. However, the predictability ratio showed the predominance of additive gene action for days to initial flowering, days to maturity and non-additive gene action for plant height, length of capsule and number of seeds per capsule.

Durga et al. (1994) studied combining ability and gene action by using 6 lines x 3 testers in sesame. Estimates of GCA and SCA variances indicated the predominance of non-additive gene action for days to maturity, height to first branch and first capsule, plant height, petiole length, productive capsules on main stem, seed yield per plant, oil yield per plant and harvest index. Among the lines, DORS 102 was good general combiner for earliness and dwarf plant type. Among the testers, Tapi was considered as good general combiner for seed yield and other component characters like earliness and number of primary and secondary branches.

In a genetic analysis of ten lines and three testers, Ram (1995) reported the predominance of non-additive gene action in the inheritance of plant height, primary branches per plant, capsules per plant and seed yield per plant. TMV 3 and CO 1 were good general combiners for all the characters, while the good specific combinations were B 67 x CO 1, C 7 x CO 1 and G.Til 1 x C 6.

Jayprakash and Subramanian (1996) studied combining ability through line x tester analysis and reported preponderance of non-additive gene action for days to 50 per cent flowering, earliness, plant height, capsules per plant and seed yield per plant. IS 242 and SVPR 1 were identified as good general combiners for earliness, whereas SVPR 1, SI 1003 and TN 8454 were good general combiners for plant height, capsules per plant and seed yield per plant. TSS -4 x SVPR 1 and TN 8454 x CO 1 expressed high sca effects for days to flowering, plant height, capsules per plant and seed yield per plant.
While studying combining ability through diallel analysis, Backiyarani et al. (1997) reported involvement of additive and non-additive gene actions in the genetic control of seed yield and its component characters. However, additive genetic variance was predominant for days to first flowering, plant height, number of primary branches, number of capsules, oil per cent and single plant yield. Two parents *viz.*, TMV 6 and TNAU 65 were good general combiners for oil percentage as well as single plant yield. The majority of the hybrids with high sca effects involved at least one parent with high gca effect.

Manivannan (1997) carried out combining ability analysis in sesame and reported that the variance due to SCA were greater than the variance due to GCA, indicated the predominant role of non-additive gene effect in the expression of seed yield. Two lines *viz.*, S 0584 and TMV 5 and a tester SVPR 1 were good general combiners for seed yield.

A 5 x 5 diallel crosses were evaluated for combining ability by Das and Chaudhary (1998) in sesame. The ratio of GCA variance to SCA variance indicated the predominance of non-additive gene action for seed yield per plant and some of its components. For number of branches per plant, both additive and non-additive gene actions were equally important.

Mansouri and Ahmadi (1998) studied the combining ability through diallel analysis in sesame and found highly significant differences for plant height, number of capsules per plant, 1000 seed weight, seed yield per plant and seed oil content. Additive gene action was predominantly involved in the genetic control of plant height, number of capsules per plant, seed yield per plant and oil per cent. However, 1000 seed weight showed predominance of non-additive gene action.

Das and Gupta (1999) studied combining ability in sesame using 8 x 8 diallel cross for seed yield, yield components and oil content. Additive genetic variance was of greater importance for number of primary branches per plant, number of secondary branches per plant, number of capsules per plant and seed yield per plant, while both additive and non-additive genetic variances were equally important for days to flowering, 1000 seed weight and oil content. GCA and SCA manifested significant interaction with year for all the characters. The relative magnitude of non-additive x year interaction was greater than additive x year interaction. The variety B 9 was good general combiner for seed yield and its major components and the cross B 14 x B 9 emerged as the best specific combiner for seed yield and its components. For
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augmenting seed yield and oil content simultaneously, the cross combination MT 67–52 x TC 25 was found promising.

Sakhare et al. (2000) performed 12 x 12 diallel analysis and reported that the relative estimates of variances due to SCA were higher in magnitude than the corresponding estimates due to GCA for 1000 seed weight, seed yield per plant, oil percent and harvest index, indicating the role of non-additive gene action in the inheritance of these characters, however, days to 50 per cent flowering had predominance of additive gene action.

Sakila et al. (2000) went through combining ability analysis using line x tester mating design for six quantitative characters in sesame. The GCA to SCA variance ratio revealed non-additive type of gene effect for all the characters. The best combiner was VRI 1 for days to flowering, plant height and total capsules per plant and Si 3315/11 for total capsules per plant and single plant yield. The cross TMV 6 x Annamalai 1 showed significant SCA effects for capsules on main stem, total capsules per plant and single plant yield.

Hoballah (2001) evaluated a half diallel set of crosses involving seven parents to study the combining ability in the F_1 generation in sesame. Analysis of variance for combining ability indicated that general (GCA) and specific (SCA) combining ability variances were highly significant for all the traits studied. Estimates of GCA effects showed that EXM 90, EFM 92 and Mutant 8 were the best general combiners for earliness, while Giza 32 and Mutant 48 were the best for seed yield and number of capsules per plant. Both the parents and their derived crosses could be utilized for hybrid sesame production and varietal improvement in terms of the probability of selecting desirable segregants for yield and yield components.

Manivannan and Ganesan (2001) evaluated 52 F_1s developed by line x tester design using twenty six genotypes as lines and two varieties as testers for four characters viz., plant height, number of branches per plant, number of capsules per plant and seed yield per plant. The magnitude of SCA variance was more than GCA variance for all the characters. It showed the preponderance of non-additive gene action including additive x additive. Fourteen lines namely SI 861, SI 1770, SI 2257, SO 573, IS 200, IS 207, IS 305, IS 534, RJS 2, BS 6-1-1, TSS 11, Paiyur 1, Gene 9101 and Thiruvellore local showed significant gca effect for seed yield per plant and also for yield components.
Mishra and Sikarwar (2001) described non-additive type of gene action for seed yield. The combination JTS 13 x TKG 22 was found to be the best on the basis of sca and per se performance. JTS 13 and EC 132856 as females and TKG 22 as male were the best general combiners for the seed yield.

Solanki and Gupta (2001) performed line x tester analysis involving 11 females and 3 males and revealed a greater magnitude of SCA variances for seed yield per plant, capsules bearing plant height, branches per plant, number of capsules per plant and 1000 seed weight, indicating the importance of non-additive gene action. GCA variances were higher for days to maturity and plant height indicated the importance of additive gene action. Among the females, IS 225-2 for seed yield and IS 186-1 for early maturity and capsules per plant, the best general combiners. Among the male parents, RT 305 was the best general combiner for all the characters except capsules per plant. Four crosses IS 147 x RT 274, HT 24 x RT 274, IS 240(B) x RT 305 and NIC 8409 x RT 274 were the best specific crosses for both seed yield and capsules per plant.

Devi et al. (2002) evaluated six parent diallel crosses including reciprocals and reported the preponderance of additive gene action for number of flowers per plant, reproductive efficiency, number of seeds per capsule, total number of seeds per plant and number of filled seeds per plant. On the other hand, non-additive gene action was found to be the important for number of ill-filled seeds per plant and seed yield per plant. The genotypes TNDU 120 and TMV 3 were identified as good general combiners for most of the reproductive traits studied. The hybrid Paiyur 1 x TMV 3 showed a high per se performance coupled with high specific combining ability effects for majority of the traits.

Kar et al. (2002a) carried out combining ability analysis for yield and yield components in a half-diallel set and reported the predominance of additive genetic variance for days to maturity, while for days to 50 per cent flowering, branches per plant, capsules on main stem, capsules per plant, capsule length and seed yield per plant, non-additive gene action was important.

Kar et al. (2002b) studied combining ability in sesame through line x tester analysis using fourteen lines and three testers and reported preponderance of non-additive gene action for plant height, height up to first capsule, branches per plant, nodes on main stem, capsules on main stem, capsules per plant, capsule length, capsule breadth, seeds per capsule, 1000 seed weight and seed yield per plant. Guj.Til
1, Sel. 73, Sel. 33, Sel. 123 and Uma were good general combiners for seed yield and yield contributing characters. Sel. 33 x Uma, Guj.Til 1 x TC 25, Sel. 84 x Sel. 185 and Sel. 73 x Uma, which showed significant sca effects can be considered as best combinations for exploitation of hybrid vigour.

Kumar and Ganesan (2002) performed a line x tester analysis with five lines and three testers to study the combining ability in sesame. The results revealed that dominant gene action was predominant for plant height, number of branches per plant, number of capsules on main stem, number of capsules on branches, total number of capsules per plant, capsule length, number of seeds per capsule, 1000 seed weight and seed yield per plant. Based on gca effects, T 6 was the best general combiner for all the nine traits. Based on sca effects, TMV 3 x Madhavi was identified as the superior hybrid.

Sankar and Kumar (2003) noticed significant additive and non-additive genetic effects for all the traits studied. However, additive gene action was predominant for plant height and non-additive gene action was predominant for days to 50 per cent flowering, number of primary branches per plant, number of capsules per plant, oil per cent and single plant yield. DCH 47-2-60 was the best general combiner for all the traits. DCH 25-1 was a good combiner for plant height, number of primary branches per plant, number of capsules per plant, oil per cent and single plant yield. The hybrids DCH 25-1 x TMV 6, TNAU 120 x CO 1, YLM 40 x SVPR 1 and TNAU 120 x SVPR 1 had high sca effects for most of the characters including oil per cent and single plant yield.

Saravanan and Nadarajan (2003) performed combining ability analysis for seed yield and its components by evaluating a set of 8 x 8 half diallel crosses of sesame and reported that additive genetic variance was of greater importance for days to 50 per cent flowering, plant height, number of primary branches per plant, 1000 seed weight, oil content and harvest index, while non-additive genetic variance played a major role for number of capsules per plant, number of seeds per capsule and single plant yield. The variety CO 1 was the best general combiner and the hybrid YLM 123 x AHT 123 emerged as the best specific combiner for seed yield and its components viz., number of branches per plant, number of capsules per plant, number of seeds per capsule, 1000 seed weight and harvest index.

Babu et al. (2004) studied combining ability analysis for nine quantitative traits in 12 sesame crosses involving four lines and three testers. The study revealed
the importance of non-additive gene action in the inheritance of days to 50 per cent flowering, number of primary branches per plant, number of capsules per plant, oil content and seed yield per plant. Additive gene action was observed for days to maturity and 1000 seed weight. Both additive and non-additive gene actions were observed for plant height and number of seeds per capsule. Madhvi and Vinayk were the best general combiners for majority of characters. Among the crosses, Tanukubrown x Vinayak and Tanukubrown x DCB 1855 were most promising crosses having good sca effects for seed yield per plant.

Kumar *et al.* (2004b) studied general and specific combining ability of 30 sesame crosses along with 13 parental lines for 7 characters *viz.*, plant height, number of branches per plant, number of capsules per plant, capsule length, number of seeds per capsule, 1000 seed weight and yield per plant. The combining ability variance indicated the preponderance of non-additive gene action for all the characters studied, indicating the scope for heterosis breeding in crop improvement. The tester SVPR 1 was a good general combiner for seed yield per plant. The crosses AUS 29 x SVPR 1 and AUS 15 x RT 125 showed the highest and significant sca effect for yield per plant, number of seeds per capsule and number of capsules per plant.

Mothilal and Manoharan (2004) studied combining ability through a line x tester analysis involving 3 female and 8 male parents of sesame for different characters. The results revealed that variances due to SCA were higher than that of GCA, indicating the predominance of non-additive gene action for plant height, number of branches, fruiting stem length, number of capsules and seed yield, while GCA variances were higher than SCA variances for 1000 seed weight, indicating the preponderance of additive gene action. TMV 4 was found to be good general combiner for number of capsules, 1000 seed weight and seed yield per plant. The good specific combiners for seed yield were TMV 3 x Si 1160, TMV 3 x Si 102, TMV 3 x Vinayak and TMV 3 x Si 0535.

A line x tester analysis was carried out by Vidhyavathi *et al.* (2005) using seven lines and four testers in sesame and found preponderance of non-additive gene action for days to 50 per cent flowering, days to maturity, plant height, number of primary branches, number of capsules per plant and seed yield per plant and additive gene action for 1000 seed weight and oil content. Two parents *viz.*, IS 184 and TNAU 2031 were good general combiners for earliness and the parents namely, SI 66 and TMV 5 were good general combiners for seed yield per plant. Among the crosses,
TMV 5 x Si 66 recorded non-significant sca effect and the gene action might be of additive nature, while the crosses, CO 1 x IS 99, CO 1 x Si 66, TMV 5 x IS 184, TMV 5 x N 32, TNAU 2031 x RT 105 and TNAU 2031 x IS 99 recorded significant sca effects and the gene action might be of additive type of epistasis.

Prajapati et al. (2006b) evaluated 10 x 10 half diallel crosses in sesame to assess the nature and magnitude of components of variation. The variance due to SCA was predominant for days to maturity, plant height, number of capsules per plant, capsule length, seeds per capsule and seed yield per plant, whereas the variance due to GCA was predominant for days to 50 per cent flowering, number of branches per plant, 1000 seed weight and oil content. Sesame cultivars PT 64, TMV 3 and AT 103 were the best general combiners for seed yield and its major components. The hybrid, TMV 3 x C 1013 emerged as the best specific combiner for seed yield and its components.

While studying line x tester analysis involving 18 females and 10 males from diverse origins, Solanki and Singh (2006) observed that there was a greater magnitude of SCA variances than GCA variances for all the characters studied, indicating the predominance of non-additive gene action for exploitation of heterosis for improving these characters. The lines HT 1, RT 281 and RMT 97 were found to be good general combiners contributing alleles with positive effects for improving all the important economic traits. Among the testers, EC 370932 and EC 351832 proved to be good general combiners for the majority of the yield contributing traits. Crosses HT 1 x IS 100 B, RMT 93 x EC 351832, RT 46 x IS 100 B and RT 46 x EC 370932 for seed yield, AT 77 x EC 370932 and AT 77 x EC 351832 for capsule bearing height and RMT 93 x EC 370932 for capsules per plant manifested high and significant desirable SCA effects.

Bayoumi and El-Bramawy (2007) carried out genetic analysis in sesame. The estimation of variances for combining ability indicated the predominance of additive gene action for all the characters studied except height of first capsule, seed yield per plant and resistance to Fusarium wilt disease. The combining ability analysis showed that the parents Toshka 3, and Mutant 8 were relatively good general combiners with high per se performance. Among F1 hybrids, Toshka 3 x Mutant 8 and Mutant 8 x Local Sharkia were the best crosses based on per se performance and sca effects.

El-Shakhess and Khalifa (2007) carried out line x tester analysis using four lines and four testers in sesame. The magnitude of SCA variances was greater than
GCA, indicating the importance of non-additive gene effects in the inheritance of yield and yield components. Among the lines, MGS 36-2 recorded desirable gca effect for number of branches per plant, number of capsules per plant, seed yield per plant and oil percentage. Among testers, two genotypes viz., Toshkal and MGS 11-47 were the best general combiners for plant height, length of fruiting zone, number of capsules per plant, capsule length, seed yield per plant and seed index.

Gawade et al. (2007) studied combining ability through diallel analysis involving eight genotypes of sesame. The results revealed that mea sum of squares due to gca and sca were significant for all the characters studied, indicating variability in combining ability of parents. SCA variances were greater than GCA variances for days to 50 per cent flowering, days to maturity, plant height at harvest, number of branches per plant, number of internodes per plant, number of capsules per plant, length of capsule, number of seeds per capsule, oil content and seed yield per plant, indicating the preponderance of non-additive gene action in the inheritance of these traits. PT 1 and JLT 54 were good general combiners for plant height at harvest, number of branches per plant, number of internodes per plant, number of capsules per plant, number of seeds per capsule and seed yield per plant. The cross combinations JLT 54 x Hawari, PT 1 x JLSV 4 and PT -1 x Hawari showed significant sca effects for seed yield per plant.

Thiyagu et al. (2007b) evaluated 36 hybrids obtained by crossing 12 lines with 3 testers in line x tester fashion and their parents for nine metric traits. Combining ability analysis indicated the preponderance of non-additive gene action for days to 50 per cent flowering, days to maturity, plant height, number of primary branches per plant, number of capsules per plant, seed yield per plant and oil yield per plant. The genotypes CO 1, TMV 4 and ORM 14 might be utilized as potential parents since they possessed high per se with significant gca effects for most of the traits under study. Based on per se performance and sca effects for yield and yield related components, the hybrids CO 1 x ORM 14, TMV 4 x ORM 17, TMV 5 x ORM 17, Paiyur 1 x ORM 14 and TNAU 2030-35 x ORM 14 were identified as the best cross combinations for further exploitation.

Anuradha and Reddy (2008b) studied the nature of gene action in the biparental progeny of the cross DCB 1799 x Gowri in NC II design for various traits and reported that seed yield and yield traits like number of primary branches, seeds per capsule, 1000 seed weight, biological yield and harvest index showed the
importance of dominance variance, while plant height, capsules on main stem and capsules on primary branches registered the importance of additive gene action.

Raghunaiah et al. (2008) studied heterosis and combining ability for yield and yield components in 24 sesame hybrids and reported that SCA variances were higher than GCA variances, indicating the preponderance of non-additive gene action for all the traits studied except days to 50 per cent flowering. EC 310447, KIS 282-2, Swetha thil and JCS 9426 were the best combiners for seed yield per plant along with their major yield contributing traits. KIS 282-2 x Swetha thil and JCS 402 x JCS 9425 and EC 310447 x Swetha thil exhibited the high and significant sca effects for seed yield per pant. Most of the crosses which recorded high sca effects involved at least one parent with desirable gca effect for that trait.

Sharmila and Ganesh (2008) showed that all the traits under study were predominantly controlled by non-additive genes. Based on mean performance and gca effect, two parents VS 9510 and Co 1 were found to be the best general combiner for seed yield per plant. The hybrid VS 9510 x CO 1 was found to be superior for more than one trait based on per se performance and sca effect.

Sumathi and Muralidharan (2008) evaluated 30 crosses developed by using five lines and six testers in a line x tester mating design. The SCA variances were greater than GCA variances for the traits viz., days to 50 per cent flowering, days to maturity, number of capsules, capsule length, number of seeds per capsule, 100 seed weight, seed yield per plant and oil content suggesting that these characters were governed predominantly by non-additive genetic components. The GCA variances were predominant in plant height and number of branches, indicating that these characters were by and large governed by additive component of heritable variance. The line TMV 3 showed high gca effect for seed yield, days to 50 per cent flowering, days to maturity, plant height, number of capsules and oil content, while the tester, KS 990812 recorded significantly high gca effect for number of capsules. The specific combining ability effects showed that out of thirty hybrids, four hybrids viz., CO 1 x Cordebergea, Paiyur 1 x KS 99153, TMV 4 x MT 34 and TMV 5 x KS 99037 showed significant positive sca effect for single plant yield.

Banerjee and Kole (2009) studied nature and magnitude of gene action and combining ability effects for some important yield contributing characters. Analysis of combining ability indicated that the variances due to GCA and SCA were highly significant in both F1 and F2 generations for plant height, number of branches per
plant, number of capsules per plant, number of seeds per capsule, 1000 seed weight, stick yield per plant and seed yield per plant, which indicated importance of both additive and non-additive gene actions for the inheritance of these characters in both the generations. OS Sel-2 appeared as best general combiner for seed yield per plant in both the generations.

Bharathikumar and Vivekanandan (2009) carried out combining ability analysis in sesame through L x T design with nine lines and five testers for yield and yield contributing characters viz., days to maturity, plant height, number of branches per plant, number of capsules per plant, capsule length, number of seeds per capsule, 1000 seed weight, oil content and seed yield per plant. Non-additive gene action was predominant for all the traits studied. Combining ability analysis revealed that three parents RT 125, VS 9701 and CO 1 were good general combiners for five traits including seed yield per plant. Considering both per se performance and gca effect, the parents VS 9701, Ajit 131 and SVPR 1 were found to be the best. Better segregants can be obtained from the hybrid combinations RT 125 x CO 1, VS 9701 x CO 1 and Uma x CO 1 for seed yield and yield contributing characters.

Kuselan and Thirugnanakumar (2009) studied gene action in sesame. The variances due to GCA were less than that of the variances due to SCA for all the seven characters studied viz., days to 50 per cent flowering, plant height at maturity, number of branches per plant, number of capsules per plant, number of seeds per capsule, 1000 seed weight and seed yield per plant, indicated that these characters were predominantly controlled by dominance and non-additive gene action. The study revealed the importance of both dominance and epistasis for evolving genotypes with higher seed yield. It may be achieved by resorting to population improvement programme.

Mishra et al. (2009) studied combining ability and nature of gene action involved in the inheritance of seed yield and its components in sesame using a half diallel set of 12 elite varieties and reported that the gene action was largely additive for primary branches and predominantly additive for plant height and 1000 seed weight. Both additive and non-additive gene actions were equally important for days to maturity and seeds per capsule. Additive gene action played a greater role in case of capsules per plant, while non-additive gene action played a greater role in the inheritance of seed yield. The varieties VRI 1 and GT 10 were good general
combiners for capsules per plant; Kalika and HT-1 for seeds per capsule; AKT 64 and Pragati for 1000 seed weight and Uma, GT 10, AKT 64 and Kalika for seed yield.

Shekhat et al. (2009) carried out combining ability analysis in a set of 10 parents, 45 F₁s and 45 F₂s. The variances due to GCA and SCA were significant for days to 50 per cent flowering, plant height, number of effective branches per plant, number of capsules per plant, number of seeds per capsule, length of capsules, days to maturity, yield per plant, 1000 seed weight, oil content, harvest index and leaf area index, which indicated that both additive and non-additive gene actions played an important role in the expression of all these characters. The GCA variances were lower than the SCA variances for all the characters except for plant height and days to maturity, which indicated preponderance of non-additive gene action in the expression of these characters. The parent ABT 22 was good general combiner along with high per se performance for number of effective branches per plant, length of capsule, 1000 seed weight, oil content and leaf area index. Two parents viz., ABT 23 and AT 34 were good general combiners for yield in both F₁ and F₂ generations. The parents AT 190, AT 92 and G.Til 2 were good general combiners for plant height in both F₁ and F₂ generations. Crosses, AT 90 x AT 104, ABT 22 x G. Til 1, ABT 23 x AT 34 and AT 104 x G. Til 2 were good specific combinations for yield and yield contributing characters.

Yamanura et al. (2009) evaluated 19 parents and their 90 crosses in sesame developed by crossing 10 females with 9 males in line x tester fashion. The results indicated that character, 1000 seed weight had a fixable additive genetic variance, which can be improved by simple selection, whereas the characters viz., plant height, days to 50 per cent flowering, days to maturing, length of capsule, total number of capsules per plant, oil content, seed yield per plant and seed yield per hectare showed the predominance of non-additive gene action, which can be improved by bi-parental mating. The parents DS 13, DS 16, DS 10 (females) and E 8, TSES 2, TSES 4, DS 1 (males) were found good general combiners for seed yield per plant. The cross combinations of DS 16 x DS 1, DS 16 x TSES 2 and DS 10 x TSES 4 exhibited high sca effects for seed yield per hectare. The parents involved in the hybrid DS 16 x TSES 2 have low x high gca effect known to have non-additive x non-additive gene action which can be improved by intermating.

Bangar et al. (2010) analyzed 8 x 8 diallel crosses for combining ability study for yield and yield components and revealed the importance of additive and non-
additive gene actions for all the characters studied. The estimated components of SCA variances were higher than the GCA variances for all the characters indicating predominant role of non-additive or dominant gene action.

Kumar and Kannan (2010) carried out line x tester analysis in sesame using 7 lines and 4 testers to estimate the combining ability effects and nature of gene action for days to 50 per cent flowering, plant height, number of branches per plant, number of capsules per plant, capsule length, number of seeds per capsule, 1000 seed weight and seed yield per plant. Non-additive gene action was predominant for all the traits studied. The analysis of variance showed significant differences among the genotypes for all the traits. The L x T interaction effect was also significant for all the traits studied. Based on the general combining ability effects, IVTS 7 among lines and TMV 6 among testers were found good general combiners for seed yield per plant. The cross combination IVTS 7 x TMV 6 exhibited the maximum positive and significant sca effect for seed yield per plant. Hybrid IVTS 8 x TMV 3 recorded desirable sca effects for earliness.

Mandal et al. (2010) carried out eight parent diallel analysis excluding reciprocals for various quantitative characters and concluded that both additive and non-additive genetic components were involved in determining the expression of the characters, but non-additive type of gene action predominated in all these characters. Kanke white was good general combiner for oil content and average general combiner for number of secondary branches per plant. Crosses RTF 46 x Kayamkulam and Kanke white x RT 125 were the best specific combiners for seed yield per plant.

Parameshwarappa and Salimath (2010) carried out line x tester analysis in sesame using four lines and three testers to study the combing ability and heterosis for yield and yield attributes viz., days to maturity, plant height, number of primary branches per plant, number of capsules on the main axis, number of seeds per capsule, 1000 seed weight and seed yield per plant. General and specific combining ability (gca and sca) variances showed major contribution of additive gene action for all the nine characters studied except number of seeds per capsule. Lines GM 38-1-2 and Dhawri 1 were good general combiners for most of the characters including seed yield per plant. On the basis of sca effects, Dhawri 1 x DS 1, OSC 09-6 x DSS 9 and TKG 22-1 x DS 1 were the promising crosses for high yield.

Prajapati et al. (2010b) studied combining ability through 10 x 10 diallel analysis for yield and its component traits in sesame. Non-additive genetic variances
were of greater importance for plant height, length of main branch, number of capsules on main branch, number of capsules per plant, capsule length, number of seeds per capsule, seed yield per plant and harvest index. Based on general combining ability, parents C 1013, AT 123 and GT 2 were found to be good general combiners for yield and yield contributing traits. The cross combinations viz., GT 2 x GT 10, Mrug 1 x PT 64 and C 1013 x ABT 23 had highly significant sca effects for seed yield and most of the yield attributing traits.

Rajaram and Kumar (2011) tested general and specific combining ability in sesame through L x T analysis with ten lines and four testers. Based on general combining ability effects of parents, line IVTS 14-07 for days to 50 per cent flowering and number of capsules per plant, IVTS 215-06 for plant height, number of branches per plant and 1000 seed weight and IVTS 24-06 for number of seeds per capsule and seed yield per plant was found to be good general combiner. The cross combination IVTS 17-07 x TMV 4 possessed negative and significant sca for days to 50 per cent flowering. AVTS 3-06 x TMV 3 exhibited positive and significant sca for number of capsules per plant and seed yield per plant.

Praveenkumar et al. (2012) carried out diallel analysis in sesame using 10 mutant lines to study combining ability in inter-mutant hybrids for various quantitative traits viz. plant height, days to 50 per cent flowering, days to maturity, number of capsules per plant, capsule length, number of seeds per capsule, 1000 seed weight, oil content and seed yield per plant. The GCA and SCA variances showed major contribution of non-additive gene action for all the characters except for days to maturity. Mutant lines viz. Mutant 353, Mutant 274, Mutant 699, Mutant 353 and Mutant 450 were the best general combiners for seed yield. Thirteen hybrids recorded significant positive SCA effects for seed yield per pant, of which the highest SCA effects were resulted in the hybrid Mutant 181 x Mutant 353 (11.16) followed by Mutant 224 x Mutant 699 (9.33), Mutant 40 x Mutant 51 (7.25), Mutant 181 x Mutant 450 (6.41) and Mutant 9 x Mutant 699 (6.20).

Salunke and Lokesha (2012) carried out combining ability analysis in 7 x 7 diallel mating design for yield and its contributing characters in sesame for nine quantitative characters viz., days to maturity, plant height, number of branches per plant, number of capsules per plant, capsule length, number of seeds per capsule, 1000 seed weight, seed yield per plant and oil yield per plan. The results revealed that the variances due to gca, sca and rca were highly significant, denoting the importance
of both additive as well as non-additive genetic components for yield and yield contributing characters. The parent DSS 9 and Dhauri local were the best combiners for seed yield per plant and oil yield per plant, whereas the crosses Dhauri local x DSS 9, DSS 9 x RT 54 and DSS 9 x Dhauri local were the best combinations for seed yield.

Sakhiya (2013) carried out diallel analysis in sesame in order to estimate the combining ability and nature of gene action involved in the inheritance of seed yield and its components characters viz., days to 50 per cent flowering, days to maturity, plant height, height to first capsule, number of branches per plant, number of internodes per plant, length of capsule, width of capsule, number of capsules per plant, number of capsules per leaf axil, 1000 seed weight, number of seeds per capsule, oil content and protein content. The GCA and SCA variances were highly significant for all the characters except width of capsule. The less than unity potential ratio also confirmed the preponderance of non-additive gene action for all the traits except number of capsules per leaf axil.

Ahmed and Adam (2014) reported that both additive and non-additive type of gene actions were important in the expression of all the traits studied. For days to 50 per cent flowering and days to maturity, Khidir was the only parent that scored negative general combining ability effects in both seasons. Therefore, it was desired to be selected for earliness. For seed yield and yield related characters, significant positive SCA effect was noted by the crosses, Kenana 2 x Gd 2002SPSN-12 and Promo x Gd 2002SPSN-12, whereas negative significant SCA effects were showed by Gadarif 1 x Umshagera. The rest of the cross combinations were inconsistent across the seasons; some of them recorded a positive value in one season and negative value in another one. Khidir and Promo recorded a positive significant GCA effects for the yield and its components at least in one season. Moreover, Promo was the best combiner with the other parental lines for earliness since it recorded negative GCA values. Therefore, Khidir, Promo and Gd 2002SPSN-12 could be recommended to produce progeny having high yield and early maturing hybrids through recurrent selection or reciprocal crosses.

Aladji Abatchoua et al. (2014) genetically screened 12 promising lines for eight characters in sesame. GCA/SCA ratio indicated that both dominant and additive gene effects were significant for these parameters with predominance of non-additive effects. Genetic analysis demonstrated that the parents differed for their general
combining ability (GCA) and the crosses for specific combining ability (SCA). Association between GCA effects and mean characters in most cases implied that parental sesame lines with high values of the characters have superior combining ability.

Azeez and Morakinyo (2014) observed that mean square values for specific combining ability (SCA) were greater than mean square values of general combining ability (GCA) for most of the traits, indicating the preponderance of non-additive gene action except for 1000 seed weight. PACH was the best general combiner for number of pods per plant, number of seeds per pod, number of seeds per plant, seed oil and protein content. Cross S 530 x PACH was good combination for 1000 seed weight, seed weight per plant, seed oil and protein content. Cross 65-8B x PACH had the highest significant positive mid and better parent heterosis for seeds per plant, primary branches and plant height, while cross S 530 x PACH for 1000 seed weight and seed oil.

Ramesh et al. (2014) reported that the parents, ES 274, SSM and TILAK were good general combiner for earliness and parents namely, GT 3, GT 4, BHACAU 1 and VRI (SV) 1 were good general combiners for seed yield per plant. Eight hybrids had superior per se performance for seed yield, its component characters and earliness. With regard to seed yield, three hybrids had both the parent as desirable combiners. Crosses involving VRI (SV) 1 as line performed better with all the testers under study indicating that this genotype can be utilized in future breeding programmes. The crosses, BHACAU 7 x GT 4, VRI (SV) 1 x GT 1, VRI (SV) 1 x GT 2, VRI (SV) 1 x GT 3 and VRI (SV) 1 x GT 4 recorded significant sca effects and the gene action might be of additive type of epistasis.

Subashini et al. (2014) studied combining through L x T design with seven lines and five testers for yield and yield contributing characters viz., days to 50 per cent flowering, plant height, number of branches per plant, number of capsules on main stem, number of capsules on main branches, number of capsules per plant, number of seeds per capsule, 1000 seed weight, oil content and single plant yield. The analysis of variance showed significant differences among the genotypes for all ten traits studied. The parents NIC 7937, NIC 7907, NIC8010 and TMV 3 were considered as better parents based on gca effects for most of the characters studied. The hybrids NIC 7936 x VRI 1, NIC7907 x TMV 3, NIC 7936 x TMV 3, NIC 7907
x SVPR 1, NIC 7933 x TMV 3, NIC 7908 x CO 1 and NIC 7936 x CO 1 had significant sca effects for majority of the traits.

A line x tester analysis using twelve lines and three testers was carried out by Vavdiya et al. (2014) to study the combining ability and gene action in sesame for seed yield and 14 quantitative traits. Analysis of variance for combining ability revealed significant differences among the mean squares due to lines, testers and lines x testers for all the characters except oil content, which indicated the existence of genetic diversity among the parents and hybrids. General and specific combining ability variances showed the involvement of both the type of gene actions in the inheritance of these characters. Among the lines, IC 81564, NIC 75, Borda 1 and among testers, G.Til 10 were good general combiners for seed yield per plant and some of its contributing traits. The cross combination, IC 81564 x G.Til 10 showed significant and positive sca effect for seed yield per plant and involved good x good combining parents. It was followed by AT 238 x G.Til 10, NIC 75 x G.Til 4, TNAU 12 x G.Til 4, Keriya 2 x G.Til 3 and Keriya 2 x G.Til 10 which involved either good x good, good x poor or poor x poor combining parents.

An attempt was made by Vekaria et al. (2014) to study the general and specific combining ability in sesame through 6 x 6 diallel analysis for yield and yield contributing characters. The analysis of variance for combining ability revealed that the mean squares due to GCA were higher than the corresponding mean squares due to SCA for days to 50 per cent flowering, plant height, height to first capsule, number of branches per plant, number of internodes per plant, number of capsules per leaf axil and oil content, indicating the predominance of the additive type of gene action in the inheritance of these characters. Based on general combining ability, the parents G.Til 1, Borda 1, G.Til 2 and G.Til 10 were good general combiners for seed yield per plant, plant height, number of branches per plant, number of internodes per plant, length of capsule, number of capsules per plant and number of seeds per capsule. Borda 1 x G.Til 10, Kalyanpur 2 x Borda 1, G.Til 1 x Borda 1 and G.Til 2 x China were the best specific combiners for seed yield and its components.

Aladji Abatchoua et al. (2015) evaluated a set of 15 F1 hybrids, their parents and six additional cultivars for seed oil content. The variance components showed the preponderance of GCA, indicating that seed oil content was largely controlled by additive gene effects. The combining ability analysis showed that the parents L2B (1.39), L1Y (2.19) and L2Y (4.39) were relatively good general combiners with high
significant and positive GCA effects. Among F₁ progenies, L1B x L1Dj, L1B x L2Dj, L2B x L1Y, L1Dj x L1Y, L2Dj x L2Y and L1Y x L2Y were the best crosses based on SCA effects.

Fahmy et al. (2015) estimated the heterosis and collected genetic information for yield and its attributing traits using half diallel set involving diverse six parental sesame genotypes. Highly significant mean squares were detected for genotypes and its components (parents, hybrids and parents vs. hybrids) for all the traits studied at both the locations and their interactions with location. Highly significant mean squares were associated with general (GCA) and specific (SCA) combining ability for all the traits studied. Also observed additive gene action in genetic control of most traits studied, indicating its usefulness in selection in early segregating generations to improve the most traits. The parents NA 52 and NA 547 seemed to be the best combiners for seed yield per fad and one or more of its components. The most desirable inter- and intra-allelic interactions (SCA) were detected in F₁ hybrids, NA 76 x NA 54, NA 52 x NA 62 and NA 52 x NA 54, which also indicated the highest heterotic effects over mid and better parents at both the locations for seed yield per fad and one or more of its attributes.

Hassan and Sedeck (2015) reported that mean squares due to both general and specific combining ability were highly significant for all the traits studied. GCA/SCA ratio was less than unity in all the traits studied reflecting non-additive types of gene action having the highest influence on the inheritance of these traits. The two parents B 35 and Tusky 1 could be considered as the better parents via estimates of general combining ability for seed yield per plant. However, the cross Family 1 x Intro 640 had the most desirable SCA effects for seed yield per plant and most studied traits.

While studying combining ability in 10 x 4 line x tester analysis, Joshi et al. (2015) observed predominance of non-additive gene action for all the characters viz., days to 50 per cent flowering, plant height, number of effective branches per plant, number of capsules per plant, capsule length, days to maturity, number of seeds per capsule, 1000 seed weight, yield per plant, harvest index and oil content which can be improved by bi-parental mating or reciprocal recurrent selection. The female parents ES 246, BAVJ 1, Kalyanpur 2, Ingorola 7 and male parent Guj.Til 1 were found as the good general combiners for seed yield per plant. The cross combinations Timbi 3 x Guj.Til 10, TNAU 2 x Guj.Til 2 and SI 968 x Guj.Til 2 showed high per se
performance and significant sca effects for yield per plant and would be exploited for future use.

Meena Kumari et al. (2015) studied the general and specific combining ability in sesame through 6 x 6 diallel analysis for yield and yield contributing characters. Based on general combining ability, the line TMV 5 was found to be a good general combiner for single plant yield, total number of capsules per plant, number of capsules on main stem, number of primary branches, number of secondary branches and days to first flowering. Among the testers, CO 1 noted good combining ability for single plant yield, 100 seed weight, plant height and number of secondary branches. The tester ORM 7 was also found to be the good general combiner for single plant yield, total number of capsules per plant, number of capsules in main stem and days to first flowering. The cross combination TMV 5 x ORM 7 had expressed the highly significant and positive sca effects for single plant yield, total number of capsules per plant and plant height but negative sca effect for 100 seed weight. Also, the cross TMV 6 x VRI 1 was found to have the significant and positive sca effects for single plant yield, 100 seed weight, total number of capsules per plant and number of primary branches.

Phadtare et al. (2016) studied the combining ability and nature of gene action in sesame (Sesamum indicum L.) through L x T mating design with three lines and seven testers for ten different quantitative and qualitative traits viz.: days to 50 per cent flowering, days to maturity, plant height, number of branches per plant, number of capsules per plant, capsule length, number of seeds per capsule, 1000 seed weight, oil content and seed yield per plant. Based on the GCA effects, female parent BSG 8 was found to be a good general combiner for seed yield, plant height, number of branches per plant, number of capsules per plant and oil content. Similarly, another female parent BSG 15 was found to be a good general combiner for days to 50 per cent flowering, days to maturity, length of capsule, 1000 seed weight and oil content. Among male parents, genotype IC 413193 was found to be a good general combiner for seed yield per plant. Five cross combinations viz., BSG 8 x LT 7, BSG 12 x IC 413193, BSG 8 x IC 413214, BSG 8 x IC 413193 and BSG 15 x IC 413193 exhibited significant and the maximum positive sca effects.

Reddy et al. (2015) studied the nature and magnitude of gene action in a set of 21 hybrids. The parent G.Til 3 was found to be the best general combiner for seed yield per plant, number of capsules per plant, number of seeds per capsule and
number of branches per plant, whereas KMR 74 was good combiner for number of branches per plant and seed yield per plant. The crosses, KMR 74 x Patan 64, KMR 24 x G.Til 3, KMR 74 x KMR 77 and G.Til 3 x G.Til 10 exhibited high sca effects.

Anyanga et al. (2016) used line x tester (9 x 5) mating design to determine the combining ability and gene action in sesame. Results showed that mean squares across locations had high significant difference for all the traits recorded indicating that locations had effect on those traits. Variances for the males were higher than the variances for the females for all the traits except capsule width, suggesting greater variability among the males than the females. Combined general combining ability (GCA) across locations showed that GCA for the lines and testers were significantly positive for a few traits. Specific combining ability (SCA) was only positively significant for days to flowering, number of capsules on branches, number of capsules on main stem, total number of capsules and capsule length.

Mishra et al. (2016) studied the nature of gene action for morpho-economic traits in sesame. Days to maturity, number of primary branches per plant and capsule breadth were largely controlled by additive gene action. In contrast, magnitude of non-additive variances were invariably much higher than additive component of variances for period of flowering, number of capsules per plant, oil content and seed yield per plant for which heterosis breeding would be most effective. However, estimates of GCA and SCA were more or less equivalent in case of number of days to cessation of flowering and seeds per capsule, which envisaged the importance of both additive and non-additive components of variation for these traits.

Pawar and Monpara (2016) crossed eight diverse genotypes of sesame in a half diallel mating fashion to study the combining ability and assessed its potentials for earliness and seed yield improvement. The results showed that variances due to specific combining ability (SCA) and general combining ability (GCA) for all the traits studied were significant. Predictability ratio revealed preponderance of non-additive gene effects for all the characters. Among the parents, AT 158 and AT 177 were good general combiners for earliness along with the former for seed yield and later for plant height. RT 54 for seed yield and days to maturity and ABT 33 for reproductive period and plant height were identified as good general combiners. The sca estimates represent dominance and epistasis. Among 28 cross combinations evaluated, the highest sca effects in desirable direction was expressed by AT 177 x G Til 1 for days to flowering initiation and reproductive period, AT 177 x RT 54 for
days to 50 per cent flowering, G Til 1 x G Til 2 for days to maturity, AT 177 x TKG 22 for plant height and AT 192 x G Til 1 for seed yield per plant. None of the cross found good specific combiner for all the characters. However, the AT 177 x G Til 1 and AT 192 x G Til 2 for four characters and AT 177 x ABT 33 and AT 192 x G Til 1 for three characters including seed yield per plant manifested significant specific combining ability values. Most good specific combination for seed yield involved average x low general combiners.

Priya et al. (2016) studied general and specific combining ability in sesame (Sesamum indicum L.) through L x T analysis with four lines and eleven testers for nine characters viz., days to 50 per cent flowering, days to maturity, plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, 1000 seed weight, seed yield per plant and oil content. Based on the general combining ability effects of parents and per se performance, the genotypes SVPR 1, RT 127, TKG 22, TKG 306 and TMV 5 have considerable potential and can be utilized for developing cultivars with high yield and oil content by using appropriate breeding strategy. Based on sca effects, the hybrids CO 1 x Shekar, CO 1 x RT 127, CO 1 x TKG 22, SVPR 1 x VRI SV 1, VRI SV 2 x TMV 6, VRI SV 2 x TKG 306 and TMV7 x TMV 4 were adjudged as better hybrids for yield and yield component traits.

Abd El-Kader et al. (2017) evaluated six parental sesame genotypes and their 15 F₁ crosses to study the combining ability and gene action. General (GCA) and specific combining ability (SCA) mean squares were highly significant for all the traits studied. Also, additive gene action was governed most of the traits studied. The best combiners detected for seed yield per plot and one or more of its components were NA 77 and NA 78.

Manapure et al. (2017) carried out combining ability analysis in sesame using line x tester analysis with three tester and fifteen lines. The analysis of variance for combining ability indicated substantial genetic variation for general and specific combining ability for all the characters under study except 1000 seed weight and oil content. The lines SI 11, JCSC 8, SP 1102-B, NIC 16207, Tarun, RT 46, Hima, SI 7-2 and testers JLT 7 and AKT 64 were good general combiners for seed yield and economic related traits. Cross combinations viz., Phule Til-1 x NIC 16207, AKT 64 x NIC 16207, JLT 7 x RT 46 and JLT 7 x GT-L showed high mean values with involvement of either parent with significant general combining ability effects and had high positive significant specific combining ability. These crosses may serve as a
better source population for deriving superior segregants. The magnitude of GCA vs. SCA ranged from 0.74 to 0.95 indicating the progeny performance can be predicted on the basis of GCA alone for most of the traits.

Mungala et al. (2017) studied combining ability for seed yield and its component traits in sesame using line x tester mating design involving 8 lines and 5 testers. Analysis of variance for combining ability revealed that the mean squares due to lines were significant for all the characters, while for testers were significant for all the characters except number of seeds per capsule and the mean squares for lines x testers interaction were also significant for all the characters except plant height and oil content. The analysis for combining ability revealed significant mean sum of squares of both general combining ability (GCA) and specific combining ability (SCA) for all the characters which indicated the presence of both additive and non-additive gene actions. The lines IC 96128, TC 66 and DPI 1484 and the testers Guj.Til-4 and Guj.Til-3 displayed high gca effects and good per se performance for seed yield per plant and some desirable traits like plant height, height to first capsule, number of branches per plant, number of internodes per plant, length of capsule, width of capsule, number of capsules per plant, number of seeds per capsule and 1000 seed weight. The crosses RT 33 x GT 10, LIMDI 9 x GT 1 and TC 66 x GT 2 displayed high sca effects for seed yield per plant and important yield components.

Rajput et al. (2017) carried out combining ability analysis in 8 x 8 half diallel mating system for ten quantitative characters in sesame (Sesamum indicum L). The results revealed the importance of both additive as well as non-additive genetic components for yield and its contributing characters. Among the parents, JLT 9707-2 was one of the best general combiner, as it depicted high gca for length of capsule, number of seeds per capsule, 1000 seed weight, and oil content. Another parent, VRI (sv)₂ was also found to be good general combiner for plant height, number of branches per plant and number of capsules per plant. These parents displayed good per se performance for most of the characters suggesting scope for their use in further breeding programme. The cross JLT 408 x VS 07-23 evinced significant sca effects for most of the yield and yield contributing characters. This revealed that high x high gca combinations need not necessarily result in high sca effects.

Saxena and Bisen (2017) performed line x tester analysis in sesame with ten lines and four testers to estimate the combining ability. The results revealed the preponderance of non-additive gene action for days to 50 per cent flowering, days to
maturity, plant height, number of effective branches, number of capsules per plant, number of seeds per capsule, capsule length and additive gene action for 1000 seed weight and seed yield per plant. The parents, IVT 6, IVT 19, GT 2 and GT 10 were good general combiners for seed yield per plant. The crosses, IVT 19 x GT 2, IVT 6 x GT 10 and IVT 13 x TKG 21 recorded desirable SCA effects for seed yield per plant and most of the traits studied.

Tripathy et al. (2017) studied combining ability in sesame in crosses using 12 x 12 diallel mating based on morpho-economic traits including seed yield and oil content. Phule Til 1, E 8, CST 785 and Pratap were the most favourably good general combiners for seed yield per plant. Cross combinations Pratap x RT 103, CST 785 x E 8, BS5 18-6 x Phule Til 1 and T 13 x E 8 manifested positive and significant SCA effects indicating non-additive gene action for high seed yield.

Pandey et al. (2018) made an attempt to estimate the associations of genetic distances using agro-morphological traits with hybrid performance. Seven parents and 21 crosses generated using half diallel mating design were evaluated at two environments. Involvement of both additive and non-additive types of gene action was revealed by components of GCA and SCA mean sums of squares which were highly significant for all the traits studied. Variances due to SCA ($\sigma^2_s$) were higher than the variances due to GCA ($\sigma^2_g$) for all the traits indicating the predominance of non-additive type of gene action in controlling the expression of these traits. This was further confirmed by low magnitude of GCA/SCA ratios, indicating the non-additive type of gene action controlling the expression of most of the traits and suggests exploitation of these non-additive genetic variations through hybrid breeding. OSC 593 and UMA were indicated as the best general combiners because they showed highly positive significant GCA effects for number of capsules per plant, number of seeds per capsule and seed yield per plant, and negative GCA effects for days to maturity indicating early maturity. Maximum positive SCA effect for seed yield per plant was observed in cross-combination of UMA x NIC 8316. Considering the SCA effects and per se performance, crosses RT 348 x TKG 352 and UMA x NIC 8316 were the top combinations.

2.3 Genetic components of variances (Hayman’s numerical approach)

Genetic effects of heritable parameters lead a plant breeder to a clear understanding of inheritance patterns of various plant traits as their relative
contribution to the final grain yield. Hayman’s approach is a powerful statistical technique, which provides six genetic components of variance and ratios of dominant and recessive genes in the parents to quantify their dominance order. Such information will be of tremendous help to accurately ascertain the merits of individual characters as yield promoting traits.

Inheritance of yield and its contributing attributes in wheat has been abundantly studied by many researchers. Foregoing research for estimation of genetic architecture of yield and its components clearly revealed that all types of gene actions were associated with expression of these characters. However, variation in gene actions was observed because of the use of different parental material, environments and their interactions. Gene effects for various characters in sesame as reported by different workers are presented as below:

In a 10 x 10 diallel analysis study in sesame, Murthy and Hashim (1974) observed significant a and b components for plant height, branches per plant, capsules per plant and plot yield, indicating, thereby, the presence of both additive and dominance gene effects. Regression coefficient of Wr, Vr was equal to unity for plant height and branches per plant in sesame. Significant deviation of the regression coefficient from unity was observed for capsule number and yield per plot. The additive (D) and dominance (H₁ and H₂) components of variance were significant for all the above characters. The H₁ was larger in magnitude than D component for branches per plant, capsules per plant and plot yield, indicates over dominance, while H₂ was larger for plant height, indicates partial dominance. The heritability in narrow sense was in the order of 77.5, 40.2, 11.8 and 13.1 per cent, respectively for plant height, branches per plant, capsules per plant and plot yield.

Bakheit and Mahdy (1987) detected epistasis for plant height and number of branches in sesame. With regard to D and H₁, the inheritance of number of branches was mainly additive, while the dominance variation was more important in plant height. The narrow sense heritability values were high for number of branches, while it was low or intermediate for the other traits.

Mahdy and Bakheit (1987) estimated the genetic parameters (D, F, H₁, H₂ and h²) for seed yield per plant. The results revealed the presence of non-allelic interaction for seed yield. The dominance genetic component (H₁) exceeded the additive one (D) for seed yield in both F₁ and F₂ generations.
El-Ahmar et al. (1996) detected partial dominance for plant height and number of branches; while seed yield per plant and seed oil content exhibited over dominance. In all the studied characters, the results showed the importance of both additive (D) and dominance (H1) genetic components except for oil content. Seed yield showed the lowest narrow sense heritability (9.34%).

Saravanan et al. (2000) estimated genetic parameters for nine earliness and economic traits using Hayman's diallel analysis in sesame. Both D and H2 components were found to be significant for number of days for first flowering and first fruiting node, height of first flowering and first fruiting node and days to 50 per cent flowering, indicating the importance of both additive and dominance factors in the expression of these traits. The mean degree of dominance was less than unity for all the traits studied except 1000 seed weight, indicating the presence of partial or incomplete dominance. Over-dominance was found to be involved in the expression of 1000 seed weight. The values of h²/H2 were less than unity for all the traits studied, indicating the unequal distribution of genes among parents. An excess of recessive alleles was involved in the expression of all the traits investigated. The heritability in the narrow sense was high for days to 50 per cent flowering and maturity and oil content; medium for height of first fruiting node and low for seed yield. The reciprocal difference was statistically significant for days to 50 per cent flowering and maturity.

Hoballah (2001) evaluated a half diallel set of crosses involving seven parents to study the nature of gene action controlling seed yield and its contributing traits in both F1 and F2 in order to identify the most efficient breeding methods leading to rapid genetic improvement in sesame. Estimates of the type of gene action confirmed the importance of both additive and non-additive (dominant) gene effects in the inheritance of the studied characters in both F1 and F2 generations. However, the dominance components were larger than the additive ones for most investigated traits in the F1 and vice versa in the F2. Over dominance was also noted. Heritability in narrow sense was low for most characters in the F1. On the other hand, high values of heritability were recorded for all the investigated traits in the F2, indicating that the genetic variance associated with those traits was mostly due to additive effects of genes, and therefore, it could be concluded that selection based on the accumulation of additive effects would be very successful in improving such traits.
While studying the gene action in sesame for yield and nine yield components in 6 x 6 half-diallel progenies (F₁), Swain et al. (2001) observed the preponderance of non-additive genetic variance for all the characters except for days to maturity. Eight traits exhibited over-dominance. Recessive alleles were predominant for branches per plant and capsules per plant. The distribution of genes with positive and negative effects were symmetrical to nearly symmetrical for 1000 seed weight, days to maturity, branches per plant, capsules on main stem, capsules per plant and seed yield. Parents possessed mostly negative genes in dominant form for capsules on main stem, capsules per plant, capsule length and 1000 seed weight and the opposite was observed for rest of the characters.

Tripathi and Hasan (2004) investigated the nature of gene action in F₁ and F₂ of a 6 parent (JT 7, N 32, TC 25, TMV 5, TNAU 11, RT 4) by diallal crosses. The analysis of variance revealed highly significant differences among the 6 genotypes for all the ten characters, indicating considerable genetic diversity among the parents and crosses. The estimates of genetic components of variance revealed that the additive component was significant for yield and yield components. The F₁ indicated non-additive genetic variance for all the characters. Recessive alleles were predominant for branches per plant and capsules per plant. The distribution of genes with positive and negative effects were symmetrical to nearly symmetrical for 1000 seed weight, days to maturity, branches per plant, capsules on main stem, capsules per plant and yield per plant.

Various genetic parameters were estimated by Mothilal and Manoharan (2005) in sesame by evaluating seven parents and their 21 hybrids. The results revealed that plant height and number of branches showed additive gene action. Non-additive gene action was involved in the expression of characters viz., number of capsules on branches, 1000 seed weight and seed yield per plant. Over dominance was observed for number of branches, number of capsules on main stem, number of capsules on branches, number of seeds per capsule and seed yield per plant. Similarly, these traits showed asymmetrical distribution of positive and negative alleles. High narrow sense heritability estimates were observed for plant height and number of branches per plant indicating the possibility of fixing these traits through pedigree breeding.

The genetics of seven quantitative traits of sesame was studied by Lavanya et al. (2006) through a full diallel cross involving six genotypes. The estimates of D were significant for days to 50 per cent flowering, number of branches per plant,
number of internodes per plant, number of capsules per plant and oil content. The values of $H_1$ and $H_2$ as well as the $H_2/4H_1$ indicated that there were unequal frequencies of alleles at all the loci for all the characters studied, except 1000 seed weight. The values of $F$ and the ratio of $(4DH_1)^{1/2}+F/(4DH_1)^{1/2}-F$ indicated the presence of excess of recessive alleles in the expression of all the traits of interest. The mean degree of dominance was more than unity for six out of the seven traits studied. The narrow sense heritability estimates were high for number of branches per plant and number of internodes per plant.

While studying the genetic analysis in sesame, Bayoumi and El-Bramawy (2007) found that the ratio $[(H1/D)^{1/2}]$ for all crosses confirmed the presence of partial dominance for the most of the traits studied. The direction of dominance was positive and significant for height of first capsule and seed yield per plant. Heritability values ($h_n$) were relatively medium to high for the most of the traits studied, were ranged from 0.13 for height of the first capsule to 0.65 for seed oil content.

El-Bramawy and Shaban (2008) studied the gene action associated with yield and ten yield components in 6 x 6 half-diallel sesame progenies ($F_1$). Highly significant differences among the 15 $F_1$s and their six parents were detected with respect to all the traits investigated. A preponderance of non-additive genetic variance was seen for all the traits studied, except for days to maturity and resistance to Alternaria leaf spot. Ten traits showed over-dominance. Recessive alleles were predominantly involved in fruiting branches per plant, capsules per plant and single plant yield. The distribution of genes with positive and negative effects were symmetrical or nearly symmetrical with respect to 1000 seed weight, fruiting branches per plant, capsules per plant, single plant yield and oil content. The parents possessed mostly negative genes in dominant form with respect to capsules per plant, 1000 seed weight and oil content, while the positive genes in recessive form were observed for the rest of the traits studied.

Sakhiya (2013) carried out diallel analysis in sesame in order to estimate the combining ability and nature of gene action involved in the inheritance of seed yield and its component characters. Estimation of variance components of $H_1$ and $H_2$ revealed preponderance of non-additive gene action for all the traits. Average degree of dominance revealed over dominance for all the traits. Asymmetrical distribution of positive and negative genes in the parents was observed for all the traits. The non-
significant estimate of ‘E’ was observed for all the traits except oil content and protein content. The negative sign of ‘F’ and KD/KR ratio less than unity was observed for height to first capsule, number of internodes per plant and oil content. High narrow sense heritability was found for plant height, height to first capsule, number of internodes per plant and number of capsules per plant.

Sedeck and Shafie (2013) estimated the gene action and interrelationship among yield characters by evaluating eight genetically diverse sesame genotypes and their 28 hybrids made in diallel fashion. The additive genetic component “D” was significant in all the traits studied. The dominance genetic components (H₁ and H₂) were significant in all the traits studied, except H₂ for plant height and seed yield per plant. Moreover, the dominance component (H₁) was higher in magnitude than additive component (D) for all the traits studied, except 1000 seed weight, resulting in the average degree of dominance (H₁ / D)¹/², which was more than one indicating over dominance for all the traits studied. The magnitudes of H₁ were larger than H₂, resulting in ( H₂/4H₁), which was less than 0.25 for all the traits studied, except 1000 seed weight, indicating that positive and negative alleles of loci for these traits were not equally distributed among the parents. The F component coupled with KD/KR was found to be positive in all the traits studied, indicating an excess of dominant alleles in genetic constitution of parental genotypes for these traits, resulting KD/KR value which was more than one for all the traits studied except 1000 seed weight and capsule length. High broad sense heritability values were obtained for all the traits studied, while narrow sense heritability values were moderate.

Aladji Abatchoua et al. (2014) genetically screened 12 promising lines for eight characters in sesame viz., days to 50 per cent flowering, days from flowering to capsule maturity, plant height, number of branches, number of capsules per plant, capsule length, number of seeds per capsule and number of days to maturity. Broad and narrow sense heritability for these characters were ranged from 0.66 (number of branches per plant) to 0.99 (number of capsule per plant) and from 0.28 (days from flowering to capsules maturity) to 0.69 (days to maturity). The direction of dominance was positive for all the traits studied, except plant height and number of branches. The average degree of dominance (H₁/D)¹/² was greater than one for all traits suggesting over dominance.

A set of 15 diallel F₁ hybrids, their parents and six additional cultivars were evaluated by Aladji Abatchoua et al. (2015) for oil content. The genetic parameters
(average degree of dominance, direction of dominance, correlation between the degree of dominance and parental value) as well as broad and narrow sense heritability were estimated. Broad and narrow sense heritability was 0.95 and 0.88, respectively, for oil content. The tested parents had a moderate proportion of dominant genes. The mean degree of dominance was less than unity for oil content, indicating the presence of partial or incomplete dominance in the expression of oil content. The positive estimation of average direction of dominance confirmed that the dominance was unidirectional and in the direction of the parent with the higher expression of the trait.

Fahmy et al. (2015) gathered genetic information for yield and its attributing traits using half diallel set involving six parental diverse sesame genotypes. Significant or highly significant values and high values of the dominance component \( (H_1) \) were observed for most of the traits studied at both the locations indicating the presence of over-dominance and it was confirmed by \( (H_1/D)^{0.5} \) (more than 1). High narrow sense heritability was obtained for days to 50 per cent flowering (82%), days to physiological maturity (80%) at Kafr El-Hamam location and first capsule height (75%) at Bahteem location, indicating that selection would be effective to improve these traits. The parents of NA 558 (P_4) and Shandwell 3 (P_5) at Kafr El-Hamam and NA 547 (P_3) at Bahteem carried the most dominant genes responsible for the expression of seed yield per plant and seed yield per fad, in contrary NA 52 and NA 558 for seed yield per fad possessed high concentration of recessive genes at Kafr El-Hamam and Bahteem locations, respectively.

Reddy et al. (2015) estimated the genetic components of variation in a set of 21 hybrids. Component of variation due to additive (D) and dominant (H_1) effect of genes were significant for plant height, number of capsules per plant, number of seeds per capsules and seed yield per plant, indicating the importance of both additive and dominant genes for the expression of these traits and it was further confirmed by the significance of both GCA and SCA variances. Significant and greater magnitude of \( H_1 \) and \( H_2 \) than D for plant height, number of capsules per plant, number of seeds per capsule, test weight and seed yield per plant, indicated the preponderance of non-additive factors involved for these traits. Significant and positive value of ‘F’ indicated high proportion of dominant alleles for the traits viz., number of capsules per plant, number of seeds per capsule and seed yield per plant. The \( h^2 \) value was significant for plant height, number of capsules per plant and number of seeds per
capsule indicating dominance at heterozygous level. The mean degree of dominance 
\((H_1/D)^{1/2}\) was more than unity, indicating the presence of over dominance in the 
inheritance of all the traits except test weight. The ratio of \(H_2/4H_1\) was less than 0.25 
for all the traits studied revealing the asymmetrical distribution of positive and 
negative genes in the parents. The ratio \(h^2/H_2\) was less than one for all the seven traits 
indicating that these traits were under the control of at least single group of genes. 
Heritability was low to medium (6.0 to 31.0 \%) showed importance of non-additive 
genetic variance in the inheritance of all these traits.

Vekaria et al. (2015) performed 6 x 6 diallel analysis of F\(_2\) population in 
sesame. The results revealed that additive component (D) was significant for days to 
50 per cent flowering, days to maturity, plant height, height to first capsule, number of 
branches per plant, number of internodes per plant, number of capsules per plant, 
number of capsules per leaf axil and oil content. The genetic variances of dominant 
components (\(H_1\) and \(H_2\)) were significant for majority of characters. An equal 
distribution of increaser and decreaser genes (F) in the parents was found for all the 
characters except for plant height, height to first capsule, number of internodes per 
plant and number of capsules per leaf axil. Narrow sense heritability was high for 
height to first capsule, plant height, number of branches per plant, length of capsule 
and number of seeds per capsule.

Mishra et al. (2016) studied the nature of gene action for morpho-economic 
traits in sesame. The dominant effect (\(H_1\)) was found to be higher than additive effect 
(D) for days to cessation of flowering, period of flowering, plant height, height to first 
capsule, number of capsules per plant, capsule length, 500 seed weight, oil content 
and seed yield per plant, which implied that the allelic interaction was well within the 
range of over-dominance. This was also evident from the mean degree of dominance 
which was more than unity (1.00). While, \(H_1\) was less than D for days to initial 
flowering, days to maturity, capsule breadth and number of seeds per capsule 
indicating partial dominance for overall expression of these traits. These characters 
have revealed high heritability among the agro-economic traits studied. However, 
number of primary branches, revealed equal estimated value (0.43) of dominant effect 
(\(H_1\)) and additive effect (D) indicating complete dominance as also confirmed by 
mean degree of dominance equal to unity (1.00). Further, \(h^2\) being positive and higher 
in magnitude for plant height and number of capsules per plant envisaged that the 
total magnitude of increasing alleles quietly surpassed than that of the decreasing
alleles for expression of these traits. Relatively high magnitude and positive value of F for number of seeds per capsule could be an indication for preponderance of dominant alleles. The proportion of genes with positive and negative effects was as high as 0.19-0.21 (i.e., around 1:5) for plant height and number of capsules per plant; while the ratio of dominant and recessive alleles was estimated to be the highest in capsule breadth (5.2) followed by number of seeds per capsule (4.37).

Napit and Arjaria (2016) studied the nature of gene action for yield and yield components in sesame (*Sesamum indicum* L.). The estimated values of additive genetic variance (D) and dominant component (H₁) were positive and significant for days to 50 per cent flowering, days to maturity, number of capsule on main branches, capsule length, 1000 seed weight, oil content and oil yield per plant indicated the importance of additive as well as non-additive genetic variance in the expression of these characters. Another measure of the dominance variance (H₂) was also significant for all the characters exhibited highly significant positive values indicated the presence of dominance genes. The estimates of mean degree of dominance *viz.* (H₁/D)⁰.⁵ indicated that all the characters showed the value of mean degree of dominance greater than one suggesting the presence of over dominance. The distribution of positive and negative genes exhibiting dominance in the characters, thus, for all the characters the distribution of positive and negative genes in the parents was unequal.

Tripathy et al. (2016a and 2016b) studied the genetics of oil content and seed yield in a set of 12 x 12 half diallel crosses of sesame. The dominant effect (H₁) was found to be higher than additive effect (D), which implied that the allelic interaction was well within the range of over-dominance for both the traits. This was also evident from the mean degree of dominance which was more than unity. The estimates of h²/H₂ was < 1.0 suggesting involvement of just one group of genes showing dominance for oil content, while for seed yield, the estimates of h²/H₂ was > 1.0 suggesting involvement of a number groups of genes showing dominance. Further, h² being positive and higher in magnitude which envisaged that the total magnitude of increasing alleles surpassed than that of the decreasing alleles controlling oil content and seed yield. Relatively high magnitude and positive value of F could be an indication for preponderance of dominant alleles for oil content in seeds, while negative value of F could be an indication for preponderance of recessive alleles for seed yield. The proportion of genes with +ve and -ve effects (H₂/4H₁) was about 1: 5
(0.210) for oil content and 1: 5.5 (0.18) for seed yield, while the ratio of dominant and recessive alleles was estimated to be approximately 7:5 (1.330) for oil content and 1:4 (0.24) for seed yield. So, high oil content sesame varieties can be bred by increasing the concentration of dominant alleles (which are increasing in nature as well) through rigorous selection in the segregating population, while high yielding sesame varieties can be bred by increasing the concentration of recessive alleles with positive effects through rigorous selection in the segregating population.

Abd El-Kader et al. (2017) carried out genetic analysis of six parental sesame genotypes for yield and its attributes in F₁ crosses and observed significant or highly significant values and high values of the dominance component \( H_1 \) for most of the traits studied, indicating the presence of over-dominance and it was confirmed by \( (H_1/D)^{0.5} \) (more than one). The effective selection and high narrow sense heritability were detected for days to 50 per cent flowering (62 %) and days to physiological maturity (77 %). The parents NA 77, NA 59 and NA 78 carried the most dominance genes responsible for the expression of seed yield per plant and seed yield per plot, while in contrary NA 80 and NA 35 for seed yield per plot possessed high concentration of recessive genes.

2.4 Genotype × environment interactions and stability analysis

Several high yielding genotypes of sesame are being developed through breeding efforts. However, most of them are showing inconsistency in seed yield over seasons, years and location, due to high genotype × environment interaction. Larger genotype × environment interaction reduces the progress of selection (Comstock and Moll, 1963). To reduce the effect of genotype-environment interaction, selection of stable genotypes that interact least with the environment is advisable to attain consistent yield. Thus, screening genotypes possessing buffering capacity under varying environmental condition has became an essential part of breeding programme. Lewis (1954) introduced the term ‘stability factor’ to measure the phenotypic stability. According to him, greater the deviation of stability factor from unity, lesser the phenotypic stability. Other stability indices include Wricke’s (1962) ecovalence, Shukla’s (1972) stability variance and Perkins and Jinks (1968) regression coefficient.

Finlay and Wilkinson (1963) developed a dynamic approach for interaction of varietal adaptability to varying environments. Average yield of a large number of varieties at different sites and seasons was used for quantitative grading of
environments. In this technique, the linear regression of yield of each variety and mean yield of all varieties in each environment provided a measure of phenotypic stability.

Eberhart and Russell (1966), further improved the technique and emphasized the need of considering both linear (\( b_i \)) and non-linear (\( S_{di}^2 \)) components of G x E interaction for judging the phenotypic stability of a genotype. Thus, a variety having higher mean performance and unit regression coefficient with least deviation from regression (approaching zero) would be considered as stable genotype.

Halikiopoulou and Mihaelides (1985) evaluated seven varieties of sesame for seed yield under un-irrigated conditions at three sites and reported that Dodekanisos and Proime were adaptable, giving high yield at all sites. Tetrachori and Ju/156 were also adaptable, but gave lower yields. In poor environments, Sindos Lefki gave yields similar to those of Dodekanisos and Proime, while in good environments, it was similar to Tetrachori and Ju/156. In terms of yield, it exhibited the highest stability.

Krishnaswami and Appadurai (1985) analyzed stability of twenty genotypes for yield and yield attributes over three seasons. Among genotypes, the culture 7828/1-15-1-4-1 followed 7721-1-1 and 7722/10-8-1 had highest yield, hence, were all classified as stable.

Osman and Nour (1985) tabulated data on yield per plot and stability parameters in 27 varieties of Sesamum indicum evaluated in three standard trials each at two sites. Varieties A/5/13 and UCR 75399 recorded relatively high yield with stability and were considered suitable for commercial production and use in breeding programme.

Henry and Daulay (1987) evaluated 14 genotype of sesame under rainfed conditions over four years and reported significant variation for genotypes and genotype x environment interaction for seed yield. The linear as well as non-linear components were significant. Deviation from regression was significant for most of the genotypes for seed yield. TC 25 gave the maximum grain yield and showed near unit response under fluctuating environments. T 13, T 43, 4-2 and Pratap were better genotypes in favourable growing seasons. N 32 performed better especially in the years of long spell of drought.

Kumar (1988) revealed the presence of genotype x environment interaction under rainfed condition and large portion of these was accounted by linear component. Non-linear component was also significant, yet the magnitude was
smaller than the linear component. The strain 4-2 and T 13 were the most stable for seed yield in better environments, whereas TC 171 and C 6 exhibited maximum stability yield in poor environments.

Mahdy and Bakheit (1988) studied genotype x environment interactions for plant height, branches per plant and capsule length in seven sesame varieties and 21 F2 populations in eight different agro-climatic environments and observed that parent x environment interactions were highly significant for the seed yield, capsules per plant, 1000 seed weight and seeds per capsule. Genotypes were significantly affected by interaction between years and planting dates. Planting date and year and their interactions with genotypes exerted significant effects on seed yield and its components.

Mahdy et al. (1988) revealed highly significant effects of environment and genotype x environment interaction for seed yield per plant, seed oil percentage, capsules per plant, capsule length and breadth, plant height, first capsule height, and branches per plant. Genotypic stability statistics indicated that introduced genotypes were stable in yield and some other traits, but their yields were low. Giza 23 gave high seed yield and was the only stable local cultivar. Moreover, six of the promising local genotypes gave high stable seed yield with average stability for most of the traits studied.

Osman (1991) determined the stability of seed yield in 20 cultivars and selections at three locations in each of three years. The material studied differed significantly for seed yield and genotypes x environments interactions. Regression coefficient were in the range of 0.57 to 1.39 and were statistically close to unity except for UCR 76437 with b=0.57. Entries with high mean yields generally had regression coefficient exceeding unity and were equal to or better than entries having smaller response even in poor environments. Deviations from regression were significant in nine cultivars per selection. Three entries, A/1/9 for cultivation in all environments, UCR 79093 for the Agadi area and UCR 76202 for the Abu Naama area, were identified as desirable cultivars/selections.

In a study of adaptability and stability of sesame, Freire et al. (1994) evaluated 29 cultivars at 17 locations for four years in Brazil. Statistical significance was observed for environmental effects, cultivars and their first order interaction. The linear component of the interaction predominated over non-linear ones. The
commercial cultivar CNPA G2 registered high seed yield and exhibited a high level of adaptability and stability.

Verma and Mahto (1994) evaluated 16 sesame genotypes for stability parameters with respect to yield and four yield components and reported significant genotype x environment interactions in sesame for all the characters. TC 326 was the most stable genotype for all the characters except branches per plant. Other stable genotypes were TC 25, CMT 11-6-5, RT 57 and OMT 34.

Quijada and Layrisse (1995) evaluated 66 F\text sub{1} hybrids developed using diallel mating design from 12 elite sesame varieties at five different environments and reported that the mean yield of the hybrids was clearly superior to the parental mean in all five locations. The best hybrid in each place yielded significantly better than the best cultivar. A large genotype x location interaction was found for all traits suggesting that hybrids should be developed for specific locations.

Rajarathinam and Muppidathi (1996) studied stability for yield by evaluating eight improved genotypes of sesame over three environments under rainfed conditions. The analysis of variance showed significant differences among genotypes and environments. The significant genotype x environment (G x E) interaction indicated that phenotypic performance of genotypes varied in different environments. The significant G x E (linear) interaction indicated that performance of genotypes across the environments was predictable. The study revealed that TMV 3 was the most stable genotype with high mean yield and average response in changing environmental conditions. Since VS 350, VS 177 and TNAU 64 had high yield potential among all the genotypes, their stability in performance can be improved upon by crossing these genotypes with stable ones so as to have consistent higher productivity.

Dixit \textit{et al.} (1997) analyzed the genotype x environment interaction of five genotypes of sesame for seed yield over two consecutive years at two locations. The analysis of variance revealed that genotype x year interaction was significant, while the genotype x location was non-significant. The variance due to location was significant which clearly showed that there was marked variation in mean yield at both the locations. The variance due to years was non-significant. The mean performance of genotypes showed similar trend at both the locations during the years. The genotypes OMT 30 gave 451.39 kg/ha mean yield followed by JLSC 58 (380.55 kg/ha) over check TC 25 (343.05 kg/ha).
Elizondo-Barron (1997) found that the early maturity cultivars, Peludo Canastilla and Iguala 200-SI-R77 and the medium maturity cultivars Criollo de Llera showed general environmental adaptability. The medium maturity cultivar Iguala 267-T72 had the best adaptability to favourable environments. In addition to that, the early maturity Chino II and the medium maturity Instituto 7 consistently performed the best in unfavourable conditions.


Singh et al. (1998) observed genotype-environment interaction for all the traits studied. Linear as well as non-linear components accounted for the interaction for all the characters except number of primary branches per plant, however, the former contributed to a greater extent. MT 5 was characterized as an ideal genotype with respect to seed yield per plot. The entries, TC 25 and T 13 were found to be stable for most of the characters including seed yield per plot. The levels of stability were not common for all the traits for most of the genotypes.

Arriel et al. (2000) determined the adaptability and seed yield stability in 13 sesame genotypes over 11 environments. Among the genotypes, CNPA 88-88 showed high productivity, adaptation to adverse conditions, responsiveness to improved environmental conditions and high stability of seed yield.

Solanki and Gupta (2000) studied G x E interaction for seed yield in 18 genotypes of sesame for seed yield and reported significant genotype (G) and environment (E) interaction. Both linear and nonlinear components of G x E interactions were significant, but linear components were predominant. On the basis of stability parameters, genotype RMT 2 was considered to be an ideal genotype, whereas RMT 7, RMT 12, RMT 18, RMT 23 and RMT 46 were identified as suitable genotypes under favourable environmental conditions.

Upadhyay et al. (2000) studied phenotypic stability for seed yield and other nine related components for nine genotypes of sesame grown over 24 environments. Significant genotype x environment interaction was observed for all the characters except capsule length, while the linear component of genotype x environment interaction was highly significant except for number of seeds per capsule, seed weight per capsule and 1000 seed weight. Single genotype NT 13-91 was identified as stable
for all the characters simultaneously and it was above average stable indicating that it can be grown suitably specifically under poor environments.

Mahto and Verma (2001) observed significant differences among genotypes and environments. TC 326, OMT 11-6-5 and RT 57 were the stable genotypes for most of the characters. No genotype showed average stability for all the traits.

Genotype x environment (G x E) interactions and stability of six sesame mutants and two controls were studied Malek et al. (2001) for number of capsules per plant, number of seeds per capsule and seed yield in seven environments. Genotypes, environments and G x E interactions were significant for all the characters. G x E (linear) interaction was significant for number of capsules per plant and number of seeds per capsule. T 6 and SM 5 were stable for number of capsules per plant. None of the genotypes was found stable for seed yield.

While evaluating seven genotypes of sesame over four environments, Solanki et al. (2001) found highly significant G x E interaction for seed yield. Both linear and non-linear component of G x E interactions were significant.

Beniwal et al. (2003) studied phenotypic stability for seed yield and related traits of 79 genotypes of sesame grown on three different dates. The results indicated that unpredictable component constituted more to the G x E component. Correlations between bi and mean (x) values for different characters indicated that better genotypes are suited more to better environment. RT 54, RT 103 and Uma were the high yielding stable hybrids.

Raghuwanshi et al. (2003) observed significant differences among the genotypes and environments, suggesting the presence of substantial variability among the genotypes and environments and their interaction. The linear component contributed a major share. Uma followed by RT 54 was found responsive and stable for yield. IRT 125, TKG 22, TC 25 and RT 103 gave consistently higher yield under favourable environments compared to other genotypes. AKT 64, VRI 1, Tapi, TKG 21 and RT 54 gave low yield under unfavourable environments, indicating their high sensitivity to environmental fluctuation.

Solanki and Gupta (2003) studied phenotypic stability of 12 sesame genotypes under three different environments and observed that mean squares due to genotypes were highly significant for seed yield, capsules per plant and plant height, indicating the presence of variability among the genotypes for all the traits studied. Mean squares due to environment were significant. Genotypes x environment interaction
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effects were significant for all the characters showing differential response of genotypes in different environments. Both linear and non-linear components of G x E interactions were significant for seed yield, but only non-linear component was significant for number of capsules per plant and plant height. Genotype RT 174 was the most adaptable, as it had high seed yield, maximum number of capsules per plant with least mean square deviation ($S^2_{di}$) and unit regression coefficient ($b_i$).

Kumar et al. (2004a) observed significant G x E interactions for all the characters of interest. However, characters differed as regard the contribution of linear and non-linear components of G x E interaction. The varieties viz., AU 1 and SVPR 1 had both genotypic and phenotypic stabilities for most of the important yield contributing characters as well as for seed yield.

Anuradha and Reddy (2005) evaluated 71 sesame genotypes for phenotypic stability of yield attributes at three locations. The result revealed that a substantial portion of the interaction was due to linear components. None of the genotype exhibited stable performance for all the traits, however, genotypes EC 355653, EC 351882, EC 357312, EC 358039, SI 1618, SI 75, YLM 17, DCB 1791 and NAC 8414 were stable for seed yield per plant.

Chaudhari et al. (2005) observed that sesame genotypes JLIS 91-8, TAC 89-309, SIK 004 and JLT 26 exhibited performance above population mean, average regression coefficient near to unity and non-significant deviation from regression coefficient, indicating these genotypes possessed average stability for seed yield and would sustain well in environmental fluctuations. The genotypes JLSV 4 and ATIS 89-210 had high mean yield and exhibited high regression coefficient ($b=1.511$ and $b=1.166$, respectively) and non-significant deviation from regression were found to be below average stability and perform better under favourable condition. The genotype ESI 91-4 showed above average stability, as it exhibited low regression coefficient ($b=0.766$) and non-significant deviation from regression indicating its suitability for stress conditions. Although the genotypes TCE 91-3 and TC 90-309 exhibited high yield and average regression coefficient ($b=1.014$ and $b=1.125$) respectively, but they did not possess least deviation from regression ($S^2_{di}=0$), thus observed to be unstable genotypes.

Kumaresan and Nadarajan (2005) evaluated 64 sesame genotypes comprising 48 hybrids and 16 parents for four stability parameters over three environments. The analysis of mean squares due to genotype x environment (linear) and non-linear
deviation were significant for all the characters studied. The parents viz., TNAU 28, TN 8467 and B 203 and the F$_1$ hybrids namely SI 42 X VRI 1 and B 203 X SVPR 1 were identified as stable genotypes with high yield and performance per se.

Adebisi and Ajala (2006) found that sesame genotypes evaluated differed significantly for seed yield and genotype x environment (G x E) interactions. Regression coefficients ranged from 0.65-1.25 and were statistically close to unity. One genotype, 530-3, with a regression coefficient value of 1.01 and smaller S$_{di}^2$ value and a relatively high seed yield, could be considered the most widely adapted genotype. Deviations from the regression were significant in all the genotypes. The highest yielding genotypes appeared less stable than the average of all entries.

Kumar et al. (2006) assessed the stability among six genotypes of sesame in three different environments. The results revealed that AUS 122 could be rated as most stable genotype, as it recorded high mean and low variability for all the characters. AUS 79 was the moderately stable genotype.

Kumar et al. (2008) evaluated 25 genotypes of sesame under three diverse environments and found that significant genotype x environment (G x E) interaction was exhibited by all the genotypes for 1000 seed weight and seed yield. The contribution of linear and non-linear component of G x E interaction varied among the different traits of interest. IVTS 05-04, IVTS 05-09 and IVTS 05-25 showed stability for seed yield.

Sumalatha et al. (2008) evaluated 10 genotypes of sesame for seed yield and its components and observed significant genotype and environment interactions for all the characters except harvest index and oil content. Both linear and non-linear components of G x E interactions were found to be effective for plant height, primary branches, secondary branches, number of capsules per plant and oil content. None of the genotype exhibited stable performance for all the traits, however, genotype Nellore Brown Local and Madhavi were stable for both seed yield per plant and seed yield per plot.

Bhandarkar and Kumar (2010) evaluated six sesame genotypes for plant height, number of primary branches and seed yield per plant under three environments. The significant genotype x environment interaction was recorded for primary branches and seed yield. Environment (linear) interaction component was significant for all the characters, while the linear component of environment interaction was significant only for plant height. The genotype TKG 22 was found
stable for plant height, while TKG 22, RT 46 and TKG -21 for number of primary branches, and RT 54, RT 46, TKG 55 and TKG 21 were found stable for seed yield.

Kumaresan and Nadarajan (2010) analyzed the G x E interaction effects on yield and its components in sesame and reported that mean squares were significant for genotypes, environments and G x E interactions for the characters viz., number of capsules, 1000 seed weight and single plant yield. The genotypes namely PSR 2007 x Co1, Si 42 x Co 1, Si 42 x VRI 1, AHT 123 x VRI 1, B 203 x SVPR 1 and YLM 4030 x SVPR 1 recorded high mean with low interaction effects, which are desirable for releasing stable hybrids. The genotypes OMT 30 x VRI 1, OMT 30 x SVPR 1 and DPI 1424 x VRI 1 exhibited high interaction effects and are suitable for specific environments.

Sarwar et al. (2010) evaluated three genotypes of sesame for three consecutive years for their stability of performance. The results of combined analysis of variance showed highly significant difference among genotypes, environments and their G x E interaction, indicated that variation exists in the genotype performance over different set of environments during three consecutive years. Overall, mean seed yield performance indicated that mutant lines NS 100P2, NS 11-2 and NS 103-1 produced higher seed yield (1871, 1547 and 1439 kg/ha, respectively) as compared to mutant check TS 3 and grand mean. NS 100P2 had regression coefficient more than unity, hence suitable for favourable environments to some extent. Similarly, NS 11-2 had also regression coefficient more than unity and had poor adaptation. The mutant line NS 103-1 proved as more stable because it produced higher mean seed yield along with regression coefficient nearer to unity and deviation from regression was lamost near to zero.

Suvarna et al. (2011) evaluated 50 genotypes of sesame at different locations for stability performance. Significant differences were observed for seed yield. Genotypes were identified as promising in different locations based on actual seed yield. Among fifty genotypes, Kanakapura local, ST 3 and ST 16 showed stability for seed yield.

Jhansi Rani et al. (2012) evaluated ten sesame genotypes for nine traits over six environments. Both linear and non-linear components of G x E interactions were significant, suggesting that genotypes interacted significantly with the environments. None of the genotype was stable for all the characters; however, the genotypes YLM 17 and YLM 78 were stable for seed yield per plant.
Kumar et al. (2013) evaluated 36 sesame genotypes under four environments to assess the genotype × environment interaction and their stability across the environments for seed yield and physiological traits. The pooled analysis of variance due to genotypes, environments as well as genotype x environment interactions was highly significant for all the characters except for photosynthetic rate at 40 DAS. Genotype x environment (linear) variance component was more than that of pooled deviations for most of the characters including seed yield. The perusal of stability parameters revealed that among the cultivars, GT 2, GT 10 and GT 1 were stable across the environments. The cultivar TMV 3 was highly responsive to favourable environments. The hybrids, GT 10 x TMV 3, TMV 3 x C 1013, GT 10 x PT 64, PB. Til 1 x PT 64, AT 124 x C 1013, GT 2 x C 1013, TMV 3 x PT 64, PT 64 x C 1013, GT 2 x PB. Til 1 and GT 2 x TMV 3 were found most stable across the environments for seed yield per plant and physiological traits.

Mirza et al. (2013) examined 10 elite genotypes of sesame across three locations for the estimation of genotypes environment (G x E) interaction and to identify stable genotype(s) using stability parameters. PR 19-9-S produced the maximum seed yield (341 kg/ha) at NARC and V 90005 produced 344 kg/ha and PARS-I produced 304 kg/ha seed yield at D.I. Khan location. The variances due to G x E interactions were highly significant for all the traits showing heritable variation among the genotypes. The linear component of G x E interaction was also significant for all the traits except branches per plant. Pooled deviation was significant only for yield indicating the differential genotypic response across the locations. The significant variance due to environment (linear) indicated that the performance of genotypes was under genetic control. The b-values of V 90005, T 89 and PARS-I was larger than unit regression; hence were suitable for favourable environments for yield, whereas V-III and Sanghar-I were with b-values less than unity indicating their below average response. For branches per plant, Sanghar-I and S-17 had regression coefficients less than one with negative sign making them suitable only for poor environments. Four genotypes namely, Sanghar-I, S 17, PR 19-9-S and Rattodero 1 had greater than unity and non-significant regression coefficients with high response towards better agronomic conditions and were stable due to low deviation from regression. Correlations of mean with b-value and S$^2$d, for seed yield were highly significant and positive suggesting that average yield could be considered as a measure of response and stability.
Chemeda et al. (2014) determined the stability of sesame with 10 genotypes for seed yield. The results showed that the variations among the genotypes and G x E interactions (G x E) were significant. Further, decomposition of the sum of squares due to environments and genotype x environment into environments (linear), genotype x environment (linear) and the pooled deviations from the regression model revealed that environment (linear) and pooled deviation were highly significant for seed yield, but G x E (linear) was non-significant. Two genotypes viz., EW002 and BG006, were identified as stable with high mean seed yield.

Narayanan et al. (2014) evaluated sixteen genotypes of sesame with the objective of testing stability in six environments. The analysis of variance for individual environments as well as pooled analysis revealed significant differences among the genotypes for all the characters studied. The results indicated differential reaction of genotypes with different environments. Among the sixteen genotypes studied, N 8, CO 1, Pragati, Nirmala and TC 289 showed stability for seed yield per plant. Considering stability parameters, H 12 exhibited high seed yield per plant. Its regression coefficient was less than unity and stability factor was around unity indicating suitability for both favourable and unfavourable environments. A simultaneous consideration of all the five parameters like mean, regression coefficient, deviation from regression, stability factor and coefficient of variation showed that VRI 1 and TMV 3 were the most adaptable genotypes for poor environment with non-significant regression coefficient and deviation of regression for low grain yield per plant. The genotypes TMV 3 and VRI 1 were found stable for yield related traits like day to 50 per cent flowering and number of capsules per plant and number of seeds per capsule coupled with moderate to high seed yield per plant indicating their commercial potential.

Sedeck et al. (2014) determined the phenotypic and genotypic stability for seed yield per plant and seed yield per fed in 12 sesame genotypes that were grown in fifteen environments (five locations and three years). The analysis of mean squares due to genotype x environment (linear) and non-linear deviation were significant for seed yield per plant and seed yield per fed. Genotypes RH1F3, RH1F8 and line 102-21 were stable according to phenotypic stability method. Meanwhile, one genotype, Giza 24 for seed yield per plant and three genotypes, M3A1, Sohag1 and Giza 19 for seed yield per fed were stable according to genotypic stability method.
Abd El-Rhman et al. (2015) studied the stability performance of 12 genetically diverse genotypes of sesame over ten environments and two summer seasons (2012 and 2013) for seed yield and its components. The partition into environment + genotype x environment mean squares showed that environments (linear) differed significantly and were quite diverse with regards to their effects on the performance of genotypes for seed yield and most yield components. Stable genotypes were identified for wider environments and specific environments with high *per se* performance (over general mean) for seed yield per plant. The results revealed that the genotypes Shandweel 3, Zahra 78, M2 A5 and H 133A7 were desirable and stable across the environments. Other genotypes M2 A61, H 111A7 and B 21 were found to be suitable for favourable situations, while genotypes H 102A521 and H 53A3-2 were responsive to poor environments for seed yield.

Chaudhari et al. (2015b) evaluated total of 50 hybrids developed by crossing five lines with ten testers along with 15 parents. Three crosses viz., G.Til 3 x AKT 101, Patan 64 x JLS 110-12 and G.Til 1 x JLT 7 along with five parents and one check G.Til 4 exhibited higher mean seed yield, unit regression (b\(_i\)) and least deviation from regression (S\(_{di}\)) and therefore, they were classified as stable with average response to environments. Five crosses expressed specific adaptability for favourable environments, while the hybrid G.Til 3 x JLS 110-12 showed specific adaptability to poor environments for seed yields per plant.

Khan et al. (2015) studied G x E interactions and phenotypic stability in sesame. Pooled analysis of variance showed highly significant differences among the genotypes (G), environments (E), year (Y), Y x E, G x E, G x Y and G x E x Y interactions suggesting differential response of the genotypes. Highly significant differences among the genotypes for seed yield indicated the presence of sufficient genetic variation among the genotypes. The variances due to G x E interactions were highly significant showing the presence of heritable variation among the genotypes to interact considerably with the environments. Furthermore, variance due to environments were also highly significant and revealed that the performance of these genotypes were variable in different environments and could not be predicted. On the average of four locations of two years, four genotypes out yielded the check TS 3 (536 kg/ha) with yield ranging from 545 to 570 kg/ha, whereas NS 44-SP1 had same yield as that of check. Seven genotypes produced more seed yield than overall mean of 501 kg/ha. NS 44-SP1 and SV III were stable genotypes. SG 27, SG 51, NS 103-1
and NS 22 were suitable for high yielding environments, whereas TS 3 was suitable for low yielding environments.

Mali et al. (2015) reported that the stability of 30 genotypes of sesame for yield and yield components in sesame were significant for seeds yield per plant, while number of capsules per plant, number of branches per plant also exhibited positive and significant association with seed yield per plant. Out of 30 genotypes, GT 2 and RT 46 showed wide adaptability to all the environments.

Twelve sesame genotypes were evaluated by Misganaw et al. (2015) at five locations in eight environments for seed yield. The highest seed yields were obtained from genotypes Acc.00047, NN 0143 and Acc.202-344 (712.8, 679.2 and 639.9 kg/ha), respectively. There were highly significant difference (P<0.01) among genotypes, environments and genotype by environment interaction (G x E), indicating that genotypes performed differently across locations and the need for stability analysis. The G x E (linear) interaction of seed yield was significant, indicating that the stability parameter (bi) estimated by linear response to change in environment was different for all genotypes or genotypes had different slopes. This confirms that G x E interactions was in a linear function of environments indices as the mean of all the genotypes tested. The deviation from the regression ($S^2_{di}$) was not significant, indicating that the nonlinear sensitivity in the expressions of seed yield was not important. Genotypes, Acc.00035, Acc.018, Hirhir-Kibe, Acc.202-344, NN 0143 and Borkena had regression coefficients greater than unity, indicating their responsiveness to favourable environments for seed yield, whereas local variety and Acc.00044 had regression coefficient significantly lower than unity, showing their adaptation to low yielding environments. Other genotypes like Acc.00046, Acc.00047, Acc.202-339 and Acc.202-340 had regression coefficients closer to unity.

Raikwar (2016) evaluated seventeen genotypes of sesame over three years to assess the stability of these genotypes for yield and its contributing traits over years and environments. Analysis of variance for stability with respect to 8 traits revealed highly significant variation due to environments for all traits which indicated differential effect of different seasons. The variances for genotypic effect were highly significant for all the traits observed, indicating thereby differential response of all the genotypes. Genotype × environment (linear) interactions were significant for seven traits namely; days to 50 per cent flowering, plant height, days to maturity, branches per plant, capsules per plant, capsule length and seed yield, indicating substantial
amount of predictable G × E interaction. Environmental indices indicated that performance of genotypes over three environments varied apparently and environment E₁ showed the highest favourable impact on grain yield. The varieties TKG 478, TKG 501, TKG 503, TKG 506, TKG 306 and TKG 512 with superior mean performance, regression coefficient near to one and non-significant $S_{2di}^2$ values showed average stability for grain yield.

Twelve sesame genotypes were evaluated by Misganaw et al. (2017) at five locations in eight environments for oil content. The highest oil yields were obtained from genotypes Acc.00047, NN-0143 and Borkena (339.2, 306.0 and 287.5 kg/ha), respectively. There were highly significant difference (P<0.01) among genotypes, environments and G x E interaction, indicating that genotypes performed differently across locations and the need for stability analysis. Proportion of total variation captured by environment was 49.6 per cent, by genotypes was 13.8 per cent and by G x E interaction was 32.1 per cent. Genotypes Borkena, NN 0143, Acc.00035, Acc.018, Hirhir-Kibe and Acc.202-344 had regression coefficients greater than unity, whereas local variety and Acc.00044 had regression coefficient significantly lower than unity. Other genotypes like Acc.00047, Acc.202339, Acc.202340 and Acc.00046 had regression coefficient closer to unity.