5. DISCUSSION

In sesame (*Sesamum indicum* L.), seed yield and oil content are the traits of economic importance. In spite of major contribution to world’s area, production and export, productivity of sesame in India is very low and remained stagnant over the years. In India, sesame improvement has been initiated as early as 1930’s and so far large numbers of varieties were developed for different agro climatic situations. Though, wide spectrum of improved varieties were available there exist perceptible gap between achievable potential and actual production. One of the major reasons for low productivity is cultivation in marginal/sub-marginal lands under poor management along with low inputs in rainfed situation. The production also showed wide fluctuation; this is attributed to high sensitivity to the changes in environments, amount and distribution of rainfall, temperature and photoperiod. Sesame breeding continues to be in traditional and classical way and most of the varieties were derived by either pure line selection or from single crosses by pedigree breeding method, resulting low variability and marginal increase in seed yield and oil content. These varieties were have narrow genetic base and not adapted over the wide range of environments and susceptible to biotic and a biotic stresses. Hence reselection from multiple combinations using diverse parents is essential to identify genotypes suitable for wide range of agro ecological regions. Heterosis breeding could be new hope for increasing the productivity in sesame, as heterosis is already well-known in many cross pollinated crops and even in few self pollinated crops like tomato. Sesame has distinct advantage in development of hybrids due to low seed rate, high seed multiplication ratio (1:150) and epipetalous floral structure enable easy emasculation. However success in hybridization depends on the extent of heterosis for seed yield and its component characters, identification of good combining parents, crosses with specific combining ability for exploitation of heterosis, gene action involved in expression of trait and cost effective
technique to produce hybrid seeds. Therefore, in present investigation attempts were made to study the extent of heterosis for seed yield and yield components, nature of gene action governing the characters under study, combining ability of the parents and their behaviour in combinations to produce hybrids with high specific combining ability effects and heterosis. G x E interaction/ Stability analysis studied to identify hybrids and parents with wider adaptability and suitability to specific condition. Inbreeding depression studied to know the behaviour of heterotic crosses in F2 generation and extent of inbreeding depression for seed yield and yield components and identify crosses with low inbreeding depression or residual heterosis for seed yield in F2 as possibility of reducing the prices of F1 seeds. The cost of hybrid seed production studied to analyze the feasibility of F1 seed production. The results obtained in present study discussed with following sub-headings.

5.1 Analysis of variance for line x testers
5.2 Heterosis
5.3 Combining ability
5.4 Combining ability variances and gene action
5.5 Genotype x Environment (G x E) interaction/Stability analysis
5.6 Inbreeding depression
5.7 Technique and cost of hybrid seed production

5.1 ANALYSIS OF VARIANCE FOR LINE X TESTER

5.1.1 Summer 2010 (E1)

The analysis of variances reveled significant differences among the parents for all the characters except the days to maturity, capsule length and number of seeds per capsule. Genetic variability among the parents is essential as it affects the effectiveness of the selection for genetic improvement in seed yield and yield attributes. The analysis of variances revealed significant differences among the crosses for all the traits except characters lacking variability in parental population. The interaction between parents and crosses recorded significant differences for characters
viz., plant height for first capsule, internode distance, number of nodes on main stem, number of capsules per plant, seed yield per plant, 1000 seeds weight and oil content, heterosis could be exploited for those characters.

5.1.2 **Kharif 2010 (E₂)**

In *kharif* season, characters *viz.*, days to flower initiation, days to maturity, capsule length and number of seeds per capsule were recorded non-significant differences among the parents and crosses. These findings confirm that for expression of heterosis presence of genetic variability is essential. The interaction between parents and crosses recorded significant differences for all the characters except, characters lacking genetic variability within parental population.

5.1.3 **Rabi 2010 (E₃)**

Similar results were revealed in *rabi* season for characters days to 50 percent flowering, days to maturity and number of seeds per capsules, whereas hybrids recorded non-significant differences for days to flower initiation and days to maturity. The interaction between parents and crosses revealed significant differences for characters *viz.*, plant height, plant height for first capsule, number of primary branches, number of nodes on main stem, number of nodes on main stem and number of capsules on main stem, heterosis could be exploited in these characters.

Karuppaiyan *et al.* (2000) observed significant differences for days to maturity and oil content. Ragiba and Reddy (2000) found highly significant differences for all 12 characters investigated, indicating large diversity among the parents. Ramesh *et al.* (2000) revealed significant differences for 1000 seed weight. Sumathi and Kalaimani (2000) reported significant differences among parents and crosses for days to 50 per cent flowering, plant height, number of primary branches per plant, number of capsules per plant and yield per plant. Thiyagu *et al.* (2007a) also reported similar results for all the character except days to 50 percent flowering and days to maturity. Pravin kumar (2009) showed contrary results for capsule length, 1000 seed weight, and oil content.
5.2 HETEROSIS

Top five hybrids selected on the basis of per se performances along with sca effects, relative heterosis, heterobeltiosis, standard heterosis, gca effects of parents and per se performance of parents involved in crosses for seventeen quantitative traits during summer-2010 (E₁), kharif-2010(E₂) and rabi-2010(E₃) presented in Table 5.1, Table 5.2 and Table 5.3 respectively.

5.2.1 Days to flower initiation

Negative heterosis for days to flower initiation is desirable trait for earliness of hybrids.

5.2.1.1 Summer 2010 (E₁)

In present investigation negative heterosis for days flower initiation recorded up to extent of -11.34%, -18.87% and -4.77% over mid parent, better parent and standard check respectively. Significant negative heterosis over better parent recorded by four hybrids viz., SI-3218 x KMS-5-873 (-18.87%), SI-3218 x SI-331517 (-18.87%), GSM-22 x KMR-116 (-14.01%) and SI-3218 x KSM-5-343 (-13.20%). Top five hybrids on the basis of per se performance were consisting of parents with medium performance. The dominance estimates for these hybrids may be responsible for negative heterosis.

5.2.1.2 Kharif 2010 (E₂)

In kharif season, heterosis ranged from -13.43 to 10.07%, -16.98 to 8.59% and -14.93 to 14.93% over mid parent, better parent and standard check respectively. Four hybrids viz., GSM-22 x KMR-116 (-16.98%), GSM-22 x SI-331517 (-16.35%), ES-111-284 x Lalguda local (-15.33%) and GSM-22 x Lalguda local (-13.21%) were exhibited significant negative heterobeltiosis. Over dominance in these hybrids may be resulted in the negative heterosis. None of the hybrid was expressed significant negative heterosis over mid parent and standard check.

5.2.1.3. Rabi 2010 (E₃)

Rabi season recorded the highest extent of negative heterosis observed over mid parent (-15.69%), better parent (-20.38%) and standard
<table>
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<th>RH</th>
<th>Hb</th>
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*** significance at 5% and 1% level respectively  
RH=Relative heterosis, Hb =Heterobeltiosis and SH=Standard heterosis
Table 5.2 Top five hybrids on basis of per se performance for quantitative traits in kharif-2010 (E2)

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<th>Crosses</th>
<th>Mean</th>
<th>SCA</th>
<th>RH</th>
<th>Hb</th>
<th>SH</th>
<th>gca of parents</th>
<th>Per se of parents</th>
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<th>RH</th>
<th>Hb</th>
<th>SH</th>
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** *** significance at 5% and 1% level respectively

RH=Relative heterosis, Hb =Heterobeltiosis and SH=Standard heterosis
### Table 5.3 Top five hybrids on basis of *per se* performance for quantitative traits in *rabi*-2010 (E3)

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<th>Character</th>
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<th>Mean</th>
<th>SCA</th>
<th>RH</th>
<th>Hb</th>
<th>SH</th>
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<th>Per se of parents</th>
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<tr>
<td>IC-413231 x KSM-5-343</td>
<td>1.81</td>
<td>-0.49*</td>
<td>-25.51**</td>
<td>-34.18**</td>
<td>-5.73</td>
<td>L X M</td>
<td>M X M</td>
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</tr>
<tr>
<td>GSM-22 x SI-331517</td>
<td>1.86</td>
<td>-0.22</td>
<td>-20.85*</td>
<td>-34.97**</td>
<td>-3.12</td>
<td>M X H</td>
<td>H X L</td>
<td></td>
</tr>
<tr>
<td>IC-413202 x KMR-116</td>
<td>1.86</td>
<td>-0.42*</td>
<td>-22.66*</td>
<td>-22.82*</td>
<td>-3.12</td>
<td>H X L</td>
<td>L X L</td>
<td></td>
</tr>
<tr>
<td>IC-413204 x Laliguda Local</td>
<td>1.90</td>
<td>-0.35</td>
<td>-5.00</td>
<td>-20.83</td>
<td>-1.04</td>
<td>M X H</td>
<td>H X L</td>
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<td><strong>Capsule length (cm)</strong></td>
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<td>ES-111-284 x SI-331517</td>
<td>3.72</td>
<td>0.69**</td>
<td>45.88**</td>
<td>28.28**</td>
<td>28.28**</td>
<td>H X M</td>
<td>L X H</td>
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<tr>
<td>GSM-22 x SI-331517</td>
<td>3.28</td>
<td>0.51**</td>
<td>18.84*</td>
<td>13.10</td>
<td>13.10</td>
<td>L X M</td>
<td>L X H</td>
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<td>IC-413231 x KMR-116</td>
<td>3.20</td>
<td>0.31</td>
<td>25.00**</td>
<td>17.65*</td>
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<td>M X M</td>
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<tr>
<td>ES-111-284 x S-0434</td>
<td>3.20</td>
<td>0.22</td>
<td>33.33**</td>
<td>23.08*</td>
<td>10.34</td>
<td>H X M</td>
<td>L X L</td>
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<tr>
<td>SI-3218 x KSM-5-343</td>
<td>3.12</td>
<td>0.48**</td>
<td>2.30</td>
<td>-2.50</td>
<td>7.59</td>
<td>M X L</td>
<td>H X H</td>
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<td>Crosses</td>
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<td>RH</td>
<td>Hb</td>
<td>SH</td>
<td>gca of parents</td>
<td>Per se of parents</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>----------------------------------------------</td>
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<td>---------</td>
<td>--------</td>
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</tr>
<tr>
<td><strong>Number of nodes on main stem</strong></td>
<td>IC-413204 x KSM-5-343</td>
<td>46.00</td>
<td>14.17**</td>
<td>21.21**</td>
<td>5.99</td>
<td>25.00**</td>
<td>M X L</td>
<td>H X L</td>
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<tr>
<td></td>
<td>IC-413209 x S-0434</td>
<td>43.00</td>
<td>5.46*</td>
<td>21.99**</td>
<td>19.44*</td>
<td>16.85</td>
<td>H X H</td>
<td>L X L</td>
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<tr>
<td></td>
<td>IC-413209 x Lalguuda Local</td>
<td>42.40</td>
<td>2.67</td>
<td>8.16</td>
<td>0.00</td>
<td>15.22</td>
<td>H X H</td>
<td>L X H</td>
</tr>
<tr>
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<td>SI-3218 x Lalguuda Local</td>
<td>42.00</td>
<td>8.53**</td>
<td>-2.55</td>
<td>-4.11</td>
<td>14.13</td>
<td>L X H</td>
<td>H X H</td>
</tr>
<tr>
<td></td>
<td>IC-413231 x KMS-5-873</td>
<td>41.20</td>
<td>2.91</td>
<td>24.47**</td>
<td>-3.74</td>
<td>11.96</td>
<td>H X L</td>
<td>L X H</td>
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<tr>
<td><strong>Number of nodes for first capsule</strong></td>
<td>IC-413209 x KMS-5-873</td>
<td>5.60</td>
<td>-0.26</td>
<td>-16.42*</td>
<td>-28.21**</td>
<td>-26.32**</td>
<td>H X L</td>
<td>L X H</td>
</tr>
<tr>
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<td>GSM-22 x KMS-5-873</td>
<td>5.60</td>
<td>-1.16**</td>
<td>-18.84*</td>
<td>-31.71**</td>
<td>-26.32**</td>
<td>H X L</td>
<td>L X H</td>
</tr>
<tr>
<td></td>
<td>IC-413209 x KMS-5-343</td>
<td>5.80</td>
<td>-0.43</td>
<td>-12.78</td>
<td>-25.64**</td>
<td>-23.68**</td>
<td>H X L</td>
<td>L X H</td>
</tr>
<tr>
<td></td>
<td>IC-413231 x KMS-5-873</td>
<td>5.80</td>
<td>-0.50</td>
<td>-12.12</td>
<td>-23.68**</td>
<td>-23.68**</td>
<td>M X H</td>
<td>L X H</td>
</tr>
<tr>
<td></td>
<td>IC-413202 x KMR-116</td>
<td>5.80</td>
<td>-0.82</td>
<td>0.00</td>
<td>-3.33</td>
<td>-23.68**</td>
<td>M X L</td>
<td>L X H</td>
</tr>
<tr>
<td><strong>Number of capsules on main stem</strong></td>
<td>IC-413231 x Lalguuda Local</td>
<td>60.50</td>
<td>4.88</td>
<td>28.18**</td>
<td>5.03</td>
<td>150.00**</td>
<td>H X H</td>
<td>M X H</td>
</tr>
<tr>
<td></td>
<td>SI-3218 x Lalguuda Local</td>
<td>54.40</td>
<td>13.31**</td>
<td>0.93</td>
<td>-5.56</td>
<td>124.79**</td>
<td>L X H</td>
<td>H X H</td>
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<tr>
<td></td>
<td>IC-413209 x KMS-5-873</td>
<td>52.40</td>
<td>15.07**</td>
<td>101.54**</td>
<td>79.45**</td>
<td>116.53**</td>
<td>M X M</td>
<td>L X L</td>
</tr>
<tr>
<td></td>
<td>IC-413202 x KMR-116</td>
<td>50.80</td>
<td>14.35**</td>
<td>5.18</td>
<td>-9.29</td>
<td>109.92**</td>
<td>M X L</td>
<td>H X H</td>
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<tr>
<td></td>
<td>ES-111-284 x Lalguuda Local</td>
<td>50.00</td>
<td>7.92**</td>
<td>16.02**</td>
<td>-13.19</td>
<td>106.63**</td>
<td>L X H</td>
<td>L X H</td>
</tr>
<tr>
<td><strong>Number of capsules per plant</strong></td>
<td>ES-111-284 x KSM-5-343</td>
<td>281.00</td>
<td>110.85**</td>
<td>165.09**</td>
<td>112.88**</td>
<td>329.66**</td>
<td>H X M</td>
<td>L X M</td>
</tr>
<tr>
<td></td>
<td>GSM-22 x Lalguuda Local</td>
<td>260.60</td>
<td>85.99**</td>
<td>84.95**</td>
<td>37.16**</td>
<td>298.47**</td>
<td>H X L</td>
<td>L X H</td>
</tr>
<tr>
<td></td>
<td>IC-413231 x Lalguuda Local</td>
<td>188.50</td>
<td>2.94</td>
<td>4.90</td>
<td>-0.79</td>
<td>188.23**</td>
<td>H X H</td>
<td>H X H</td>
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<tr>
<td></td>
<td>SI-3218 x Lalguuda Local</td>
<td>185.20</td>
<td>34.20**</td>
<td>-14.93*</td>
<td>-24.53**</td>
<td>183.18**</td>
<td>L X H</td>
<td>L X H</td>
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<tr>
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<td>ES-111-284 x Lalguuda Local</td>
<td>173.20</td>
<td>-34.44**</td>
<td>28.30**</td>
<td>-8.84</td>
<td>164.83**</td>
<td>H X H</td>
<td>L X H</td>
</tr>
<tr>
<td><strong>Number of seeds per capsule</strong></td>
<td>ES-111-284 x SI-331517</td>
<td>80.17</td>
<td>16.38**</td>
<td>48.93**</td>
<td>33.06**</td>
<td>28.27**</td>
<td>H X M</td>
<td>L X M</td>
</tr>
<tr>
<td></td>
<td>IC-413231 x KMR-116</td>
<td>68.96</td>
<td>6.55</td>
<td>25.00**</td>
<td>17.65</td>
<td>10.34</td>
<td>M X M</td>
<td>L X M</td>
</tr>
<tr>
<td></td>
<td>ES-111-284 x S-0434</td>
<td>68.96</td>
<td>4.55</td>
<td>33.33**</td>
<td>23.08</td>
<td>10.34</td>
<td>M X L</td>
<td>L X M</td>
</tr>
<tr>
<td></td>
<td>SI-3218 x KSM-5-343</td>
<td>67.24</td>
<td>9.54</td>
<td>2.29</td>
<td>-2.50</td>
<td>7.58</td>
<td>M X L</td>
<td>M X H</td>
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<tr>
<td></td>
<td>IC-413209 x KMR-116</td>
<td>64.65</td>
<td>4.75</td>
<td>14.94</td>
<td>10.29</td>
<td>3.45</td>
<td>L X M</td>
<td>L X M</td>
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<tr>
<td><strong>Seed yield per plant (g)</strong></td>
<td>ES-111-284 x KSM-5-343</td>
<td>34.61</td>
<td>13.05**</td>
<td>136.25**</td>
<td>74.80**</td>
<td>325.18**</td>
<td>H X M</td>
<td>L X H</td>
</tr>
<tr>
<td></td>
<td>GSM-22 x Lalguuda Local</td>
<td>31.69</td>
<td>8.78**</td>
<td>111.69**</td>
<td>74.12**</td>
<td>289.31**</td>
<td>H X H</td>
<td>L X H</td>
</tr>
<tr>
<td></td>
<td>SI-3218 x Lalguuda Local</td>
<td>27.82</td>
<td>8.03**</td>
<td>18.08*</td>
<td>-3.80</td>
<td>241.77**</td>
<td>L X H</td>
<td>H X H</td>
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<td></td>
<td>IC-413231 x Lalguuda Local</td>
<td>24.50</td>
<td>1.01</td>
<td>29.60**</td>
<td>24.94*</td>
<td>200.98**</td>
<td>H X H</td>
<td>H X H</td>
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<tr>
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<td>IC-413204 x S-0434</td>
<td>22.59</td>
<td>7.44**</td>
<td>22.27*</td>
<td>-0.92</td>
<td>177.52**</td>
<td>L X L</td>
<td>L X H</td>
</tr>
<tr>
<td><strong>1000 seed weight (g)</strong></td>
<td>IC-413202 x SI-331517</td>
<td>3.29</td>
<td>0.09</td>
<td>16.58**</td>
<td>10.89**</td>
<td>5.79</td>
<td>M x H</td>
<td>H x L</td>
</tr>
<tr>
<td></td>
<td>IC-413204 x Lalguuda Local</td>
<td>3.26</td>
<td>0.05</td>
<td>8.73</td>
<td>3.93</td>
<td>4.82</td>
<td>L x L</td>
<td>H x M</td>
</tr>
<tr>
<td></td>
<td>ES-111-284 x S-0434</td>
<td>3.25</td>
<td>0.05</td>
<td>9.61*</td>
<td>6.91</td>
<td>4.50</td>
<td>L x L</td>
<td>H x M</td>
</tr>
<tr>
<td></td>
<td>IC-413208 x SI-331517</td>
<td>3.25</td>
<td>-0.05</td>
<td>10.49**</td>
<td>1.56</td>
<td>4.50</td>
<td>L x H</td>
<td>H x L</td>
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<td>IC-413204 x S-0434</td>
<td>3.25</td>
<td>0.02</td>
<td>7.85</td>
<td>3.61</td>
<td>4.50</td>
<td>L x L</td>
<td>H x M</td>
</tr>
<tr>
<td><strong>Oil content (%)</strong></td>
<td>IC-413231 x SI-331517</td>
<td>49.60</td>
<td>1.12</td>
<td>2.99</td>
<td>1.38</td>
<td>1.81</td>
<td>L x H</td>
<td>H x H</td>
</tr>
<tr>
<td></td>
<td>ES-111-284 x KMR-116</td>
<td>48.50</td>
<td>3.89*</td>
<td>-0.35</td>
<td>-0.45</td>
<td>-0.45</td>
<td>H x H</td>
<td>H x H</td>
</tr>
<tr>
<td></td>
<td>IC-413202 x KMR-116</td>
<td>48.40</td>
<td>0.26</td>
<td>-0.55</td>
<td>-0.66</td>
<td>-0.66</td>
<td>H x H</td>
<td>H x H</td>
</tr>
<tr>
<td></td>
<td>IC-413202 x KSM-5-343</td>
<td>48.20</td>
<td>-0.67</td>
<td>0.29</td>
<td>-0.86</td>
<td>-1.07</td>
<td>H x H</td>
<td>H x H</td>
</tr>
<tr>
<td></td>
<td>IC-413209 x KMR-116</td>
<td>47.70</td>
<td>-1.31</td>
<td>-3.00</td>
<td>-3.90</td>
<td>-2.09</td>
<td>L x H</td>
<td>H x H</td>
</tr>
</tbody>
</table>

* ** significance at 5% and 1% level respectively
RH = Relative heterosis, Hb = Heterobeltiosis and SH = Standard heterosis
check (-15.69%). Negative heterosis was shown by twenty five, thirty and forty two hybrids over mid parent, better parent and standard variety respectively. Hybrid SI-3218 x S-0434 expressed significant negative heterosis over the mid parent, better parent and standard check, and consist of parents with medium and low performance for earliness. Thus over dominance and dispersion of the genes may be responsible for heterosis.

Therefore hybrids *viz.*, SI-3218 x KMS-5-873, SI-3218 x SI-331517, GSM-22 x KMR-116, SI-3218 x KSM-5-343, GSM-22 x SI-331517, ES-111-284 x Lalguda local, and GSM-22 x Lalguda local and SI-3218 x S-0434 could be utilized for developing early flowering high yielding varieties in later segregating generations.

Dixit (1976) and Jadon and Mehrotra (1988) also observed negative heterosis for days to flowering. Ray and Sen (1992) revealed that heterosis over mid parent and better parent were pronounced for number of days to flowering. Durga and Raghunadhan (2001) reported desirable heterotic effects for days to flower initiation. Sumathi and Muralidharan (2008) found that cross TMV-5 x Cordebergea was early in flowering and duration.

**5.2.2 Days to 50 percent flowering**

**5.2.2.1 Summer 2010 (E1)**

Desirable negative heterosis was exhibited by thirty four, thirty seven and fourteen hybrids over mid parent, better parent and standard check respectively and up to extent of -13.27%, -22.03% and -4.35% respectively. Significant negative heterobeltiosis was expressed by four hybrids *viz.*, GSM-22 x KMR-116 (-22.03%), SI-3218 x KSM-5-343 (-18.33%), IC-413202 x S-0434 (-16.67%) and IC-413204 x S-0434 (-16.67%). None of the hybrid was shown significant superiority over standard check. Hybrid SI-3218 x KMS-5-343 was significantly superior over mid parent and better parent, however non-significant over standard check. There was difference in rank of hybrids on the basis of *per se* performance and the heterosis estimates, indicating that hybrids should be selected on the basis of heterosis.
5.2.2.2 Kharif 2010 (E<sub>2</sub>)

In kharif season, negative heterosis observed up to extent of -15.10%, -21.39% and -15.07% over mid parent, better parent and standard check respectively. Significant mid parent heterosis was shown by GSM-22 x SI-331517 (-15.10%), whereas eight hybrids were revealed significant negative heterobeltosis with highest by GSM-22 x KMR-116 (-21.39%) followed by SI-3218 x KMS-5-873 (-20.63%), SI-3218 x KMR-116 (-20.63%) and GSM-22 x SI-331517 (-20.32%). All hybrids recorded negative non-significant heterosis over standard check. There is no agreement between per se performance and the rank of hybrids showing highest negative heterobeltiosis, indicating that hybrids should be selected on the basis of heterosis estimates.

5.2.2.3 Rabi 2010 (E<sub>3</sub>)

Extent of negative heterosis over mid parent, better parent and standard check observed up to -15.79%, -17.24% and -11.11% with twenty four, thirty four and twenty six hybrids with negative heterosis respectively. Hybrids IC-413209 x SI-331517 and IC-413209 xS-0434 were shown significant negative heterosis over mid parent and better parent, whereas four hybrids viz., IC-413209 x SI-331517 (-17.24%), IC-413209 x KMS-5-873 (-17.24%), IC-413209 x KSM-5-343 (-17.24%) and IC-413209 x S-0434 (-15.52%) were expressed significant negative heterobeltiosis. There was agreement between the ranks of hybrids with low per se performance and the negative heterobeltiosis, indicating that hybrids could be selected on the basis of per se performance. Three out of four hybrids with negative heterobeltiosis consist of parents with low x low combinations, indicates that heterosis may be due to dispersion of genes and over dominance as potency ratio was >1.

Three hybrids viz., ES-111-284 x SI-331517, IC-414208 x KMS-5-873 and IC-413209 x KMR-116 shown non-significant negative standard heterosis over the seasons, whereas GSM-22 x KMR-116 and SI-3218 x KMS-5-343 were recorded significant negative heterobeltiosis in summer.
and Kharif season.


5.2.3 Days to maturity

Negative heterosis for number of days required for physiological maturity indicates early maturity in the hybrids. Early maturity is desirable traits as sesame cultivated during summer, kharif and rabi seasons. Early maturity reduces crop duration and provide opportunity in rain fed conditions and drought prone areas, and also possible to go for multiple cropping systems. Sometimes, early maturity helps to escape from disease and pests occurring late in the season. Early maturity, determinate growth habit and non-shattering are highly desirable in sesame.

5.2.3.1 Summer 2010 (E₁)

Negative heterosis recorded up to extent of -10.23%, -16.30% and -13.48% over mid parent, better parent and standard check respectively, however significant heterosis observed over better parent only. Forty three hybrids were shown negative heterobeltiosis and IC-413202 x S-0434 (-16.30%) was significant, followed by IC-413231 x S-0434 (-14.13%) and IC-413209 x S-0434 (-14.13%). These hybrids consist of parents with high x low \textit{per se} performance. The potence ratio (P) for these hybrids were >1. Thus heterosis may be due to over dominance and the dispersion of genes in parents.

5.2.3.2 Kharif 2010 (E₂)

During kharif season, heterosis ranged from -8.04 to 14.62, -14.04 to 9.52 and -11.88 to 10.89 percent over mid parent, better parent and standard check respectively. Non-significant negative relative heterosis, heterobeltiosis and standard heterosis recorded by twenty six, thirty six and
forty one hybrids respectively. Top five hybrids on the basis of *per se* performance viz., IC-413204 x SI-331517, IC-413204 x S-0434, IC-413208 x Lalguda local, IC-413208 x S-0434 and IC-413209 x Lalguda local were consist of at least one parent with low *per se* performance (delayed maturity); however hybrids IC-413208 x Lalguda local and IC-413208 x S-0434 were consist of both parents with delayed maturity, thus heterosis may be due to dispersion of genes in parents and duplicate gene action in cross combinations.

### 5.2.3.3 *Rabi 2010 (E₃)*

Desirable heterosis for days to maturity observed during *rabi* season, up to extent of -10.75%, -16.67% and -14.43% over parental mean, better parent and standard check. None of the hybrid recorded significant negative heterosis over mid parent and standard check, however four hybrids viz., SI-3218 x S-0434 (-16.67%), SI-3218 x KMS-5-873 (-14.91%), SI-3218 x Lalguda local (-14.91%) and SI-3218 x SI-331517 (-14.91%) were recorded significant negative heterobeltiosis. There was no agreement between ranks on basis of *per se* performance and heterosis estimates, therefore hybrids should be selected on the basis of heterosis. In these crosses female and male were shown delayed maturity and medium maturity respectively, indicating that dispersion of genes and partial dominance may responsible for heterosis.

Six hybrids viz., SI-3218 x KMS-5-343, SI-3218 x SI-331517, SI-3218 x KMR-116, SI-3218 x KMS-5-873, SI-3218 x S-0434 and SI-3218 x Lalguda local were expressed negative heterobeltiosis over the seasons and these hybrids could be utilized for developing early maturing high yielding varieties.

Sarafi (1976) observed relative heterosis for early maturity and correlation between yield, plant height and late maturity. Tyagi and Singh (1981) found that crosses between intermediate maturity and early maturity were early maturing. Ragiba and Reddy (2000) recorded very high negative heterosis in RT54 x X198. Durga and Rahunadhan (2001) reported negative
heterosis for days to maturity. Kar and Swain (2001) reported 3.90% negative heterosis for days to maturity. Thiyagu et al. (2007a) observed the range of heterosis from -13.09 to 13.53 percent. Anuradha and Reddy (2008a) observed the relative heterosis and heterobeltiosis for days to maturity (1.77 to 17.43%, -2.05 to 14.38%). Prajapati et al. (2010) also revealed similar results. Rao and Gangadhara (2011) reveled the early duration along with highest number of branches and tall plant height in cross E-8 x M.T. 101.

5.2.4 Plant height (cm)

Plant height is one of the important yield contributing character and directly affects biomass accumulation and seed yield of the plant, while indirectly through the other characters such as number of capsules per plant, number of capsule on main stem, capsule bearing plant height and internode distance. Tall plant along with determinate growth habit is desirable, however indeterminate growth habit results in delayed maturity and shattering in lower capsules.

5.2.4.1 Summer 2010 ($E_1$)

Heterosis for plant height observed in both the directions, however positive heterosis recorded up to extent of 24.77%, 18.48% and 64.24% over parental mean, better parent and standard check respectively and significant positive heterosis over mid parent and standard check shown by three and twenty three hybrids respectively. Hybrids viz., IC-413204 x S-0434, GSM-22 x SI-331517 and SI-3218 x SI-331517 were recorded significant heterosis over mid parent and standard variety. There was good agreement between the ranks of hybrids on the basis of per se performance and heterosis estimates, and hybrids could be selected on the basis of per se performance. Hybrids with high per se performance contained at least one parent with high per se performance. Therefore over dominance and dispersion of genes in parents may responsible for heterosis.

5.2.4.2 Kharif 2010 ($E_2$)

Heterosis was ranged from -20.77 to 32.84%, -27.50 to 29.57% and -
9.69 to 52.10% over mid parent, better parent and standard check respectively and consists of thirteen, five and thirty three hybrids with significant positive heterosis respectively. Four hybrids viz., ES-111-284 x KMS-5-873, IC-413204 x KMR 116, IC-413204 x Lalguda local and IC-413209 x Lalguda local were exhibited significant positive heterosis over mid parent, better parent and standard check. There was fair agreement between *per se* performances of hybrids and the heterosis estimates, indicates that per performance could be reliable criteria for selection of hybrids. Generally, hybrids with high *per se* performances consist of at least one parent with low *per se* performance, however hybrids IC-413204 x Lalguda local and IC-413204 x S-0434 contained both parents with low *per se* performance, indicates that dispersion of the genes in parents and over dominance may be responsible for heterosis.

5.2.4.3 Rabi 2010 (E₃)

Positive heterosis for plant height recorded up to the extent of 32.39%, 18.75% and 82.12% over mid parent, better parent and standard check respectively. Hybrid GSM-22 x KMR-116 had showed significant positive heterosis over all three bases of heterosis along with highest *per se* performance, and consist of parents with high x low *per se* performance. Hybrids GSM-22 x KMR-116, SI-3218 x Lalguda local and IC-413231 x S-0434 and IC-413204 x Lalguda local with high *per se* performance shown high heterosis over standard check contained at least one parent with low or medium *per se* performance. Thus, heterosis may be the result of over dominance and dispersion of genes in parents.

Three hybrids *viz.*, IC-413204 x Lalguda local, GSM-22 x Lalguda local and SI-3218 x Lalguda local were shown significant positive standard heterosis over the season, these hybrids could be utilized for isolating transgressive segregants in later segregating generations.

Similar result were reported by Dixit (1976), Tyagi and Singh (1981), Jadon and Mehrotra (1988), Tu *et al.* (1991) and Tripathi and Mishra (2005). Sodani and Bhatnagar (1990) and Santha *et al.* (2001)

5.2.5 Plant height for first capsule (cm)

Plant height for first capsule is one of the earliness related characters and heterosis in negative direction is desirable. Varieties with reduced plant height for first capsule were showed early maturity and reduced internode distance.

5.2.5.1 Summer 2010 (E₁)

Heterosis observed in both the directions; however desirable negative heterosis recorded up to extent of -60.55%, -67.27% and -9.42% over parental mean, better parent and standard check. Eighteen and thirty two hybrids were shown significant negative relative heterosis and heterobeltiosis respectively. There was no agreement between high per se performance and high heterosis, therefore heterosis should be considered as selection criteria. Seventeen hybrids were expressed significant negative heterosis over both mid parent and better parent. Hybrids viz., SI-3218 x KMS-5-873 (-67.27%), IC-413231 x KMS-5-873 (-56.90%) and IC-413204 x KMS-5-873 (-50.34%) were exhibited high negative heterobeltiosis and consist parents with low x low per se combinations. Thus dispersion of genes and over dominance (p>1) may be responsible for heterosis.
5.2.5.2 Kharif 2010 (E₂)

Desirable negative heterosis recorded over parental mean, better parental mean and standard check up to extent of -17.01%, -34.02% and -27.17% respectively. Significant negative heterosis recorded by ten and five hybrids over better parent and standard check. There was mismatch between hybrids list with high per se and highest desirable heterobeltiosis, hence, heterosis should be considered as criteria for selection of hybrids. Hybrids viz., ES-111-284 x KMR-116 (-34.02%), IC-413231 x KMR-116 (-27.04%) and GSM-22 x KMR-116 (-25.71%) were shown high negative better parent heterosis, and consist of parents with low x high per se performance. Heterosis in these hybrids may be the result of partial dominance (P=0 to 1) and dispersion of genes.

5.2.5.3 Rabi 2010 (E₃)

Wide range of heterosis was observed in both the directions; however desirable negative heterosis expressed up to the extent of -62.25%, -66.80% and -51.44% over parental mean, better parent and standard check, and thirty four, forty four and seven hybrids were recorded significant negative heterosis respectively. Seven hybrids viz., IC-413231 x KMS-5-343, IC-413231 x KMS-5-873, IC-413231 x Lalguda local, IC-413208 x KMR 116, IC-413209 x KMS-5-873, IC-413209 x S-0434 and IC-413202 x KMS-5-873 showed significant negative heterosis over mid parent, better parent and standard variety. There was agreement between lists of hybrids with high per se performance and high heterosis; therefore hybrids could be selected on the basis of heterosis. Three out of five hybrids with low per se performance consist of parents with low x low per se performance and two with low x medium per se performance. Thus dominance and dispersion of genes may be responsible for high heterosis.

Six hybrids viz., ES-111-284 x KMS-5-343, ES-111-284 x SI-331517, ES-111-284 x KMR-116, ES-111-284 x S-0434, GSM-22 x SI-331517 and GSM-22 x KMR-116 shown significant heterobeltiosis over the seasons. These hybrids could be utilized for isolation of transgressive
segregants with reduced plant height for first capsule along with other traits in segregating generation.

Similar results were recorded by and Tu et al. (1991) and Durga and Raghunadhan (2001). Kar and Swain (2001) observed a maximum of 55.00% negative heterosis for height up to first fruiting node. Uzun et al. (2004) also reported significant heterosis over mid parent and better parent.

5.2.6 Capsule bearing plant height (cm)

Capsule bearing plant height is the length of main axis which contributes directly to the seed yield per plant and indirectly through the number of nodes on main stem, internode distance and number of capsules on main stem.

5.2.6.1 Summer 2010 (E₁)

Heterosis observed in both the directions; however positive heterosis revealed up to the extent of 35.40%, 34.89% and 66.83% respectively over parental mean, better parent and standard check respectively and consists of seven, four and twenty seven hybrids with significant positive heterosis respectively. Four hybrids viz., IC-413204 x S-0434, IC-413202 x SI-331517, IC-413202 x S-0434 and SI-3218 x SI-331517 were shown significant positive heterosis over mid parent, better parent and standard check. These hybrids expressed high per se performance, indicates that hybrids could be selected on the basis of per se performance. Hybrid IC-413204 x S-0434 consist of parents with medium x low per se performance, whereas remaining hybrids were have parents with low x low per se performance. Heterosis may be due to over dominance and dispersion of genes in parents.

5.2.6.2 Kharif 2010 (E₂)

During kharif season, extent of positive heterosis observed up to 48.94%, 36.28% and 92.10% for relative heterosis, heterobeltiosis and standard heterosis respectively and consists of fourteen, five and thirty four hybrids with significant heterosis respectively. Five hybrids viz., IC-413204 x S-0434 (36.28%), IC-413204 x KMR-116 (27.83%), ES-111-284 x KSM-
5-343 (25.82%), GSM-22 x KMR-116 (23.94%) and GSM-22 x SI-331517 (19.75%) were exhibited the significant heterosis over mid parent, better parent and standard variety. A good agreement between high per se performance and high heterosis indicates that hybrids could be selected on basis of per se performance. Hybrids with high per se performance consist of parents with high x low, medium x low and low x low per se performance and dominance estimate (P) value was >1. Thus, the over dominance and dispersion of genes may be responsible for high heterosis.

5.2.6.3 Rabi 2010 (E₃)

Positive heterosis observed up to extent of 39.13%, 27.55% and 77.13% in case of relative heterosis, heterobeltiosis and standard heterosis respectively and consist of thirty one, four and twenty eight hybrids with significant heterosis respectively. Hybrid IC-413231 x Lalguda local, GSM-22 x Lalguda local and SI-3218 x Lalguda local were shown significant relative heterosis, heterobeltiosis and standard heterosis. These hybrids were registered high per se performance and consist of parents with high x medium, low x medium and low x medium per se performance. Dominance estimates (P value) was more than one, thus heterosis may be due to over dominance and dispersion of genes in parents. Sixteen hybrids were shown significant positive standard heterosis over the seasons.

Dixit (1976) and Tu et al. (1991) reported similar results for capsule bearing plant height on main axis.

5.2.7 Number of primary branches

Primary branches is one of the major yield contributing characters, directly affect the seed yield per plant and indirectly through other yield components such as number of capsules per plant, and number of capsules on primaries and secondaries.

5.2.7.1 Summer 2010 (E₁)

Heterosis observed in both the directions, however positive heterosis reveled up to extent of 82.61%, 75.00% and 150.00% over parental mean, better parent and standard check respectively and significant heterosis was
shown by eleven, eight and fourteen hybrids respectively. Seven hybrids viz. S-111-284 x KMR 116, IC-413208 x KMR 116, IC-413202 x KMS-5-873, GSM-22 x KMS-5-343, GSM-22 x KMS-5-873, GSM-22 x S-0434 and SI-3218 x Lalguda local had exhibited high *per se* performance and significant positive heterosis over mid parent, better parent and standard check. These hybrids were expressed over dominance (P>1) and contain at least one parent with low or medium *per se* performance. Thus heterosis may be result of over dominance and dispersion of genes.

5.2.7.2 *Kharif 2010* (*E*₂)

Desirable relative heterosis, heterobeltiosis and standard heterosis observed up to extent of 86.32%, 61.48% and 159.52% respectively and fifteen, twelve and thirty four hybrids were shown positive significant heterosis respectively. Twelve hybrids viz., ES-111-284 x SI-331517, ES-111-284 x KMS-5-873, IC-413231 x KMR-116, IC-413231 x KMS-5-873, IC-413231 x S-0434, IC-413208 x KMS-5-873, IC-413204 x KMR-116, IC-413204 x S-0434, IC-413204 x Lalguda local, IC-413202 x S-0434, GSM-22 x KMS-5-873, SI-3218 x Lalguda local were expressed high *per se* performance and significant positive heterosis over mid parent, better parent and standard check. These hybrids shown dominance estimates more than one (P>1) consist with at least one parent with high or medium *per se* performance. Therefore heterosis may be due to over dominance and dispersion of genes in parents.

5.2.7.3 *Rabi 2010* (*E*₃)

Desirable positive heterosis for number of branches per plant recorded significantly by six, two and seventeen hybrids up to extent of 58.33%, 46.15% and 71.43% respectively over mid parent, better parent and standard check. Two hybrids ES-111-284 x SI-331517 and IC-413204 x KMS-5-873 were shown heterosis over mid parent, better parent and standard check. There was no agreement between ranks of hybrids on the basis of high *per se* and the heterosis estimates, therefore hybrids should be selected on the basis of heterosis performance. These both hybrids
expressed over dominance (P>1) and consist of parents with low x low per se performance; therefore heterosis may be the result of over dominance and dispersion of genes in parents. These hybrids could be utilized for isolating transgressive segregants for number of branches per plant along with other yield components in segregating generations of crosses.

Hybrid IC-413204 x SI-331517 had shown significant relative heterosis over the season. Six hybrids viz., IC-413208 x S-0434, GSM-22 x KMS-5-343, GSM-22 x KMS-5-343, GSM-22 x KMS-5-873, GSM-22 x S-0434 and SI-3218 x Lalguda local were exhibited significant standard heterosis over the season.

Alam et al. (1999) reported significant positive heterobeltiosis in crosses B14 x IS 5 and TSS 130 x IS 5 for number of primary branches per plant along with seed yield. Dikshit and Swain (2000) found that heterosis for seed yield was very much associated with heterosis for number of capsule per plant and branches per plant. Ragiba and Reddy (2000) observed range of mid parent and better parent heterosis from -49.75 to 182.64 and -88.99 to 157.97 percent respectively. Reddy et al. (2001) and Misra et al. (2008) observed heterosis over better parent. Mothilal and Ganesan (2005) observed significant positive heterosis over mid parent in cross Vinayak x Madhavi. Anuradha and Reddy (2008a) observed the relative heterosis and heterobeltiosis for number of primary branches (-100.00 to 84.39%, -100.00 to 59.83%). Rao and Gangadhara (2011) observed early duration, highest number of branches and tallest plant height in cross E-8 x M.T. 101. Heterosis for plant height also studied by Dixit (1976), Srivastava and Prakash (1977), Tyagi and Singh (1981), Singh et al. (1986), Jadon and Mehrotra (1988), Sodani and Bhatnagar (1990), Tu et al. (1991) and Tripathi and Mishra (2005).

5.2.8 Internode distance (cm)

Internode distance is one of the yield components and affect yield directly and indirectly through number of nodes on main stem, number of capsules on the main stem and number of capsules per axils. Negative
heterosis is desirable for internode distance.

5.2.8.1 summer 2010 ($E_1$)

During summer season fifteen, twenty two and two hybrids were recorded the significant negative heterosis up to extent of -41.16%, -44.19% and -23.89% over parental mean, better parent and standard check respectively. Two hybrids IC-413204 x KMS-5-873 and ES-111-284 x Lalguda local were shown significant negative heterosis over all three basis of heterosis, whereas three hybrids viz., ES-111-284 x S-0434, IC-413204 x Lalguda local and IC-413204 x S-0434 were expressed negative heterosis over three basis and significant over mid parent and better parent. These hybrids exhibited either over dominance or partial dominance and contained at least one parent with medium or high per se performance for internode distance. Thus, heterosis may be due to either over dominance or partial dominance and dispersion of genes in parents.

5.2.8.2 Kharif 2010 ($E_2$)

Negative significant heterosis for internode distance recorded by six and eighteen hybrids up to extent of -25.97% and -35.64% over parental mean and better parent respectively. Hybrids viz. ES-111-284 x SI-331517, IC-413208 x SI-331517, IC-413204 x KMR 116 and IC-413209 x KMR 116 were shown significant negative heterosis over mid parent and better parent. These hybrids expressed high per se performance and consist of at least one parent with low per se performance. The over dominance (P>1) and dispersion of genes in parents may be responsible for heterosis in these crosses.

5.2.8.3 Rabi 2010 ($E_3$)

Heterosis over mid parent, better parent and standard check revealed in both directions, however twelve and twenty hybrids were shown significant negative heterosis with extent of -33.98% and -38.18% over mid parent and better parent respectively. Four hybrids viz., IC-413231 x KMS-5-343, IC-413209 x KMS-5-343, IC-413202 x KMR 116 and GSM-22 x SI-331517 were recorded significant negative relative heterosis and
heterobeltiosis and contained parents with medium x low, low x low, low x
low and high x low per se performance respectively. Thus heterosis may be
due to dispersion of genes in parents and partial or over dominance
estimates.

Three hybrids viz., ES-111-284 x KMS-5-343, ES-111-284 x SI-
331517 and IC-413231 x SI-331517 were shown significant negative
heterobeltiosis over the season. These hybrids could be utilized for
isolating transgressive segregants with reduced internode distance along
with other yield components in segregating generations of crosses.

5.2.9 Capsule length (cm)

Length of capsule is one of the major yield contributing character
and affects the seed yield per plant directly and indirectly through the other
characters namely capsule width, number of seeds per capsule, number of
locules per capsule, pod circumference and percentage of shattering.

5.2.9.1 Summer 2010 (E₁)

Heterosis were observed in both directions, however positive
heterosis over mid parent, better parents and standard check recorded up to
extent of 33.08%, 29.15% and 40.00% respectively and consist of twenty
three, twenty and thirty eight hybrids with positive heterosis respectively.
Two hybrids GSM-22 x S-0434 and GSM-22 x SI-331517 were shown
significant heterosis over mid parent, better parent, and standard check.
These hybrids expressed high per se performance, over dominance (P>1)
and contained parents with medium x low and medium x medium per se
performance. Thus dispersion of genes in parents and over dominance may
be resulted in high heterosis.

5.2.9.2 Kharif 2010 (E₂)

During kharif season, the extent of positive heterosis was low in
comparison to summer season. Heterosis over mid parent, better parent and
standard check observed up to 16.26%, 9.77% and 22.74% respectively.
Significant heterosis over mid parent and standard check was recorded by
IC-413204 x KMS-5-343. Five hybrids viz., IC-413208 x KMS-5-873, IC-
413204 x KMS-5-343, IC-413231 x KMS-5-343 and ES-111-284 x KMS-5-343 and IC-413208 x KMS-5-343 were shown high *per se* performance and contained parents mostly with medium x medium or medium x low or low x medium *per se* performance.

### 5.2.9.3 Rabi 2010 (E₃)

Wide range of heterosis observed in this season and positive of relative heterosis, heterobeltiosis and standard heterosis recorded up to extent of 45.88%, 28.28% and 28.28% respectively. Three hybrids *viz.*, ES-111-284 x SI-331517 (28.28%), ES-111-284 x S-0434 (23.08%) and IC-413231 x KMR-116 (17.65%) were shown significant heterosis over mid parent and better parent. These hybrids exhibited high *per se* and over dominance (*P* > 1); also consist of parents with low x high, low x medium and low x low *per se* performance respectively. Thus heterosis may be due to over dominance and complementation of dispersed genes in parents.

Two hybrids ES-111-284 x SI-331517 and GSM-22 x SI-331517 were expressed positive standard heterosis over the season. These hybrids could be exploited for isolating transgressive segregants in later generations of crosses for improving capsule length along with seed yield.


### 5.2.10 Number of nodes on main stem

Number of nodes on main stem affects the seed yield indirectly through the characters *viz.*, plant height, plant height for first capsule, number of nodes for first capsule, capsule bearing plan height, internode...
distance, number of capsule per node and number capsules on main stem.

5.2.10.1 Summer 2010 (E₁)

Number of nodes on main stem showed heterosis in both the directions; however the desirable positive heterosis was shown significantly by eleven, six and twenty five hybrids with extent of 68.88%, 68.15% and 79.47% over mid parent, better parent and standard check respectively. Six hybrids viz., ES-111-284 x Lalguda local, IC-413209 x Lalguda local, IC-413202 x Lalguda local, SI-3218 x SI-331517, SI-3218 x S-0434 and IC-413204 x S-0434, were recorded significant positive relative heterosis, heterobeltiosis and standard heterosis. First 3 hybrids were consists of low x low, 2 with medium x medium and one with high x medium per se performance of parents, and dominance estimates expressed over dominance (p>1) for these hybrids. The high heterosis with low x low parental combinations may be due to repulsion phase linkages and complementation of dispersed genes in parents.

5.2.10.2 Kharif 2010 (E₂)

Positive significant heterosis recorded by fifteen, six and twenty hybrids with maximum of 52.07%, 48.81% and 64.04% over parental mean, better parent and standard check respectively. Significant relative heterosis, heterobeltiosis and standards heterosis was shown by six hybrids viz., IC-413204 x KMR 116, IC-413204 x S-0434, IC-413204 x Lalguda local, IC-413209 x S-0434, GSM-22 x KMS-5-873 and GSM-22 x Lalguda local; these hybrids were shown high per se performance and consists of either low x low or medium x low per se performance of parents. Thus dispersion of genes and over dominance may be responsible for high heterosis in these crosses.

5.2.10.3 Rabi 2010 (E₃)

Heterosis over parental mean, better parent and standard check observed up to extent of 28.62%, 19.44% and 25.00% respectively. Significant relative heterosis was recorded by seven hybrids viz., IC-413209 x KMS-5-873 (28.62%), IC-413202 x SI-331517 (25.62%), IC-413231 x
KMS-5-873 (24.47%), GSM-22 x SI-331517 (23.78%), IC-413209 x S-0434 (21.99%), IC-413204 x KMS-5-343 (21.21%) and ES-111-284 x KMS-5-873 (20.44%). *Per se* performance of parents showed combination of low x low in 4 crosses, high x low in 2 crosses and medium x low in one cross. Thus either over dominance or partial dominance and dispersion of genes in parents could be resulted in heterosis. In low x low *per se* combinations of parent’s genes may be in repulsion phase which complemented in cross combination.

Two hybrids IC-413204 x KMS-5-343 and GSM-22 x SI-331517 with significant positive standard heterosis and relative heterosis respectively over the season, could be utilized for isolation transgressive segregants in later segregating generations.

### 5.2.11 Number of nodes for first capsule

Number of nodes for first capsule is one of the earliness related morphological trait in sesame. It indirectly affect the seed yield per plant through other characters *viz.*, plant height for first capsule, internode distance, number of nodes on main stem and capsule bearing plant height. Negative heterosis is desirable for this character.

#### 5.2.11.1 summer 2010 (E₁)

Heterosis for number of nodes for first capsule observed in both directions, negative heterosis recorded up to extent of -31.58%, -45.83% and -8.00% over mid parent, better parent and standard check respectively. Five hybrids namely SI-3218 x KMS-5-873, SI-3218 x Lalguda local, SI-3218 x SI-331517, IC-413204 x KMS-5-873 and IC-413208 x Lalguda local were exhibited significant negative relative heterosis and heterobeltiosis. These hybrids were involved at least one parent with low *per se* performance. Except SI-3218 x SI-331517, all hybrids were expressed over dominance. Thus over dominance and dispersion of genes may be responsible for heterosis in majority of these crosses.

#### 5.2.11.2 Kharif 2010 (E₂)
In *kharif* season negative desirable heterosis recorded significantly by one, nine and two hybrids with extent of -16.46%, -29.05% and -21.62% over mid parent, better parent and standard check respectively. Nine hybrids viz., SI-3218 x KMS-5-343 (-29.05%), SI-3218 x SI-331517 (-24.65%), GSM-22 x SI-331517 (-24.29%), SI-3218 x KMR-116 (-24.30%), GSM-22 x KMR-116 (22.14%), ES-111-284 x KMR-116 (-20.00%), ES-111-284 x KMS-5-343 (-19.58%), GSM-22 x KMS-5-343 (-18.93%) and ES-111-284 x S-0434 (-17.50%) were recorded significant negative heterosis over better parent. Most of these hybrids were recorded partial dominance and involved parents with low x high *per se* performance. Thus heterosis may be due to partial dominance and dispersion of genes in parents.

5.2.11.3 *Rabi 2010 (E₃)*

Significant negative heterosis over mid parent, better parent and standard check recorded by seventeen, thirty one and twenty one hybrids respectively with maximum heterosis up to -34.07%, -42.31% and -26.32% respectively. Eleven hybrids viz., IC-413209 x KMS-5-873, GSM-22 x KMS-5-873, ES-111-284 x SI-331517, IC-413231 x Lalguda local, ES-111-284 x Lalguda local, ES-111-284 x KMS-5-343, SI-3218 x KMR-116, IC-413208 x Lalguda local, IC-413209 x S-0434, IC-413204 x Lalguda local and SI-3218 x KMS-5-343 were shown significant negative heterosis over parental mean, better parent and standard check. Parents involved in these hybrids showed low x low and low x high *per se* performance for four and seven crosses respectively. Thus dispersion of genes in parents may be responsible for heterosis in these hybrids.

Two hybrids SI-3218 x KMS-5-343 and SI-3218 x SI-331517 were shown significant negative heterobeltiosis over the season, these hybrids could be utilized to isolate transgressive segregants with less nodes for first capsule along with other yield components in later segregating generations.

Durga and Rahunadhan (2001) recorded negative but desirable heterotic effects for plant height for first capsule along with height for first branch, plant height and days to first flowering.
5.2.12 Number of capsules on main stem

Number of capsules on main stem is one of the yield contributing character, directly affects seed yield per plant and indirectly through the number of capsules per plant. The characters such as plant height, number nodes on main stem, number of nodes for first capsule, plant height for first capsule, internode distance, number of capsules per node affects the number of capsule on main stem.

5.2.12.1 Summer 2010 (E₁)

Heterosis for number of capsule on main stem observed in positive direction up to extent of 64.66%, 64.00% and 99.04% and consists of nine, seven and thirty four hybrids with significant positive heterosis over mid parent, better parent and standard check respectively. Seven hybrids viz. ES-111-284 x S-0434, ES-111-284 x Lalguda local, IC-413204 x S-0434, IC-413202 x S-0434, IC-413202 x Lalguda local, SI-3218 x SI-331517 and SI-3218 x S-0434 were expressed significant heterosis over mid parent, better parent and standard check. First five hybrids consist of parents with per se performances of low x low, while low x medium and high x low in remaining hybrids respectively. Over dominance (P>1) and dispersion of genes in parents may be responsible for heterosis in these crosses.

5.2.12.2 Kharif 2010 (E₂)

Positive heterosis shown by five, three and eighteen hybrids up to extent of 45.03%, 37.08% and 59.66% over parental mean, better parent and standard check respectively. However the significant positive heterosis over three bases was exhibited by hybrids viz., GSM-22 x Lalguda local and IC-413204 x Lalguda local. These hybrids revealed over dominance and consist of parents with low x low and medium x low per se performance respectively. Heterosis in these crosses may be due to over dominance and dispersion of genes in parents.

5.2.12.3 Rabi 2010 (E₃)

Extent of positive heterosis was higher than summer and kharif season and significant heterosis was shown by fifteen, six and thirty hybrids
with maximum of 185.34%, 79.45% and 150.00% over mid parent, better parent and standard check respectively. Six hybrids *viz.*, ES-111-284 x S-0434, IC-413231 x KMS-5-343, IC-413231 x S-0434, IC-413208 x KMS-5-343, IC-413204 x KMS-5-343 and IC-413209 x KMS-5-873 were shown significant relative heterosis, heterobeltiosis and standard heterosis. *Per se* performance of parents reveled that 4 hybrids had low x low *per se* performance, while 2 hybrids consist of medium x low *per se* performance. Therefore over dominance (P>1) and dispersion of genes in parents may be the reason for high heterosis in these crosses.

Nine hybrids *viz.*, IC-413231 x KMR-116, IC-413208 x S-0434, IC-413204 x KMS-5-343, IC-413204 x SI-331517, IC-413204 x Lalguda local, IC-413209 x KMS-5-873, IC-413202 x Lalguda local, GSM-22 x SI-331517 and GSM-22 x Lalguda local were exhibited significant positive standard heterosis over the seasons. These hybrids could be utilized for isolating transgressive segregants in later generations of crosses.

Mothilal and Ganesan (2005) observed significant positive relative heterosis in cross Vinayak x Madhavi for number of capsule on main stem along with seed yield and other yield components. Anuradha and Reddy (2008a) observed the relative heterosis and heterobeltiosis for capsules on main stem (-42.62 to 54.16%, -42.97 to 45.23%). Significant heterosis for number of capsules on main stem also reported by Dixit (1976), Ray and Sen (1992) and Durga and Raghunadhan (2001).

### 5.2.13 Number of capsules per plant

Number of capsule per plant is one of the major yield contributing characters and directly affect the seed yield per plant. Characters *viz.*, number of primary branches, plant height, plant height for first capsule, capsule bearing plant height, number nodes on main stem, nodes for first capsule, number of capsule on main stem, number of capsule per node and internode distance influences the number of capsule per plant.

#### 5.2.13.1 summer 2010 (E₁)
Heterosis for number of capsules per plant observed in both the directions, however the extent of positive heterosis revealed up to 118.40%, 110.81% and 157.60%, with significance by nineteen, eight and twenty two hybrids over mid parent, better parent and standard check respectively. Significant positive relative heterosis, heterobeltiosis and standard heterosis recorded by seven hybrids viz., ES-111-284 x KMS-5-343, ES-111-284 x Lalguda local, IC-413231 x SI-331517, ES-111-284 x KMR-116, SI-3218 x KMS-5-343, SI-3218 x S-0434 and SI-3218 x Lalguda local. Three hybrids involved parents with low x low per se performance, whereas rest of the four hybrids consist of at least one parent with high or medium per se performance. Therefore heterosis may be due to over dominance ($P>1$) and dispersion of genes in parents.

5.2.13.2 Kharif 2010 (E$_2$)

Desirable heterosis was recorded up to extent of 243.37%, 215.96% and 399.35% including thirty one, twenty one and forty one hybrids with significance over parental mean, better parent and standard check respectively. Significant relative heterosis, heterobeltiosis and standard heterosis was shown by twenty one hybrids. Hybrids viz., GSM-22 x Lalguda local, IC-413204 x S-0434, IC-413204 x Lalguda local, SI-3218 x Lalguda local and IC-413231 x KMS-5-873 were the top five hybrids showing high per se performance and significant heterosis over all three bases. These hybrids expressed over dominance and contain parents mostly with high x low per se performance. Thus over dominance and dispersion of genes in parents may resulted in high heterosis.

5.2.13.3 Rabi 2010 (E$_3$)

In rabi season, heterosis observed in both directions, however positive heterosis over parental mean, better parent and standard check recorded up to the extent of 165.09%, 112.88% and 329.66% respectively and significant heterosis shown by twelve, six and thirty five hybrids respectively. Significant positive heterosis over all three bases expressed by six hybrids viz., ES-111-284 x KMS-5-343, ES-111-284 x SI-331517, ES-
111-284 x KMS-5-873, IC-413209 x KMS-5-873, IC-413202 x SI-331517 and GSM-22 x Lalguda local. Four hybrids were consisting of parents with low x low per se performance, whereas low x medium and low x high per se performance in last two hybrids respectively. High heterosis in these crosses may be due to over dominance (P>1) and dispersion of genes in parents which complement in cross combination.

Eighteen hybrids showed significant positive standard heterosis over the season, while six hybrids were shown significant relative heterosis over the season. These hybrids could be utilized for isolating transgressive segregants in late generation of crosses along with other yield components.

Singh et al. (1986) stated that number of capsule per plant contributed most to heterosis for yield. Ding et al. (1987) suggested that heterosis for number of capsules per plant in hybrid combinations was related to parental values for these characters and that these were important characters for early selection for high yield. Osman (1989a) observed that number of capsule per plant and number of seeds per capsule in F1 and number of capsule per plant in parents were the most important yield contributing characters. Kumar (1994) found that capsule number had a positive effect on yield potential. Mishra and Yadav (1996) observed significant positive heterobeltiosis and standard heterosis for number of capsule per plant in crosses TC-289 x Phule-1 and JLT-7 x TC-25. Alam et al. (1999) reported significant positive heterobeltiosis in two F1’s viz., B14 x IS 5 and TSS 130 x IS 5. Dikshit and Swain (2000) found that heterosis for seed yield was very much associated with heterosis in capsules per plant. Ragiba and Reddy (2000) recorded highest range of per se performance for number of capsule per plant in parents and hybrids; crosses X198 x R84-4-2 and X198 x R84-4-2 recorded higher heterosis over mid parent and better parent. Reddy et al. (2001) recorded significant better parent heterosis for number of capsule per plant in TKG-64 x E-8 and TC-397 x E-8. Anuradha and Reddy (2008a) observed the relative heterosis and heterobeltiosis for capsules per plant (-74.00 to 130.27%, -77.62 to
Sumathi and Muralidharan (2008) revealed that cross TMV 3 x KS 990813 was superior for number of capsules per plant. Heterosis for number of capsule per plant also reported by Murty (1975), Dixit (1976), Tyagi and Singh (1981), Jadon and Mehrotra (1988), Sodani and Bhatnagar (1990), Tu et al. (1991), Ray and Sen (1992), Sakhare et al. (1998), Uzun et al. (2004), Tripathi and Mishra (2005), Misra et al. (2008), Baberjee and Kole (2010), Prajapati et al. (2010) and Gaikwad and Lal (2011).

5.2.14 Number of seeds per capsule

Number of seeds per capsule is one of the yield components and directly affected by characters such as capsule length, number of locules per pod and shattering percentage.

5.2.14.1 Summer 2010 (E₁)

Positive heterosis over parental mean, better parent and standard check recorded up to extent of 27.73%, 22.33% and 23.64% respectively. Significant heterosis showed by three and one hybrids over mid parent and standard check respectively. Hybrids viz., IC-413202 x S-0434, IC-413208 x KMR-116 and IC-413202 x KSM-5-343 were exhibited significant relative heterosis, whereas SI-3218 x S-0434 shown significant standard heterosis. These hybrids were expressed over dominance (P>1) and involved at least one parent with low or medium per se performance.

5.2.14.2 Kharif 2010 (E₂)

In comparison to summer season, lower heterosis was observed. Positive heterosis recorded up to extent of 33.58%, 13.05% and 1.75% over mid parent, better parent and standard check respectively. Five hybrids viz., SI-3218 x Lalguda local, IC-413204 x KMR-116, ES-111-284 x KMR-116, SI-3218 x SI-331517 and IC-413209 x S-0434 were shown high per se performance. Three hybrids were having parents with medium x low and two with medium x medium per se performance.

5.2.14.3 Rabi 2010 (E₃)

Desirable heterosis observed up to extent of 48.93%, 33.06% and 28.27% over parental mean, better parent and standard check respectively;
however significant heterosis was shown by three, one and one hybrid respectively. Three hybrids viz., ES-111-284 x SI-331517, ES-111-284 x S-0434 and IC-413231 x KMR-116 were expressed significant positive relative heterosis. These hybrids were expressed over dominance and contained parents with low x medium \textit{per se} performances for two hybrids and low x low \textit{per se} performances in another.

Three hybrids viz., IC-413231 x KMR-116, IC-413208 x KMR-116 and IC-413202 x S-0434 were exhibited positive relative heterosis over the seasons. These hybrids should be utilized to isolate transgressive segregants in later generations.

Ding \textit{et al.} (1987) observed that heterosis for number of seeds per capsule related to parental values for this character. Osman (1989a) observed that number of seeds per capsule and number of capsule per plant were most important yield contributing characters. Mishra and Yadav (1996) observed heterosis in both direction, while significant heterobeltiosis and standard heterosis for number of seeds per capsule recorded by crosses TC-289 x Phule-1 and JLT-7 x TC-25. Reddy \textit{et al.} (2001) observed significant heterosis over better parents for number seeds per capsule in crosses TKG-64 x E-8 and TC-397 x E-8. Uzun \textit{et al.} (2004) reported absence of heterotic effects for seeds per capsule. Mothilal and Ganesan (2005) found significant relative heterosis for number of seeds per capsule in cross Vinayak x Madhavi. Anuradha and Reddy (2008a) observed the relative heterosis and heterobeltiosis for seeds per capsule (-20.86 to 24.13\%, -23.52 to 16.66\%). Sumathi and Muralidharan (2008) observed good performance for number of seeds per capsule in Paiyur1 x MT 34 along with desirable heterosis for seed yield. Banerjee and Kole (2010) reported the cumulative effect of heterosis for number seeds per capsule on seed yield. Gaikwad and Lal (2011) recorded superior performance in cross GT1 x ES 3 for number of seeds per capsule. Heterosis for number of seeds per capsule also studied by Jadon and Mehrotra (1988), Tu \textit{et al.} (1991), Tripathi and Mishra (2005), Misra \textit{et al.} (2008) and Prajapati \textit{et al.} (2010).
5.2.15 Seed yield per plant (g)

Seed yield per plant is economically important trait and main criteria for selection of variety or hybrid for cultivation. Seed yield per plant is complex trait and affected by yield components viz., plant height, number of branches per plant, days to maturity, number of capsules per plant and 1000 seed weight. Heterosis over >40% considered as significant heterosis, whereas crosses with >60% as heterotic crosses. For seed yield per plant, heterosis over better parent and standard check are more important for plant breeder in comparison to relative heterosis. Hybrids with high heterosis for seed yield per plant could be exploited for commercial cultivation and developing high yielding varieties.

5.2.15.1 Summer 2010 (E₁)

Heterosis for seed yield per plant observed in both positive and negative directions, however positive heterosis revealed up to extent of 84.09%, 65.31% and 193.10% respectively with significant by twenty, nine and twenty eight hybrids over mid parent, better parent and standard check respectively. Two hybrids IC-413202 x KMS-5-873 and SI-3218 x S-0434 were expressed more than 60.00% heterobeltiosis. Nine hybrids viz., ES-111-284 x SI-331517, IC-413231 x SI-331517, IC-413204 x KMS-5-873, IC-413204 x S-0434, IC-413202 x KMS-5-873, SI-3218 x SI-331517, SI-3218 x S-0434 and SI-3218 x Lalguda local were shown significant positive heterosis over mid parent, better parent and standard check. Per se performance of the parents had shown combinations of low x low in four, high x high in three, low x high in one and high x low in one cross. Thus over dominance and dispersion of genes in parents could be responsible for heterosis in these crosses. However, top five hybrids on the basis of per se performance consist of at least one parent with high per se performance.

5.2.15.2 Kharif 2010 (E₂)

Seed yield per plant recorded wide range of heterosis, however positive heterosis observed up to 246.47%, 240.51% and 382.85% and
consists of twenty six, eighteen and thirty six hybrids with significant heterosis over the parental mean, better parent and standard check respectively. Significant positive heterosis over the three bases was revealed by eighteen hybrids. Top five hybrids on the basis of per se performance viz. GSM-22 x Lalguda local, IC-413204 x S-0434, SI-3218 x Lalguda local, IC-413204 x Lalguda local and IC-413209 x Lalguda local were showed significant heterosis over all three bases and involved parents with medium x medium, high x low, high x medium, high x medium and low x medium per se performance respectively. This indicated that at least one parent should have high or medium per se performance for expressing high heterosis. Therefore, over dominance (P>1) and dispersion of genes could be responsible for heterosis in these crosses.

5.2.15.3 Rabi 2010 (E₃)

In rabi season, significant positive heterosis was expressed by eighteen, seven and thirty six hybrids over parental mean, better parent and standard check respectively with extent of 156.12%, 112.84% and 325.18% respectively. Seven hybrids viz., ES-111-284 x KMS-3-343, ES-111-284 x SI-331517, ES-111-284 x KMS-5-873, IC-413231 x Lalguda local, IC-413209 x KMS-5-873, GSM-22 x SI-331517 and GSM-22 x Lalguda local were exhibited significant heterosis over mid parent, better parent and standard check. These hybrids were shown over dominance and parents with per se performance of low x low in 4 hybrids, low x high in 2 hybrids and high x high in one hybrid. Therefore, over dominance and dispersion of genes in parents may be responsible for heterosis.

Sixteen hybrids were shown significant standard heterosis over the seasons, while six hybrids viz., IC-413204 x KMS-5-873, IC-413204 x S-0434, IC-413209 x KMS-5-873, GSM-22 x SI-331517, GSM-22 x KMS-5-873 and GSM-22 x Lalguda local were expressed significant relative heterosis over the seasons. These hybrids could be utilized for isolating high yielding transgressive segregants in later generations of crosses.

Dixit (1976) observed that best hybrid yielded 77.39% more than its
superior parent. Sarafi (1976) observed correlations between yield and plant height and yield and late maturity in the hybrids. Godawat and Gupta (1983) observed heterosis for seed yield in cross RSE1 X JT7 up to extent of 87.42% over the mid parent and 65.46% over better parent. Sharma and Chuhan (1983) observed that heterosis for seed yield attributable to heterosis for capsule number/plant, which was in turn attributable to additive action for numbers of primary and secondary branches. Singh et al. (1986) observed that Til1 X Pb1 showed highest heterosis for yield (327.74%) over the better parent and (108.36%) over the standard variety T12. Capsules/plant contributed most to heterosis for yield. Goyal and Kumar (1988) observed high heterosis for yield and its components. Jadon and Mehrutra (1988) observed the MP and BP heterosis for seed yield ranged from 38.99 to 130.68% and 48.38 to 118.77%, respectively. Tu et al. (1988) investigated for heterosis in yield and found that the F1 hybrids gave an average seed yield/plant of 14.78 g as against 11.33 g for their better parent and 13.13 g for the control. Heterosis ranged from -24.8 to 141.1% over the better parent and from -37.1 to 67.6% over the control. It was noted that in geographically distant hybridization, it is preferable to cross an introduced high-yielding variety not adapted to local conditions with a low-yielding local one to achieve maximum heterosis. Reddy and Haripriya (1990) recorded heterosis for seed yield of 71% and 50% over mid parent (MP) and better parent (BP), respectively for hybrid R 84-4-2 x VS 16. Reddy and Haripriya (1990) observed non-additive gene action for seed yield per plant. Sasikumar and Sardana (1990) observed that heterosis for yield was generally accompanied by heterosis for yield components. The study reveals good scope for commercial exploitation of heterosis as well as isolation of pure lines among the progenies of other heterotic F1. Zhan et al. (1990) studied heterosis for seed yield and yield components; found correlation between yield per plant and capsules per plant; however negative correlation observed between yield per plant and 1000 seed weight. Tu et al. (1991) observed that F1 hybrids from ms2 X Danbackggae,
Danbackggae X Yuzhi 1 and Danbackggae X ms2 displayed highest heterosis; their yields surpassed that of local variety Yuzhi 1 by 155.02, 135.87 and 117.93%, respectively. Ray and Sen (1992) recorded pronounced heterosis for seed yield over better and mid parents. Reddy et al. (1992) observed that mid and better parent heterosis was moderate to high for seed yield/plant. Xiao et al. (1992) concluded that development of strong hybrid vigour through selective mating of parents and selection of cross combination may be of use in sesame breeding programme. Reddy and Haripriya (1993) observed that mid parental (MP) and better parent (BP) heterosis for seed yield ranged from -91.9 to 76.3% and -47.1 to 72.5% respectively. Kumar (1994) revealed positive effect of capsule number on yield potential. Fatteh et al. (1995) found that heterosis in yield was influenced by branches per plant and capsules per plant. The best hybrid TMV3 x HT1 showed 68.94% heterosis over better parent. Quijada and Layrisse (1995) observed that 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, the differences ranging from 28 to 109%. Mishra and Yadav (1996) observed significant positive heterobeltiosis and standard heterosis for seed yield and yield component in crosses TC-289 x Phule-1 and JLT-7 x TC-25. Padmavathi (1998), Ragiba and Reddy (2000) and karuppaiyan et al. (2000) revealed that close association between per se performance of hybrid and heterotic expression suggest that selection of crosses based on per se would be more reliable in sesame. Sakhare et al. (1998) observed that cross Phule Til-1 x IC-41930 exhibited 98.15% increase in seed yield over the check variety. Ganesh et al. (1999) observed 43.94% standard heterosis in cross Si3315/11 x Col for seed yield. Dikshit and Swain (2000) found the range of relative heterosis and heterobeltiosis for seed yield were -36.8% to 83.5% and -42.5% to 66.0%, respectively. Kavitha et al. (2000) observed that cross CMS-T6 X Si 1525 shown high per se performance and maximum heterobeltiosis (40.00%) for seed yield along with oil content. Ragiba and
Reddy (2000) revealed range of mid parent and better parent heterosis for seed yield from -92.26 to 137.81% and -42.37 to 146.98% respectively. Durga and Raghunadhan (2001) observed that hybrids DORS-106 x Gauri (35.25%), DORS-165 x Tapi (39.08%) and DORS-112 x Guari (91.50%) recording high heterosis for seed yield along with yield attributes indicating the cumulative effect of heterosis for individual yield components to the heterosis of seed yield. Dusane et al. (2001) identified Tapi x Yuzhi-7, Tapi x TRS-12 and Tapi x Guj. Til No. 1 as heterotic hybrids and could be exploited for a large scale cultivation in future if they will give stable yields over years and seasons. Reddy et al. (2001) observed significant heterosis over better parent in cross TKG-64 x E-8. Sankar and Kumar (2001) found that combinations TNAU 120 x CO 1 and DCH 25-1 x TMV 6 showed a highly significant relative heterosis, heterobeltiosis and standard heterosis for most of the traits. 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 % standard heterosis, respectively, and can be utilized for hybrid development. Kumaresan and Nadarajan (2003) revealed high per se performance and significant standard heterosis in hybrid OMT 30 x VRI 1 for single plant yield and oil content. Kumar et al. (2004) revealed that crosses TMV 6 x T6 and TMV 3 x T6 showed significant and positive standard heterosis for seed yield per plant and most of the yield component characters. Uzun et al. (2004) recorded highest positive heterosis and heterobeltiosis up to the extent of 500.8 % and 300.9 % by Dur-4-1/5 x Camdibi respectively for seed yield, with range of heterosis from 187.7 to 500.8 %. Tripathi and Mishra (2005) revealed that hybrids TNAU-11 x TC-25, TKG-55 x CO-1 and JLT-7 x TMV-5 were the most superior for exploitation of seed yield and other contributing characters. Mothilal and Ganesan (2005) found that Vinayak x Si 3012 and Padma x Si 97 exhibited significant heterosis over mid parent and better parents for seed yield per plant. The higher estimate of heterosis in these traits may be due to dominance or epistasis or both. Yadav et al. (2005)
studied the standard heterosis for seed and found that 32 among 300 F$_1$ hybrids recorded positive heterosis, while 30 exhibited negative heterosis for seed yield. Two cross combinations viz., JTS-14 x HT-36 (87.50%) and JTS-14 x TC-328 (77.77%) showed a higher magnitude of standard heterosis for seed yield. Thiyagu et al. (2007a) found that heterosis for yield was generally accompanied by heterosis for component traits. The crosses 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 could be used for pedigree breeding method due to additive x additive nature of epistatic gene action. Sumathi and Muralidharan (2008) recorded superior performance for seed yield in crosses TMV 5 x Cordebergea, TMV 3 x KS 990813 and Paiyur 1 x MT 34. Gaikwad et al. (2009) suggested that based on per se performance and standard heterosis for yield and its components, crosses ES 3 x JLT 8, ES 3 x GT1, T 12 x GT 1 and TC 289 x JLT 8 may be used for commercial exploitation of heterosis in sesame. Khan et al. (2009) observed that based on average heterotic effects for mid parents, number of pods plant$^{-1}$ (39.56%) was the main yield component contributing towards heterosis for seed yield plant$^{-1}$ followed by branches plant$^{-1}$ (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 could be considered as elite crosses and could be exploited for isolating high yielding pure lines; parents of these hybrids could be utilized in breeding programme for developing future commercial varieties of sesame. Banerjee and Kole (2010) recorded maximum mid-parent and better-parent heterosis in CST2002 x TKG22 (43.30%) and MT34 x B67 (27.22%) respectively. Parameshwarappa and Salimath (2010) observed highest standard heterosis in cross GM 38-1-2 x E-8 suggested that heterosis and per se performance may be used to select crosses for exploitation of heterosis in sesame. Prajapati et al. (2010) recorded pronounced hybrid vigour for yield and most of the yield components. The hybrid ABT 23 x ABT 26 expressed highest heterobeltiosis for seed yield per plant. Gaikwad and Lal (2011)
observed that JLT 8 x ES 3 recorded highest relative heterosis (38.85%), heterobeltiosis (20.57%) and standard heterosis (54.05%) for seed yield per plant. Praveen Kumar et al. (2012) recorded highest magnitude of heterosis in cross (Mutant 9 x Mutant 699) 45.2% over CC1 and 108.77% over CC2, (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 these hybrids have been identified as best hybrids from productivity point of view. Heterosis for seed yield was also studied by Kar and Swain (2001) and Misra et al. (2008).

5.2.16 1000 seed weight (g)

One thousand seed weight is one of the major yield contributing character. Generally bold seeded varieties tend to have more test weight; in current study it was observed that genotypes with black or brown seed color recorded low test weight.

5.2.16.1 Summer 2010 (E₁)

Heterosis for 1000 seed weight observed in both directions, however positive heterosis was recorded up to extent of 36.69%, 28.38% and 36.20% over mid parent, better parent and standard check respectively and consists of six, two and two hybrids with significant heterosis. Two hybrids SI-3218 x SI-331517 and GSM-22 x SI-331517 were exhibited significant positive relative heterosis, heterobeltiosis and standard heterosis. These hybrids expressed over dominance (P>1) and consist of parents with low x high per se performance. Thus over dominance and dispersion of genes may be the reasons for heterosis in these crosses.

5.2.16.2 Kharif 2010 (E₂)

In kharif season, extent of positive heterosis observed up to 13.86%, 8.15% and 3.00% over parental mean, better parent and standard check respectively. Two hybrids GSM-22 x Lalguda local (13.86%) and IC-413202 x KMS-5-873 (9.94%) were recorded significant heterosis over mid. These hybrids shown over dominance (P>1) and consisting of parents with low x low and low x high per se performance respectively. Over
dominance and dispersion of genes may be responsible for heterosis in these crosses.

5.2.16.3 Rabi 2010 (E₃)

Desirable heterosis over mid parent and better parent observed up to extent of 16.58% and 10.89% respectively. Two hybrids IC-413202 x SI-331517 (10.89%) and SI-3218 x S-0434 (10.03%) were shown significant heterobeltiosis, and showed over dominance (P>1) and consisting of parents with high x medium and medium x high per se performance. It indicates that at least one parents with high per se performance should be involved in cross combinations.

Srivastava and Prakash (1977) observed highest heterosis for 1000 seeds weight in F₁ 78/67 x Nagpur 128. Ding et al. (1987) found that heterosis for 1000 seed weight related to parental values for this character and its one of the character could be used in early selection for high yield. Tu et al. (1991) recorded significant standard heterosis for 1000 seed weight. Ray and Sen (1992) observed pronounced heterosis over better parent and mid parent for 1000 seed weight. Reddy et al. (2001) recorded significant better parent heterosis for test weight. Santha et al. (2001) observed high heterosis for1000 seed weight. Uzun et al. (2004) reported absence of heterotic effects for 1000 seed weight. Mothilal and Ganesan (2005) revealed significant mid parent heterosis for 1000 seed weight in cross Vinayak and Madhavi; the high estimates of heterosis may be due to dominance or epistasis or both. Misra et al. (2008) recorded minimum heterosis for 1000 seed weight in comparison to seed yield, capsules per plant and branches per plant. Baberjee and Kole (2010) observed that heterosis for 1000 seeds weight affects cumulatively heterosis for seed yield. Heterosis for 1000 seed weight was also observed by Jadon and Mehrotra (1988) and Tripathi and Mishra (2005).

5.2.17 Oil content (%)

Oil content is the important quality trait in sesame. Improvements of oil content along with seed yield per plant are major objective trait in
sesame breeding. In present study it was found that varieties and hybrids with black and brown seed color were having low oil content in comparison to white seeded varieties and hybrids.

5.2.17.1 Summer 2010 (E₁)

Heterosis observed in both directions. Extent of positive heterosis was 4.02%, 2.50% and 2.50% over mid parent, better parent and standard check and sixteen, nine and fifteen hybrids were exhibited non-significant positive heterosis respectively. Five hybrids on basis of per se performance viz., IC-413231 x KMS-5-34, IC-413204 x SI-331517, ES-111-284 x KMR-116, ES-111-284 x KMS-5-343 and IC-413231 x SI-331517 were expressed over dominance (P>1) and consist of parents with high x high per se performance.

5.2.17.2 Kharif 2010 (E₂)

In kharif season, none of the hybrids recorded significant positive heterosis and the extent of positive heterosis is very low as 6.74%, 6.22% and 4.37% respectively over mid parent, better parent and standard check. The top five hybrids on the basis of per se performance viz., IC-413208 x KMS-5-873, IC-413204 x KMS-5-343, ES-111-284 x KMS-5-343, IC-413202 x KMS-5-873 and IC-413202 x SI-331517 were consist of parent with high x high per se performance.

5.2.17.3 Rabi 2010 (E₃)

In rabi season also, none of the hybrid recorded significant heterosis and most of the hybrids revealed negative heterosis. Maximum positive heterosis observed up to extent of 4.02% and 1.38% over parental mean and better parent. Thirty six hybrids showed recessive overdominance.

Generally, crosses between parents with high per se performance resulted in negative significant heterosis, this may be due to association of genes in parents, and dominance and epistatic gene interaction may be acted in opposite directions. Hybrids with significantly high heterobeltiosis for seed yield per plant and black or brown colored seeds were recorded low oil content.
Singh et al. (1986) observed high heterotic values for oil content, however Osman (1989a) and Reddy and Haripriya (1993) revealed insignificant heterotic effects for oil content. Reddy et al. (1992) observed that mid and better parent heterosis was either low or negative for oil content. Alam et al. (1999) revealed that crosses, B9 x B14 and B67 x TSS6 expressed significantly positive heterobeltiosis for percentage oil content. Kavitha et al. (2000) revealed high per se performance in cross CMS-T3 x SVPR 1 for oil content, while cross CMS-T6 x Si 1525 recorded significant positive heterobeltiosis up to maximum 40.00 %. Durga and Raghunadhan (2001) found low to moderate heterotic effects for oil content, however oil yield per plant recorded maximum heterosis. Reddy et al. (2001) observed significant heterobeltiosis for oil content. Kumaresan and Nadarajan (2003) observed high per se performance and standard heterosis for oil content along with single plant yield. Sumathi and Muralidharan (2008) observed superior performance for oil content in cross Paiyur 1 x MT 34. Banerjee and Kole (2011) exhibited highest positive heterosis for oil yield plant -1 over mid-parent (43.6%) and better parent (28.4%) in hybrid CST2002 x MT34, whereas MT34 x B67, TKG22 x 'Rama', MT34 x 'Rama' and CST2002 x TKG22 were recorded high, positive and significant heterosis for oil yield plant -1, over both mid parent and better parent.

Hybrids viz., GSM-22 x SI-331517, SI-3218 x Lalguda local, SI-3218 x S-0434, SI-3218 x SI-331517, IC-413202 x S-0434, IC-413204 x S-0434 recorded heterosis for seed yield per plant along with major yield components during summer season (E₁). Hybrids viz., GSM-22 x KMS-5-873, GSM-22 x SI-331517, IC-413204 x KMR-116, IC-413204 x Lalguda local and IC-413204 x S-0434 were revealed desirable heterosis for seed yield and major yield components during kharif season (E₂). Hybrids viz., GSM-22 x Lalguda local, IC-413209 x KMS-5-873, IC-413231 x Lalguda local, ES-111-284 x KMS-5-873 and ES-111-284 x SI-331517 were recorded desirable heterosis for seed yield per plant along with other major yield attributes during rabi season (E₃).
These heterotic hybrids should be utilized for developing high yielding varieties and hybrids. Population improvement method such as recurrent selection which allows intermating between selected individuals in early segregating generations and delaying selection in later generations, when dominance and epistatic gene action disappear and desirable genes accumulated in homozygous conditions. Similar results for heterosis for seed yield and yield components were reported by Mishra and Yadav (1996), Kar and Swain (2001), Reddy et al., (2001), Kar et al. (2002), Senthil kumar et al. (2003), Kumar et al. (2004), Mothilal and Ganesan (2005), Thiyagu et al., (2007a) and Prajapati et al. (2010).

5.3 COMBINING ABILITY

5.3.1 Analysis of variances for combining ability

Analysis of variances for combining ability provide information about the variability in crosses, lines, testers and interaction between line and testers. The estimates of variances due to general combining ability and specific combining ability revealed nature of non-allelic gene interaction and the appropriate breeding methods to be adopted for genetic improvement of quantitative traits.

5.3.1.1 Summer 2010 (E₁)

Significant differences among the crosses indicates presence variability among the crosses for all the characters except earliness to flowering, days to maturity, number of seeds per capsule and 1000 seed weight. Lines were have more diversity than testers for all traits except capsule bearing plant height, internode distance, number of nodes on main stem, number of capsule on main stem, number of seeds per capsule, 1000 seed weight and oil content indicates dispersion of genes in parents for quantitative traits. The significance of variances due to line x tester interaction revealed the specific combining ability for all the traits except days to flower initiation, days to maturity, internode distance, capsule length, number of seeds per capsule and 1000 seeds weight.

5.3.1.2 Kharif 2010 (E₂)
All characters except earliness in flowering and maturity were revealed significant differences among the crosses. Testers were have more diversity than lines for the characters viz., capsule length, number of capsules per plant, number of seeds per capsule, seed yield per plant, 1000 seed weight and oil content. These differences between lines and testers may result into heterosis in specific cross combinations when dispersed genes complement in positive directions. Variances due to line x tester interaction were significant for all the characters except earliness to flowering, maturity, capsule length and number of seeds per capsule, indicates high specific combining ability.

5.3.1.3 Rabi 2010 (E₃)

In rabi season also earliness to flowering and maturity expressed insufficient variability in crosses. Lines were having more diversity than testers for all the characters except capsule bearing plant height, number of primary branches, number of capsules on main stem, number of capsules per plant, seed yield per plant, 1000 seed weight and oil content, for which testers were having more diversity. These differences in diversity among lines and testers for different quantitative traits may be resulted into dispersion of genes in parents.

Kar et al. (2001) Observed significant differences in variances due to lines, testers, hybrids and line x testers for all the traits, except height up to first capsule, for which mean square due to testers was non-significant. Mishra and Sikarwar (2001) revealed that lines and their interaction were significant for all the above characters studied. Solanki and Gupta (2001a) observed that variance due to male were greater than those due to female for all the characters except for capsule per plant indicating greater diversity in male than in females. The variances due to line x tester interaction were significant for all the characters, thereby showing there high specific combining ability. Santha et al. (2001) revealed significant difference among the lines for all the traits. The interaction between the lines and the testers differed significantly for all the traits examined. Thirugnana
Thirugnana Kumar et al. (2005) observed that the variance due to female were significant for eight out of ten characters studied, indicating greater diversity in females than males. The variance due to line x tester interaction was significant for nine out of ten traits studied, thereby showing high specific combining ability. Thiyagu et al. (2007b) revealed significant differences among parents and crosses for all the traits studied. Raghunaiah et al. (2008) indicated significant differences among the lines for all the traits except grain yield, whereas testers showed significant differences for all traits except capsule length and oil content. The interaction between lines and testers were significant for all the yield components indicating existence of wide variability in the material under study.

5.3.2. General and specific combining ability studies

The capacity or ability of an inbred line to transmit superior performance to its progeny or crosses is referred as combining ability; it helps in the selection of suitable good general combiner parents for hybridization through the estimation of general combining ability (gca) effects, and identification of superior cross combinations for commercial exploitation of heterosis through estimation of specific combining ability (sca) effects. The gca is considered as the intrinsic genetic value of the parent for trait which is due to additive genetic effects and is fixable. The estimates of sca represent dominance and epistatic gene action. Combining ability analysis also provides information about gene action involved in the expression of quantitative character and breeding procedures to be followed for genetic improvement of trait. Data on per se performance of parental lines is given in appendix-II for studies of general combining ability in relation to per se performance.

5.3.2.1 Days to flower initiation

5.3.2.1.1 summer 2010 (E₁)

In summer season all lines shown negative gca effects except two lines, and high negative gca effects shown by IC-413202 (-1.67), followed by IC-413208 and IC-413204 (-1.33), whereas three testers viz. KMR-116
(−1.38), KMS-5-873 (−1.12) and SI-331517 (−0.25) shown non-significant negative gca effects. Two lines GSM-22 and SI-3218 were expressed significant positive gca effects. These parents are good combiners for earliness to flower initiation and having high per se performance. Highest sca effects was exhibited by GSM-22 x KMR-116 (−3.46), followed by SI-3218 x SI-331517 (−2.75) and SI-3218 x KMS-5-873 (−1.88). These hybrids were shown high per se performance, high relative heterosis and consist of parents with low x medium gca effects. Both additive and non-additive gene actions were important for earliness in these hybrids.

5.3.2.1.2 Kharif 2010 (E2)

Nine parents were shown non-significant negative gca effects. Line IC-413209 (−1.49) exhibited highest negative gca effects, followed by IC-413208 (−1.38) and IC-413204 (−1.16), whereas GSM-22 (2.56) and SI-3218 (2.45) expressed significant positive gca effects. Three testers KSM-5-343 (−0.77), KMR-116 (−0.65) and Lalguda local (−0.56) were good combiners for days to flower initiation, whereas S-0434 (1.31), SI-331517 (0.35) and KMS-5-873 were shown positive gca effects. Hybrid ES-111-284 x Lalguda local (−4.66), SI-3218 x KMS-5-873 (−4.53) and IC-413208 x KSM-5-343 (−4.28) were good combiners and revealed high sca effects. These hybrids involve parents with medium x medium, low x medium and medium x medium gca effects, indicating that at least one parents should have medium gca effects. Thus additive x additive and non-additive x additive gene action might be responsible for high sca effects.

5.3.2.1.3 Rabi 2010 (E3)

Combining ability study reveled that IC-413209 (−1.96), SI-3218 (−1.79) and IC-413202(−0.96), SI-331517 (−0.92), KMR-116 (−0.67) and Lalguda local (−0.29) were good combiners for earliness to flowering. Hybrids ES-111-284 x KMR-116 (−3.83), IC-413204 x KSM-5-343 (−3.79), SI-3218 x S-0434 (−3.71) and IC-413208 x KMS-5-873 (−3.71) were shown high sca effects. These hybrids were involve parents with low x medium,
low x low, medium x low and low x low \( gca \) effects, indicates the involvement of non-additive gene action in expressing high \( sca \) effects.

Three parents IC-413209, IC-413202 and KMR-116 were good combiners over the season. Six hybrid \( \text{viz.} \), IC-413231 x KMS-5-873, IC-413202 x KMS-5-343, GSM-22 x SI-331517, GSM-22 x KMR-116, SI-3218 x KMS-5-343 and SI-3218 x SI-331517 were specifically good combiners over the seasons.

Solanki and Gupta (2001b) found that variety RT-127 was good combiner for all the characters except early flowering.

**5.3.2.2 Days to 50 percent flowering**

**5.3.2.2.1 Summer 2010 (E\(_1\))**

Five parents \( \text{viz.} \), IC-413202 (-2.92), IC-413209 (-2.58), KMR-116 (-1.54), SI-331517 (-1.29) and S-0434 (-0.29) were good combiners for earliness for days to 50 percent flowering and exhibited high \( \text{per se} \) performance. Hybrid SI-3218 x KSM-5-343 (-6.29) was shown high significant \( sca \) effects and high heterosis, however not expressed high \( \text{per se} \) performance. This hybrids involved parents with low x low \( gca \) effects, indicates the role of dominance x dominance epistatic gene action.

**5.3.2.2.2 Kharif 2010 (E\(_2\))**

Parents \( \text{viz.} \), IC-413209 (-2.63), IC-413204 (-2.54), KSM-5-343 (-1.78), KMR-116 (-1.09) and SI-331517 (-0.13) with high \( \text{per se} \) performance were good combiners for days to 50 percent flowering. Good specific combining ability were shown by SI-3218 x KMS-5-873 (-4.98), GSM-22 x SI-331517 (-4.04) and IC-413209 x S-0434 (-3.83). These hybrids involved parents with low x low, low x medium and high x low \( gca \) effects, and indicates the importance of non-additive gene action.

**5.3.2.2.3 Rabi 2010 (E\(_3\))**

Four parents \( \text{viz.} \), IC-413209 (-4.15), IC-413231 (-2.15), SI-331517 (-1.69) and KMS-5-873 (-0.44) were good combiner for earliness to 50 percent flowering. Hybrids GSM-22 x KSM-5-343 (-4.73), ES-111-284 x KMR-116 (-4.44) and IC-413204 x Lalguda local (-4.31) were shown high
relative heterosis and high per se performance. These hybrids involved at least one parent with low gca effects, indicates the role of non-additive gene action.

Six parents viz., IC-413209, IC-413202, IC-413204, ES-111-284, IC-413231 and SI-331517 were shown good combining ability over the season. Eight hybrids viz., ES-111-284 x S-0434, IC-413231 x S-0434, IC-413208 x KMS-5-873, IC-413208 x S-0434, GSM-22 x KMS-5-343, GSM-22 x KMR-116, GSM-22 x Lalguda local and SI-3218 x SI-331517 were good specific combiner over the seasons.

Solanki and Gupta (2001b) observed that variety RT-127 was good combiner for all the characters was bad combiner for early flowering. Krishnaiah et al. (2003) found that Madhavi was good general combiner for days to 50 percent flowering along with primary branches and capsules on main stem. Sumathi and Muralidharan (2008) found that TMV 3 was having high gca effects for days to 50 percent flowering. Praveen Kumar et al. (2012) observed highest sca effects for days to 50 percent flowering in Mutant 224 x Mutant 274.

5.3.2.3 Days to maturity

5.3.2.3.1 Summer 2010 (E₁)

For early maturity, four parents viz., IC-413202 (-4.69), KSM-5-343 (-1.73), KMR-116 (-1.35) and S-0434 (-1.35) were shown positive gca effects. Top five hybrids with high per se performance were involved parents with high x low, medium x low gca effects and involved at least one parents with low gca effects. Hybrids IC-413204 x KMR-116 (-4.98), IC-413209 x S-0434 (-3.81) and IC-413231 x KMS-5-873 (-3.77) were registered high sca effects and contained at least one good combiner parent, and expressed additive x additive and additive x non-additive type of gene action.

5.3.2.3.2 Kharif 2010 (E₂)

Eight parents viz., IC-413209 (-3.12), IC-413208 (-2.23), IC-413204 (-2.01), IC-413202 (-1.93), S-0434 (-1.47), SI-331517 (-1.20), KMS-5-343
(-0.84) and Lalguda local (-0.42) were good combiners. Top five hybrids with high per se performance were exhibited parents mostly with high x low, medium x low and low x low gca effects, and involved at least one parent with low gca effects. Hybrid IC-413204 x SI-331517 (-5.97) shown highest specific combining ability and parents with medium x medium gca effects, and simple pedigree method should be followed to select recombinants in early segregating generations.

5.3.2.3.3 Rabi 2010 (E₃)

Top five hybrids with high per se performance were involving parents mostly with medium x medium gca effects, indicating the importance of additive x additive gene interactions for earliness. Parents viz., ES-111-284 (-5.31), IC-413231 (-2.48), IC-413202 (-1.81), IC-413209 (-1.65) and IC-413204 (-0.81), KSM-5-343 (-2.35) and KMS-5-873 (-0.23) were good combiners for earliness in maturity. Hybrids IC-413231 x KSM-5-343 (-8.15), IC-413209 x KSM-5-343(-6.98), GSM-22 x KSM-5-343 and ES-111-284 x S-0434 (-6.81) were good combiners for earliness with high per se performance and contain at least one parent with good gca effects.

Four parents viz., IC-413202, IC-413204, IC-413209 and KSM-5-343 were good combiners for earliness over the seasons and should be utilized for developing early maturing varieties. Six hybrids viz., IC-413208 x Lalguda local, IC-413209 x KMS-5-343, IC-413202 x KMS-5-873, GSM-22 x KMS-5-343, GSM-22 x Lalguda local and SI-3218 x KMS-5-873 were shown good specific combining ability for early maturity.

Murty (1975) observed good general combining ability for earliness and oil content in SI1783 and Sel-R. Bukheit and Mahdy (1987) recorded significant gca effects, however non-significant sca effects for days to maturity. Saravanan et al. (2000) identified Si125 as good combiner for all the traits including earliness, whereas cross Si 1125 x Si 250 seemed to be good combiner for all earliness related traits; also noted that superior cross combinations involved at least one good general combining parent. Durga and Raghunadhan (2001) revealed that DORS-102 was good combiner for
earliness and dwarfness, whereas Tapi was good combiner for earliness along with seed yield. Solanki and Gupta (2001b) found that variety ES-123-1-84 was good combiner for early maturity. Solanki and Gupta (2001a) observed that genotype IS-186-1 was best combiner for early maturity and capsules per plant. Sumathi and Muralidharan (2008) revealed the good combining ability of line TMV 3 for early maturity along with days to 50 percent flowering, seed yield and yield components. Praveen Kumar *et al.* (2012) observed highest *sca* effects for early maturity in Mutant 450 x Mutant 699.

5.3.2.4 Plant height (cm)

5.3.2.4.1 Summer 2010 (*E₁*)

Four parents *viz.*, GSM-22 (9.16), SI-3218 (8.39), SI-331517 (5.36) and S-0434 (5.19) were good combiners for increasing plant height, whereas IC-413209 (-8.63), SI-331517 (5.36) and S-0434 (5.19) were good combiners for reducing plant height. Hybrids GSM-22 x KMS-5-873 (13.75), IC-413208 x KMR-116 (11.70) and IC-413204 x S-0434 (11.58) were exhibited high *sca* effects, high *per se* performance and high relative heterosis. These hybrids had parents with high x high, low x low, medium x high *gca* effects, indicates additive x additive, non-additive x non-additive and additive x additive type of gene action.

5.3.2.4.2 Kharif 2010(*E₂*)

Parents *viz.*, IC-413204 (12.76), IC-413231 (8.85), Lalguda local (4.21) and KMS-5-873 (3.42) were good combiners for increasing plant height. Top five hybrids on the basis of *per se* performances were consist of at least one parent with high or medium *gca* effects. Hybrids GSM-22 x SI-331517 (21.37), ES-111-284 x KMS-5-873 (15.29) and IC-413202 x KMR-116 (14.93) were shown high *sca* effects, high *per se* performance and high relative heterosis. These hybrids had parents with low x medium, medium x medium and low x low *gca* effects, indicating the importance of both additive and non-additive gene action. Transgressive segregants should be selected in later segregating generations when dominance and epistatic gene
interaction disappears.

5.3.2.4.3 Rabi 2010 (E₃)

Parents GSM-22 (12.10) and IC-413231 (6.31) and Lalguda local (8.60) were good combiners for increasing plant height, whereas ES-111-284 (-6.32), SI-3218 (-5.81) and KMS-5-873 (-4.80) should be utilized for reducing the plant height. Top five hybrids on basis of per se performance consist of at least one parent with high gca effects. Twenty hybrids were shown positive sca effects, however GSM-22 x KMR-116 (39.97), SI-3218 x Lalguda local (18.17) and IC-413204 x KSM-5-343 (13.32) were expressed high sca effects. These hybrids involved parents with high x medium, low x high and medium x low gca effects. Improvement in selection could be achieved through bi parental mating design as it will break the linkage and accumulate the favourable genes in homozygous condition.

Parent IC-413204 was shown positive gca effects over the season. Two hybrids ES-111-284 x KMS-5-343 and IC-413202 x KMS-5-873 were exhibited positive sca effects over the seasons.

Durga and Raghunadhan (2001) found that DORS-102 was good combiner for earliness and dwarfness. Krishnaiah et al. (2003) observed good combining ability for plant height and harvest index in NSI-4. Shakhess and Khalifa (2007) found that Toshkal and MGS11-47 were best general combiners for plant height along with yield and yield components. Sumathi and Muralidharan (2008) identified TMV 3 as good general combiner for plant height along with early maturity. Praveen Kumar et al. (2012) observed highest sca effects for plant height in Mutant 274 x Mutant 699.

5.3.2.5 Plant height for first capsule (cm)

5.3.2.5.1 Summer 2010 (E₁)

Reducing the plant height for first capsule, seven parents viz., IC-413209 (-3.64), IC-413202 (-3.13), IC-413208 (-2.69), IC-413204 (-2.63), IC-413231 (-2.53), KMR-116 (-1.69) and KMS-5-873 (-1.03) were good
combiners with high \textit{per se} performance. Eleven hybrids were shown significant \textit{sca} effects and were good combiners, however SI-3218 x KMS-5-873 (-10.62) shown highest, followed by GSM-22 x KMR-116 (-6.89) and GSM-22 x Lalguda local (-5.02). These hybrids had parents with low x high, low x high and low x medium \textit{gca} effects, indicating that at least one parent should have high or medium \textit{gca} effects. Selection should be delayed in later segregating generations when dominance and epistatic gene actions disappear.

5.3.2.5.2 Kharif 2010 (E$_2$)

There was good agreement between \textit{per se} performance and \textit{gca} effects, and five parents \textit{viz.}, IC-413202 (-8.89), IC-413208 (-6.60) and IC-413209 (-3.93), KMR-116 (-4.19) and KSM-5-343 (-4.18) were good combiners. Seven hybrids registered significant \textit{sca} effects, including ES-111-284 x KMR-116 (-9.22), IC-413231 x KMR-116 (-7.20) and GSM-22 x KMS-5-873 (-7.13). Parents involved in these crosses were have low x high, low x high, low x low \textit{gca} effects, indicates the importance of non-additive gene action.

5.3.2.5.3 Rabi 2010 (E$_3$)

Negative \textit{gca} effects recorded by nine parents, and IC-413209 (-3.22), IC-413231 (-2.69), IC-413202 (-2.18) and Lalguda local (-1.85) with significant effects were good combiners. Hybrids with high \textit{per se} performance were having high \textit{sca} effects and high relative heterosis; therefore hybrids could be selected on the basis of \textit{sca} effects. Highest \textit{sca} effect shown by GSM-22 x S-0434 (-8.80) followed by GSM-22 x Lalguda local (-8.72) and IC-413208 x KMR-116 (-8.51) and involved parents with low x medium, low x high, medium x low \textit{gca} effects respectively, indicates that at least one parent should have high or medium \textit{gca} effects.

Parents IC-413209, IC-413202, IC-413208 and IC-413204 were good combiners over the seasons. Five hybrids \textit{viz.}, IC-413231 x KMS-5-873, IC-413231 x Lalguda, IC-413209 x KMS-5-343 and IC-413209 x S-0434 and IC-413209 x SI-331517 were expressed negative \textit{sca} effects over
the season; these hybrids should be utilized for isolating transgressive segregants in later segregating generations.

5.3.2.6 Capsule bearing plant height (cm)

5.3.2.6.1 summer 2010 (E₁)

Top five hybrids on the basis of per se performances consist of parents with mostly high x high or medium x high gca effects. Parents IC-413204 (4.84), IC-413202 (1.56), SI-331517 (6.34) and S-0434 (3.57) were good combiners for increasing capsule bearing plant height; however there was no agreement between per se performance and combining ability. Highest sca effects shown by IC-413202 x S-0434 (10.96) followed by ES-111-284 x KMR-116 (9.86) and GSM-22 x KMS-5-873 (9.70). These hybrids had parents with medium x high, low x low, low x low gca effects, indicates that its not always necessary to attempt crosses between parents with high gca effects. Bi-parental mating design should be utilized for improvement in these crosses, as it will break the undesirable linkages and release the hidden variability.

5.3.2.6.2 Kharif 2010 (E₂)

Parents IC-413204 (12.92), IC-413208 (5.46), SI-331517 (3.71) and KMR-116 (2.04) were good combiners for increasing capsule bearing plant height. Hybrids IC-413204 x S-0434 (16.72), IC-413231 x KMR-116 (14.52) and ES-111-284 x KSM-5-343 (13.66) were exhibited high sca effects. There was good agreement between high per se performance, sca effects and high relative heterosis, therefore sca effects could be considered as index for selecting hybrids. These hybrids had parents with high x low, medium x medium and low x low gca effects, indicating the importance of both additive and non-additive gene action.

5.3.2.6.3 Rabi 2010 (E₃)

There was no agreement between per se performance and gca effects of parents, therefore parents should be selected on the basis of gca effects. Parent IC-413231 (10.65), GSM-22 (1.27) and ES-111-284 (0.14) and Lalguda local (10.21) were good combiners. Hybrid GSM-22 x KMR-116
(15.39) shown highest $sca$ effects, followed by SI-3218 x Lalguarda local (14.52) and IC-413209 x KMS-5-873 (13.84). These hybrids were consist of parents with medium x low, low x high and low x low $gca$ effects; therefore selection of transgressive segregants should be delayed in later generations when dominance and epistatic gene action disappear.

Parent IC-413231 showed positive $gca$ effects over the season. Four hybrid *viz.*, IC-413209 x KMS-5-873, GSM-22 x SI-331517, SI-3218 x Lalguarda local and IC-413202 x KMS-5-873 were expressed positive $sca$ effects over the seasons and should be utilized for isolating transgressive segregants in later generations of crosses.

Solanki and Gupta (2001b) observed that EC-351819 was good combiner for capsule bearing plant height along with plant height. Kar *et al.* (2002) observed similar results for correlation between parental mean and $gca$ effects.

**5.3.2.7 Number of primary branches**

**5.3.2.7.1 summer 2010 ($E_1$)**

Six parents were shown positive $gca$ effects, and GSM-22 (0.89) and S-0434 (0.20) were good combiners. There was no agreement between *per se* performance and $gca$ effects. Hybrid GSM-22 x S-0434 (1.93), SI-3218 x Lalguarda local (1.43) and IC-413208 x KMR-116 (1.20) were good combiners with high *per se* and relative heterosis. These hybrids had parents with high x high, medium x medium and low x low $gca$ effects, therefore both additive x additive and non-additive x non-additive gene interaction involved in these hybrids.

**5.3.2.7.2 Kharif 2010 ($E_2$)**

Parents IC-413204 (0.52), SI-3218 (0.50), IC-413231 (0.46) and GSM-22 (0.36), S-0434 (0.71) and Lalguarda local (0.40) were good combiners with high *per se* performance. Top five hybrids on basis of *per se* performance were mostly shown high x high $gca$ effects, indicating additive x additive epistatic gene interactions. Hybrids SI-3218 x Lalguarda local (1.94), IC-413204 x S-0434 (1.88) and GSM-22 x KMS-5-873 (1.72)
were exhibited high *sca* effects, high *per se* performance and high relative heterosis. Simple pedigree method should be followed for selecting transgressive segregants.

5.3.2.7.3 *Rabi 2010 (E₃)*

Three parents *viz.*, GSM-22 (0.32), SI-3218 (0.24) and S-0434 (0.47) were good combiners. Eight hybrids were good combiners and IC-413204 x S-0434 (0.83) shown highest *sca* effects, followed by ES-111-284 x SI-331517 (0.71) and SI-3218 x Lalguda local (0.70). There was good agreement between high *per se* performance, *sca* effects and relative heterosis; therefore selection should be based on *sca* effects. Parents involved in these hybrids expressed medium x high, medium x medium and high x low *gca* effects with at least one parents with high or medium *gca* effects.

Parents GSM-22, S-0434 and SI-3218 were good combiners over the seasons. Hybrid SI-3218 x Lalguda local had shown significant positive *sca* effects over the seasons. These hybrids may be utilized for isolating transgressive segregants in later segregating generations.

Bakheit and Mahdy (1987) observed significant general combining ability effects for all traits including number of primary branches; however specific combining ability effects were non-significant for number of branches. Krishnaiah *et al.* (2003) observed that Madhavi was good general combiner for primary branches along with earliness to flowering and capsules on main stem. Shakhess and Khalifa (2007) revealed MGS36-2 as good general combiner for branches per plant.

5.3.2.8 *Internode distance (cm)*

5.3.2.8.1 *Summer 2010 (E₁)*

Negative *gca* effects registered by six parents *viz.*, GSM-22 (-0.14), IC-413204 (-0.12), ES-111-284 (-0.12), Lalguda local (-0.22), S-0434 (-0.09) and SI-331517 (-0.08). Hybrids IC-413204 x KMS-5-873 (-0.45), IC-413209 x KMS-5-873 (-0.34) and GSM-22 x KMR-116 (-0.31) were revealed high *sca* effects. Ranks of hybrids on the basis of *per se*
performance, relative heterosis and \textit{sca} effects were not same, therefore hybrids should be selected on the basis of heterosis estimates. These hybrids had parents with medium x low, low x low and medium x low \textit{gca} effects, indicating the importance of non-additive gene action in these crosses.

\textbf{5.3.2.8.2 Kharif 2010 (E\textsubscript{2})}

Most of the parents were shown negative \textit{gca} effects. Top five crosses on the basis of \textit{per se} performance mostly consist of parents with high x medium or medium x low \textit{gca} effects. Hybrids IC-413209 x KMR-116 (-0.40) and IC-413204 x KMR-116 (-0.37) were good combiners for internode distance. These hybrids expressed high relative heterosis and involved parents with low x low and medium x low \textit{gca} effects, indicating non-additive x non-additive and additive x non-additive type of gene interaction. Recurrent selection could be utilized for isolating superior segregants in later generations.

\textbf{5.3.2.8.3 Rabi 2010 (E\textsubscript{3})}

Eight parents exhibited negative \textit{gca} effects, and IC-413209 (-0.34), IC-413202 (-0.15) and SI-331517 (-0.17) were significant. Hybrid IC-413231 x KSM-5-343 (-0.49), IC-413202 x KMR-116 (-0.42) and IC-413208 x S-0434 (-0.41) were good combiners and involved parents with low x medium, high x low and low x low \textit{gca} effects. Non-additive gene interaction involved in these crosses.

Parents IC-413204, GSM-22, SI-331517 and Lalguda local recorded negative \textit{gca} effects over the seasons. Six hybrids \textit{viz.}, ES-111-284 x SI-331517, IC-413231 x KMS-5-343, IC-413204 x S-0434, IC-413202 x KMR-116, SI-3218 x KMS-5-873 and SI-3218 x Lalguda local were shown negative \textit{sca} effects over the seasons. These crosses may be utilized for isolating transgressive segregants in later generations when dominance and epistatic gene action disappear.

\textbf{5.3.2.9 Capsule length (cm)}

\textbf{5.3.2.9.1 Summer 2010 (E\textsubscript{1})}
Parents GSM-22 (0.17) and SI-331517 (0.15) were shown significantly positive gca effects, however top five hybrids on basis of per se performance were mostly consist of parents with medium x medium or medium x low gca effects. Hybrid GSM-22 x S-0434 (0.59) was good combiner and involved parents with high x medium gca effects, indicating the additive x additive epistatic gene action. Improvement through selection could be achieved following simple pedigree method and delaying the selection to later generations.

5.3.2.9.2 Kharif 2010 (E<sub>2</sub>)

Two parents IC-413204 (0.06) and KSM-5-343 (0.12) were good combiners for increasing the capsule length. Hybrid IC-413208 x KMS-5-873 (0.35) exhibited significant positive sca effects, followed by IC-413204 x S-0434 (0.26) and IC-413204 x KSM-5-343 (0.21). These hybrids expressed high mean, high heterosis along with high sca effects, and consist of medium x medium, medium x low and medium x high gca effects of parents. These hybrids involved at least one parent with medium or high gca effects.

5.3.2.9.3 Rabi 2010 (E<sub>3</sub>)

Parents ES-111-284 (0.25), IC-413208 (0.10), IC-413208 (0.08) and SI-3218 (0.01), KMR-116 (0.10), SI-331517 (0.08) and S-0434 (0.03) were shown positive gca effects. Hybrids ES-111-284 x SI-331517 (0.69), GSM-22 x SI-331517 (0.51), SI-3218 x KSM-5-343 (0.48) and IC-413204 x KMS-5-873 (0.42) were good combiners. These hybrids with high mean and relative heterosis consist of parents with high x medium, low x medium, medium x low and low x low gca effects respectively. Breeding methods like bi-parental mating and diallel selective mating should be utilized for isolating transgressive segregants in later generations of crosses.

Parent SI-331517 had showed positive gca effects over the season. Seven hybrids viz., IC-413231 x KMR-116, IC-413208 x KMS-5-343, IC-413208 x KMS-5-873, IC-413204 x Lalguda local, IC-413209 x KMR-116, IC-413202 x Lalguda local and GSM-22 x SI-331517 recorded positive sca
effects over the seasons. These hybrids could be utilized for isolating transgressive segregants in later segregating generations.

Krishnaiah et al. (2003) found that Rajeshwari was good general combiner for capsule length. Shakhess and Khalifa (2007) observed that Toshkal and MGS11-47 were best general combiners for capsule length. Gaikwad et al. (2009) revealed the major contribution of additive gene action for all the traits except length of capsule. Praveen Kumar et al. (2012) observed highest $sca$ effects for capsule length in Mutant 40 x Mutant 181.

5.3.2.10 Number of nodes on main stem

5.3.2.10.1 Summer 2010 ($E_1$)

Five parents GSM-22 (4.16) and SI-3218 (2.79), S-0434 (3.24), Lalguda local (1.90) and SI-331517 (1.43) were good combiners with high $per se$ performance. High $gca$ effects may be due to additive and additive x additive epistatic gene actions. Three hybrids ES-111-284 x Lalguda local (7.08), IC-413204 x S-0434 (4.52) and IC-413231 x SI-331517 (3.60) revealed significant $sca$ effects along with high $per se$ performance and relative heterosis. Parents involved in these hybrids shown medium x high, medium x high and low x high $gca$ effect and indicates that at least one parent should be good combiner.

5.3.2.10.2 Kharif 2010 ($E_2$)

The parents IC-413204 (4.26), GSM-22 (2.65) and IC-413231 (1.77) and Lalguda local (2.42) with significant $gca$ effects were good combiners. Hybrid IC-413209 x S-0434 (9.05), ES-111-284 x KSM-5-343 (6.93) and GSM-22 x Lalguda local (6.41) were shown high $sca$ effects along with high relative heterosis. These hybrids had parents with low x medium, medium x low and high x high $gca$ effects and both additive and non-additive gene actions were important in these hybrids, therefore selection should be delayed in later segregation generations.

5.3.2.10.3 Rabi 2010 ($E_3$)
Parents IC-413231 (5.17), IC-413209 (2.16) and IC-413208 (1.96), Lalguda local (4.16) and S-0434 (1.97) were exhibited significant positive \( gca \) effects. Hybrids IC-413204 x KSM-5-343 (14.17), SI-3218 x Lalguda local (8.53) and IC-413208 x KSM-5-343 (7.97) registered high \( sca \) effects and involved parents with medium x low, low x high, high x low \( gca \) effects. These hybrids revealed importance of both additive and non-additive gene actions.

Parents IC-413204, S-0434 and Lalguda local were shown positive \( gca \) effects over the season, whereas six hybrids \( viz. \), ES-111-284 x Lalguda local, IC-413231 x KMS-5-343, IC-413208 x S-0434, IC-413209 x Lalguda local, IC-413202 x Lalguda local and SI-3218 x KMS-5-343 expressed positive \( sca \) effects over the seasons. These hybrids should be exploited for isolating transgressive segregants in later segregating generations along with other traits.

5.3.2.11 Number of nodes for first capsule

5.3.2.11.1 Summer 2010 (\( E_1 \))

Four parents \( viz. \), IC-413209 (-0.56), IC-413202 (-0.55) and IC-413208 (-0.45) and KMS-5-873 (-0.33) with significant negating \( gca \) effects were good combiners for nodes for first capsule. Five hybrids recorded significant negative \( sca \) effects, and SI-3218 x Lalguda local (-1.24), SI-3218 x KMS-5-873 (-0.93) and GSM-22 x KMR-116 (-0.92) expressed high \( sca \) effects. These hybrids had parents with low x medium, low x high and low x medium \( gca \) effects of parents, indicates importance of non-additive gene action.

5.3.2.11.2 Kharif 2010 (\( E_2 \))

Six parents \( viz. \), IC-413209 (-0.59), IC-413202 (-0.58) and IC-413208 (-0.45), KSM-5-343 (-0.57), SI-331517 (-0.51) and KMR-116 (-0.39) were good combiners. Hybrid IC-413231 x KMS-5-873 (-1.21) had shown significant negative \( sca \) effects, followed by SI-3218 x KSM-5-343 (-0.88) and IC-413204 x Lalguda local (-0.81). There were differences in ranks of hybrids on the basis of \( sca \) effects, \textit{per se} performance and relative
heterosis. These hybrids involved parents with low x low, low x high, medium x low \( gca \) effects, indicates the potential of parents with low \( gca \) effects to express high \( sca \) effects in combinations.

5.3.2.11.3 Rabi 2010 (E_3)

The parents IC-413209 (-0.57) and ES-111-284 (-0.36) and KMS-5-873 (-0.33) were good combiners for nodes for first capsule. Six hybrids revealed significant negative \( sca \) effects and GSM-22 x KMS-5-873 (-1.16) shown highest, followed by IC-413208 x S-0434 (-1.11) and SI-3218 x KMR-116 (-1.10). These hybrids with low x high, low x low and low x low \( gca \) effects of parents, indicates the predominance of non-additive gene action.

Two parents IC-413209 and IC-413202 were good combiner over the seasons. Six hybrids \textit{viz.}, IC-413231 x KMS-5-873, IC-413204 x KMS-5-873, IC-413202 x S-0434, SI-3218 x SI-331517 and SI-3218 x Lalguda local were shown negative \( sca \) effects over the seasons. These hybrids should used to isolate transgressive segregants in later segregating generations.

5.3.2.12 Number of capsule on main stem

5.3.2.12.1 summer 2010 (E_1)

Number of capsule on main stem is one of the major yield components and six parents \textit{viz.}, GSM-22 (2.81), ES-111-284 (1.84), SI-3218 (1.84) and IC-413204 (1.64), S-0434 (5.96) and SI-331517 (1.98) were good combiners. There was mismatch between \textit{per se} performances and the \( gca \) effects of the parents, therefore parents should be selected on \( gca \) effects. Five hybrids recorded significant positive \( sca \) effects and ES-111-284 x Lalguda local (9.53) exhibited highest, followed by IC-413209 x KMS-5-873 (6.10) and IC-413202 x S-0434 (5.11), these hybrids were expressed high mean, relative heterosis and consist of parents with high x medium, low x low and low x high \( gca \) effects. Both additive and non-additive gene actions were involved in these crosses and selection should be
delayed in later generations of crosses.

5.3.2.12.2 Kharif 2010 (E$_2$)

The parents IC-413204 (4.54), IC-413208 (2.69) and IC-413231 (2.16) and Lalguda local (1.56) were good combiners. Top five hybrids on basis of *per se* performance involve at least one good combiner parent. Highest positive *sca* effects shown by IC-413231 x KMR-116 (7.94), followed by ES-111-284 x KSM-5-343 (7.56) and GSM-22 x Lalguda local (5.69) and involved parents with high x low, low x low and low x high *gca* effects, therefore it’s not always necessary to attempt crosses between parents with high *gca* effects.

5.3.2.12.3 Rabi 2010 (E$_3$)

Nine parents were exhibited negative *gca* effects, whereas IC-413231 (11.43) and Lalguda local (8.23) were shown significant positive *gca* effects. Hybrid IC-413209 x KMS-5-873 (15.07) recorded highest *sca* effects, followed by IC-413204 x KSM-5-343 (14.45) and IC-413202 x KMR-116 (14.35). There was difference in ranks of hybrids on basis of *sca* effects and relative heterosis; therefore selection should base on heterosis estimates. These hybrids were have parents with medium x medium, low x low and medium x low *gca* effects, indicating the importance of non-additive gene action.

Parent Lalguda local were expressed positive *gca* effects over the seasons. Three hybrids *viz.*, IC-413208 x S-0434, IC-413209 x KMS-5-873 and GSM-22 x SI-331517 were shown positive *sca* effects over the season. These hybrids should be exploited for isolating transgressive segregants in later segregating generations.

Krishnaiah *et al.* (2003) observed that Madhavi was a good general combiner for number of capsule on main stem along with earliness to 50 percent flowering and primary branches.

5.3.2.13 Number of capsules per plant

5.3.2.13.1 Summer 2010 (E$_1$)
Significant positive gca effects were expressed by five parents viz., GSM-22 (26.27), SI-3218 (21.61) and ES-111-284 (6.37), S-0434 (15.06) and Lalguda local (9.50). Top five hybrids on the basis of per se performance were having parents with high x high gca effects. Hybrid ES-111-284 x Lalguda local (38.87) revealed highest positive sca effects, followed by IC-413208 x KMR-116 (29.53) and SI-3218 x Lalguda local (25.10). Hybrids with similar sca effects were exhibited different heterosis e.g. IC-413208 x KMR-116 have high sca effect but negative relative heterosis, therefore selection should be made on heterosis estimates rather than sca effects.

5.3.2.13.2 Kharif 2010 (E₁)

There was no agreement between gca effects and per se performance of parents, therefore gca effects should be utilized for selecting parents. The parents GSM-22 (22.40), IC-413204 (19.78) and SI-3218 (17.23), Lalguda local (34.60) and KMS-5-873 (7.96) were good combiners. Hybrid GSM-22 x Lalguda local (94.67) was shown highest sca effects, followed by IC-413204 x S-0434 (57.55) and IC-413202 x KSM-5-343 (35.14) and involved parents with high x high, high x low and low x low gca effects, indicates that both additive and non-additive gene actions were involved.

5.3.2.13.3 Rabi 2010 (E₃)

The parents ES-111-284 (41.60), IC-413231 (19.52), GSM-22 (8.57) and Lalguda local (42.24) were good combiners for increasing capsules per plant. Most of the hybrids were recorded positive sca effects and ES-111-284 x KSM-5-343 (110.85) shown highest, followed by GSM-22 x Lalguda local (85.99) and IC-413208 x KMR-116 (71.36) and involved parents with high x medium, high x high and low x low gca effects. Hybrids with similar level of sca effects were expressed different heterosis; therefore hybrids should be selected on the basis of heterosis estimates.

Parents GSM-22 and Lalguda local were good combiners over the seasons. Six hybrids viz., IC-413209 x KMS-5-873, IC-413208 x S-0434, GSM-22 x Lalguda local, IC-413204 x S-0434, SI-3218 x Lalguda local
and ES-111-284 x KMS-5-343 were shown positive \textit{sca} effects over the seasons. These hybrids could be used for isolating transgressive segregants in later generation of crosses when dominance and epistatic gene action disappear.

Solanki and Gupta (2001b) observed that EC-351819 was best combiner for capsules per plant. Solanki and Gupta (2001a) observed that four crosses \textit{viz.}, 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 best combiner for capsules/plant along with seed yield. Mothilal and Manoharan (2004) recorded good combining ability in TMV 4 for number of capsule along with seed yield per plant. Shakhess and Khalifa (2007) observed that MGS36-2, Toshkal and MGS11-47 were best general combiners for capsules per plant, whereas two crosses L2 x T1 and L4 x T3 were best specific combiners for capsules per plant. Sumathi and Muralidharan (2008) revealed that TMV 3 and KS 990812 were having high \textit{gca} effects for capsules per plant. Praveen Kumar \textit{et al.} (2012) observed highest \textit{sca} effects for number of capsule per plant in Mutant 224 x Mutant 699.

\textbf{5.3.2.14 Number of seeds per capsule}

\textbf{5.3.2.14.1 Summer 2010 (E1)}

Parents SI-3218 (3.38), IC-413204 (1.00) and IC-413202 (0.74) and S-0434 (3.24) were good combiners for number of seeds per capsule. None of the hybrid recorded significant positive \textit{sca} effects, however ES-111-284 x KSM-5-343 (9.14), IC-413208 x KMR-116 (8.63) and SI-3218 x S-0434 (7.88) were shown high \textit{sca} effects involved parents with low x low, low x medium and medium x medium \textit{gca} effects. Top five hybrids on the basis of \textit{per se} performance mostly involved parents with medium x medium \textit{gca} effects indicating importance of both additive and non-additive gene action.

\textbf{5.3.2.14.2 Kharif 2010 (E2)}

Positive \textit{gca} effects were recorded by parents \textit{viz.}, SI-3218 (3.81), IC-413209 (2.79), KMR-116 (3.58), Lalguda local (1.79) and SI-331517 (1.45). Highest positive \textit{sca} effects exhibited by ES-111-284 x S-0434
There was a difference in ranks of hybrids on the basis of $sca$ effects and heterosis; therefore, hybrids should be selected from heterosis estimates. These hybrids had parent with low x low, medium x low and low x low $gca$ effects, indicating the importance of non-additive gene action.

5.3.2.14.3 Rabi 2010 (E$_3$)

Parents ES-111-284 (5.52), IC-413208 (2.29) and KMR-116 (2.43) were good combiners for increasing the number of seeds per capsule. Hybrid ES-111-284 x SI-331517 (16.38) shown highest significant positive $sca$ effect, followed by SI-3218 x KSM-5-343 (9.54) and IC-413204 x KMS-5-873 (8.78). These hybrids had parents with high x medium, medium x low and low x low $gca$ effects.

Parents SI-3218 and KMR-116 were good combiners over the season. Five hybrids viz., IC-413231 x KMR-116, IC-413204 x KMS-5-873, IC-413202 x S-0434, IC-413202 x Lalguda local and GSM-22 x KMS-5-873 were expressed positive $sca$ effects over the seasons. These hybrids could be utilized for isolating superior transgressive segregants in later generations.

Krishnaiah et al. (2003) observed highest general combining ability effects for seeds per capsule along with capsule length in parent Rajeshwari. Gaikwad et al. (2009) found that general and specific combining ability variances showed major contribution of non-additive gene action for number of seeds per capsule along with capsule length. Praveen Kumar et al. (2012) observed highest $sca$ effects for number of seeds per capsule in Mutant 181 x Mutant 224.

5.3.2.15 Seed yield per plant (g)

5.3.2.15.1 Summer 2010 (E$_1$)

Significant positive $gca$ effects along with high $per se$ performance were recorded by parents GSM-22 (4.59), SI-3218 (3.29), S-0434 (2.21), SI-331517 (1.11) and Lalguda local (0.64); therefore high $gca$ effects may be due to additive and additive x additive epistatic gene action. Top five
hybrids on basis of *per se* performance were mostly involved parents with high x high $gca$ effects. Significance $sca$ effects were recorded by thirteen hybrids and hybrid IC-413208 x KMR-116 (5.11) shown highest, followed by SI-3218 x Lalguda local (3.63) and IC-413204 x S-0434 (3.51). There was good agreement between *per se* performance, $sca$ effects and relative heterosis; hence hybrids could be selected on basis of $sca$ effects. These hybrids were have parents with low x low, high x high and medium x high $gca$ effects respectively. Both additive x non-additive and additive x additive gene action involved in expression of high $sca$ effects. Simple pedigree methods could be utilized for the genetic improvement of crosses with high x high $gca$ effects of parents and delaying the selection in later generations when dominance and epistatic gene interactions disappear.

### 5.3.2.15.2 Kharif 2010 ($E_2$)

Parents IC-413204 (4.57), GSM-22 (1.94) and Lalguda local (7.58) were good combiners for seed yield per plant. Eight hybrids shown significant positive $sca$ effects and IC-413204 x S-0434 (13.84) exhibited highest, followed by GSM-22 x Lalguda local (12.30) and GSM-22 x SI-331517 (6.34). There was good agreement between high *per se* performance, $sca$ effects and relative heterosis, therefore $sca$ effects could be considered as effective index for selection of hybrids. These hybrids consist of parents with high x low, high x high and high x low $gca$ effects, indicates that at least one parents with high $gca$ effects required in combinations. It also reveled the potential of parents with low $gca$ effects to produce high $sca$ effects in combinations. Both additive and non-additive gene actions are important for high heterosis. Improvement in crosses with high x high $gca$ effects could be achieved through simple pedigree methods with delayed selection in later generations. Non-conventional breeding methods such as bi-parental mating and diallel selective mating design should be utilized which breaks the linkages and accumulate the genes in homozygous conditions.

### 5.3.2.15.3 Rabi 2010 ($E_3$)
There was no agreement between gca effects and per se performance of the parents, may be due to predominance of non-additive gene action. Four parents’ viz., ES-111-284 (4.70), IC-413231 (2.08) and GSM-22 (1.49) and Lalguda local (5.45) were good combiners. Top five hybrids on the basis of per se performance consist of at least one parent with high gca effects. Nine hybrids were recorded significant positive sca effects, out of them ES-111-284 x KSM-5-343 (13.05) expressed highest, followed by IC-413208 x KMR-116 (9.52) and GSM-22 x Lalguda local (8.78). There was good agreement between per se performance, sca effects and relative heterosis. These hybrids had parents with high x medium, low x low and high x high gca effects, and shown additive x additive, non-additive x non-additive and additive x additive gene action. Breeding methods such as biparental mating, diallel selective mating should be utilized for the improvement under selections, as these methods exploit both additive and non-additive gene actions.

Parents, GSM-22 and Lalguda local were good combiner over the seasons and should be utilized in further hybridization. Seven hybrid viz., IC-4 13204 x S-0434, IC-413209 x KMS-5-873, ES-111-284 x KMS-5-343 and SI-3218 x Lalguda local, GSM-22 x SI-331517, GSM-22 x Lalguda local and IC-413208 x S-0434 were shown positive sca effects over the seasons. These hybrids could be exploited for isolating transgressive segregants for seed yield in later generations of crosses.

Sharma and Chauhan (1985) observed that when additive gene effects are primarily important, a good degree of association between per se and gca effects likely to be observed. Bakheit and Mahdy (1987) observed significant general combining ability effects and specific combining ability effects for seed yield. Goyal and Kumar (1988) found that Vinayak was the best general combiner and Pratap X Vinayak the best specific combinations for seed yield, also revealed that mean performance of the crosses was in close association with sca effects, suggesting that it can be taken as a criterion for effective heterosis breeding. Jadon and Mehrotra (1988)
observed that crosses Type 85 x C 2 and Sel R x Type 10 involved high general combining parents, and exhibited very high heterosis and \( \text{sca} \) effects for seed yield, and should be exploited for developing high yielding lines. Reddy et al. (1990) observed the hybrids B9/R84-4-2, B9/R84-360-3 and RT54/R84-4-2 had significant \( \text{sca} \) effects for seed yield. Ding et al. (1991) found that heterosis and specific combining ability were greatest for yield/plant. Reddy et al. (1992) observed that RT 54, R 84-4-2 and R84-360-3 were good combiner for seed yield and oil content, whereas RT 54 x R84-4-2 may throw superior transgressive segregants for seed yield and oil as additive x additive x additive gene action involved in these crosses. Reddy and Haripriya (1993) observed that hybrids R84-4-2 x VS16 and RT54 x VS16 involving high \( \text{GCA} \) parents, showed very high and significant heterosis, and \( \text{SCA} \) effects for seed yield, and are useful for exploiting hybrid vigor. Fatteh et al. (1995) found that parents PT64 and HT1 were good general combiners for yield per plant and some of its components. Hybrids TMV3 x HT1, PT64 x C1013 and HT1 x TMV3 were the best combinations for most of the yield components. Quijada and Layrisse (1995) observed that specific combining ability effects were more important than general combining ability effects, and suggested that 'Arawaca' and 'Piritu' should be chosen as parents in view of their large \( \text{GCA} \) effects. Saravanan et al. (2000) identified Si1125 as good combiners for all traits of interest including yield. Good agreement between \( \text{per se} \) performance and \( \text{gca} \) effects observed, however there was only fair agreement between \( \text{per se} \) performance, \( \text{SCA} \) effects, heterosis and heterobeltiosis. Durga and Raghunadhan (2001) recorded good combining ability effects for seed yield in lines DORS-165 and Tapi, whereas crosses DORS-102 x Madhavi and DORS-112 x Tapi recorded highest specific combining ability effects for seed yield. Kar and Swain (2001) observed non-significant correlation between \( \text{gca} \) effects and parental mean, whereas highly significant correlation observed between \( \text{sca} \) effects and \( F_1 \) mean. Mishra and Sikarwar (2001) found that the combination JTS-13 x TKG-22
was the best on the basis of *sca* effects and *per se* performance. JTS-13 and EC-132856 as females and TKG-22 as male were the best general combiners for seed yield. Solanki and Gupta (2001b) observed that RT-127 and SI-718 were good general combiners, whereas crosses EC-370823 x RT-127, EC-370663 x RT-127, EC-351832 x RT-305 and SI-718 x RT-305 were the best for seed yield and its component characters. Solanki and Gupta (2001a) found IS-225-2 good combiner for seed yield, whereas 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 for both seed yield and capsules/plant. Reddy *et al.* (2001) observed E-8, one of the parents exhibiting superiority in producing heterotic hybrids. Kar *et al.* (2002) found that Guj. Til 1, Sel 73, Sel 33, Sel 123 and Uma were good combiner for seed yield. There was lack of relationship between parental *per se* and *gca* effects. Promising crosses were mostly having parents with high x high, high x low or medium x high combining ability effects. Saravanan and Nandarajan (2002) observed that the crosses with high *sca* effects did not rank top, in all the top ranking hybrids for seed yield per plant involved at least one parent with high best *gca* effects. Mothilal and Manoharan (2004) revealed that TMV 4 was a good general combiner for 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. Thirugnana Kumar et al. (2005) observed that genotypes viz., VRI 1, SJV local and AVTS 5 were found as a good general combiner for seed yield after shattering. The cross combinations viz., Annamalai 1 x CO 1; VS 9701 x CO 1; SJV Local x TMV 3 and AVTS 5 x TMV 6 were best specific combiners for seed yield after shattering. Shakhess and Khalifa (2007) found that MGS36-2, Toshkal and MGS11-47 were good combiners for seed yield along with other traits, whereas L2 x T1 and L4 x T3 were the best combiners for yield per plant along with number of capsules per plant and oil percent. Raghunaiah *et al.* (2008) observed that EC-310447, KIS-282-2, Swetha thil and JCS-9426 were best combiners for seed yield per plant along with major yield
contributing traits. KIS-282-2 x Swetha thil followed by JCS-402 x JCS-9426 and EC-310447 x Swetha thil tested highest standard heterosis and significant sca for seed yield per plant. Most of the crosses with high sca effects involved at least one parent with desirable gca effect for that trait. Sumathi and Muralidharan (2008) observed good combining ability effects for TMV3 for seed yield along with early maturity, whereas 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. Gaikwad et al. (2009) identified lines ES 3 and TC 289 as good combiner for seed yield and yield components. Yamunara and Nadaf (2009) revealed that parents DS-13, DS-16, DS-10 (females) and E-8, TSES-2, TSES-4, DS-1 (males) were good combiners for seed yield per plant. Parameshwarappa and Salimath (2010) observed major contribution of additive gene action for seed yield. Praveen Kumar et al. (2012) observed that Mutant lines viz., Mutant 274, Mutant 699, Mutant 353, and Mutant 450 were best general combiners for seed yield. Mutant 181 x Mutant 51 were recorded highest sca effects for seed yield per plant.

5.3.2.16 1000 Seed weight (g)

5.3.2.16.1 Summer 2010 (E₁)

The parents SI-3218 (0.13) and IC-413209 (-0.12) and SI-331517 (0.22) were good combiners for 1000 seed weight. Three hybrids viz., SI-3218 x SI-331517 (0.68), IC-413208 x KMS-5-873 (0.25) and IC-413202 x KSM-5-343 (0.20) were shown significant positive sca effects along with high per se and high relative heterosis. Parents involved in these hybrids expressed high x high, medium x low and medium x medium gca effects and there was predominance of additive x additive epistatic gene interaction, though non-additive gene action was also important. Therefore pedigree methods with delayed selection should be utilized for isolation superior transgressive segregants.

5.3.2.16.2 Kharif 2010 (E₂)
All parents were exhibited significant positive \textit{gca} effects except SI-3218 (-0.41), GSM-22 (-0.40), S-0434 (-0.40) and Lalguda local (-0.10). Top five hybrids on the basis of \textit{per se} performance had parents with high x high \textit{gca} effects. Hybrid GSM-22 x Lalguda local (0.61) followed by SI-3218 x S-0434 (0.45) and GSM-22 x S-0434 (0.27) were shown significant positive \textit{sca} effects and consists of parents with low x low \textit{gca} effects, indicates non-additive x non-additive gene action.

5.3.2.16.3 \textit{Rabi 2010 (E$_3$)}

Parents SI-3218(0.08), GSM-22 (0.08), IC-413231(0.06), SI-331517 (0.08) and KMS-5-343(0.07) were good combiners for 1000 seed weight. Hybrids IC-413231 x KSM-5-343 (0.58) and IC-413208 x KMS-5-873 (0.20) recorded high \textit{sca} effects along with positive heterosis and consist of parents with high x high and low x low \textit{gca} effects, indicates that its not necessary to always attempts crosses between parents with high \textit{gca} effects.

Three hybrids \textit{viz.}, IC-413231 x KMS-5-343, IC-413208 x KMS-5-873 and IC-413202 x KMS-5-873 were shown positive \textit{sca} values over the seasons.

Krishnaiah \textit{et al.} (2003) observed that genotype Krishna showed highest \textit{gca} for 1000 seed weight. Mothilal and Manoharan (2004) revealed that TMV 4 was good general combiner for 1000 seed weight along with number of capsules and seed yield per plant. Praveen Kumar \textit{et al.} (2012) recorded highest \textit{sca} effects for 1000 seed weight in Mutant 51 x Mutant 181.

5.3.2.17 Oil content (%)

5.3.2.17.1 \textit{Summer 2010 (E$_1$)}

Six parents \textit{viz.}, ES-111-284 (2.96), IC-413231 (1.85) and IC-413208 (1.44), SI-331517 (4.04), KMR-116 (3.59) and KSM-5-343 (2.49) shown significant \textit{gca} effects with high \textit{per se} performance, indicates presence of additive and additive x additive epistatic gene action. Top five hybrids on basis of \textit{per se} performance were consisting of parents with
mostly high x high \textit{gca} effects. Hybrids SI-3218 x Lalguda local (6.43), ES-111-284 x S-0434 (5.08) and GSM-22 x S-0434 (4.70) were expressed significant positive \textit{sca} effects and involved parents with medium x low, high x low and low x low \textit{gca} effects. These hybrids with high \textit{sca} effects were not have high \textit{per se} performance and involved parents with poor performance. Therefore the low heterosis may be due to association of genes in parents i.e. less dominant alleles in \textit{F}_1 in comparison to parents.

\textbf{5.3.2.17.2 Kharif 2010 (E\textsubscript{2})}

Parents IC-413204 (1.93), ES-111-284 (1.80), SI-331517 (2.78), KMR-116 (1.66) and KSM-5-343 (1.27) were shown significant positive \textit{gca} effects. Hybrids IC-413208 x KMS-5-873 (3.99) and IC-413231 x S-0434 (3.89) were exhibited significant positive \textit{sca} effects and consists of parents with low x medium and medium x low \textit{gca} effects. These hybrids were having involvement of both additive and non-additive gene actions; therefore improvement in these crosses should be made through recurrent selection, as it breaks the linkages and allow the selection with more dominant genes in homozygous condition.

\textbf{5.3.2.17.3 Rabi 2010 (E\textsubscript{3})}

Parents ES-111-284 (1.93), IC-413202 (1.17), GSM-22 (0.28), KSM-5-343 (3.17), KMS-5-873 (2.80), SI-331517 (2.03) and KMR-116 (1.24) were good combiners for oil content. Four hybrids \textit{viz.}, GSM-22 x Lalguda Local (6.08), SI-3218 x Lalguda Local (5.16), IC-413202 x SI-331517 (4.07) and ES-111-284 x KMR-116 (3.89) recorded significant positive \textit{sca} effects and involved parents with high x low, low x low, high x high and high x high \textit{gca} effects. In most of the cases at least one parent with high \textit{gca} effects was involved.

Parents ES-111-284, KSM-5-343, SI-331517 and KMR-116 were expressed significant positive \textit{gca} effects over the seasons, and should be utilized for devolving varieties with high oil content along with high seed yield. Eight hybrids \textit{viz.}, IC-413208 x KMS-5-873 and SI-3218 x Lalguda local, IC-413231 x KSM-5-343, IC-413231 x SI-331517, IC-413204 x
KSM-5-343, IC-413202 x SI-331517, IC-413202 x KMR-116 and GSM-22 x Lalguda local were shown positive \textit{sca} effects over the seasons. These hybrids should be exploited through bi-parental mating or diallel selective mating design to break undesirable linkages and accumulate favourable genes in homozygous condition.

Murty (1975) observed that Sel-R was best combiner for oil content. Reddy \textit{et al.} (1992) observed that parental lines RT 54, R 84-4-2 and R84-360-3 possessed more favourable genes for both oil content and seed yield. Shakhess and Khalifa (2007) found that among the lines, the genotype MGS36-2 recorded desirable \textit{gca} effect for oil content along with number of branches/plant, number of capsules/plant and seed yield/plant. Two top crosses (L2 x T1 and L4 x T3) were the best combiners for oil\% along with number of capsules/plant and seed yield/plant. Sumathi and Muralidharan (2008) observed that line TMV3 showed high \textit{gca} for oil content along with seed yield, days to 50 percent flowering, days to maturity, plant height and number of capsules. Praveen Kumar \textit{et al.} (2012) observed highest \textit{sca} effects for oil content in Mutant 274 x Mutant 450.

Parental lines \textit{viz.}, GSM-22, SI-3218, SI-331517, S-0434 and Lalguda local were good combiners for seed yield and major yield contributing character during summer season (E$_1$), whereas during \textit{Kharif} season IC-413204, GSM-22 and Lalguda local were good combiners for seed yield and yield components; and during \textit{Rabi} season (E$_3$) ES-111-284, IC-413231, GSM-22 and Lalguda local were good combiners for seed yield per plant along with major yield components. These parents should be utilized further hybridization and developing high yielding hybrids.

Hybrids IC-413204 x S-0434, IC-413208 x KMR-116, SI-3218 x Lalguda local and GSM-22 x KMS-5-873 were good combiners for seed yield per plant along with major yield components. during summer season (E$_1$), whereas hybrids IC-413231 x KMR-116, IC-413204 x S-0434, GSM-22 x SI-331517 and GSM-22 x Lalguda local were shown good specific combining ability for seed yield along with other major yield components in
Kharif season (E<sub>2</sub>); in summer season (E<sub>3</sub>) hybrid SI-3218 x Lalguda local, IC-413202 x KMR-116, IC-413202 x SI-331517, IC-413209 x KMS-5-873 and IC-413208 x KMR-116 were good combiners for seed yield per plant along with major yield contributing characters.

It's revealed that these hybrids could be exploited for developing hybrids, further, these crosses mostly consist of parents with high x high, high x medium, high x low, medium x low and low x low gca effects for seed yield and yield components. Therefore it's not always necessary to attempt crosses between high x high gca effects and revealed the potential of parents with low gca effects to results into high sca effects in combinations. Breeding methods such as recurrent selection along with bi-parental mating, diallel selective mating should be utilized for isolating high yielding transgressive segregants in advanced generations.

### 5.4 COMBINING ABILITY VARIANCE AND GENE ACTION

Higher estimates of specific combining ability (SCA) variances than general combining ability (GCA) variances for all the characters except days to 50 percent flowering and days to maturity over the season, indicates that majority of the variation among these characters was due to non-additive gene action and specific combing ability might be useful for improvement in these characters. The dominance variances were higher than additive variances for all the characters, except days to 50 percent flowering and days to maturity. Therefore, bi-parental mating or diallel selective mating should be utilized to exploit non-additive gene action. Characters such as days to 50 percent flowering, days to maturity could be improved through simple selection or pedigree method. The ratio of GCA variance to SCA variance was less than unity for all the characters, indicates predominance of non-additive gene action and hybrid vigor could be exploited. However in case of characters with ratio less than unity and predominance of both additive and non-additive gene actions were important.

Chavan et al. (1981) found that additive and dominance had played
important role in the expression of yield components and additive x additive was important epistatic gene action. Tyagi and Singh (1981) revealed non-additive gene action for yield and most yield components, indicating the scope for exploiting heterosis in breeding. Chavan et al. (1982) observed complementary gene action for days to maturity and selection in segregating generation would be effective for this character. Krishnadoss et al. 1987, Mishra and Yadav (1996) and Padmavathi (1999) reported predominance of non-additive genetic component for seed yield, plant height, branches per plant, capsules per plant and 1000 seed weight. Reddy et al. (1992) observed higher magnitude of GCA than SCA variance and higher GCA/SCA variance ratio for oil content indicating the predominance of additive gene action; whereas for seed yield non-additive type of gene action was important. Kamala (1999) found that character days to maturity was highly heritable with additive effects whereas plant height, branches, capsules per plant, seeds per capsule, 1000 seed weight and seed yield per plant were moderate to low heritable with non-additive effects in the form of dominance. Saravanan et al. (2000) recorded higher SCA variance higher than GCA variance for seed yield per plant; both SCA and GCA variances were significant for 1000 seed weight and oil content. However the GCA variance alone was predominant for all the earliness related traits; suggested that in presence of both additive and non-additive variances, these could be simultaneously exploited through F1 hybrid development. Kar and Swain (2001) reported non-additive gene action for days to 50 percent flowering, days to maturity and plant height for first fruiting node along with seed yield. Mishra and Sikarwar (2001) found that the dominance component of variance estimated on basis of SCA variances was from 7 (branches per plant) to 180 (maturity) times higher than additive genetic variance, indicating tremendous possibilities for exploitation of hybrid vigor. Solanki and Gupta (2001a) observed greater magnitude of SCA variances for seed yield per plant, capsule bearing plant height, branches per plant, capsules per plant and 1000 seed weight as well as greater GCA variances for days to
maturity and plant height. Swain et al. (2001) indicated that both additive and non-additive components of genetic variance were involved with predominance of dominance variance for branches per plant, capsules per plant, 1000 seeds weight, capsules on main stem, capsules per plant, capsule length except days to maturity. Mothilal and Manoharan (2004) observed that variance due to SCA was higher than that of GCA, indicating predominance of non-additive gene action for all the seven traits including seed yield. Rajput et al. (2005) observed that the magnitude of GCA variance was higher than SCA variance for all the characters namely days to 50 percent flowering, days to maturity, plant height, number of capsules per plant, yield per plant, length of capsule and 1000 seed weight, except number of seeds per capsule and oil content, indicating the predominant role of additive gene action in the inheritance of these characters. Bramawy and Shaban (2007) reported the predominance of additive gene action for days to maturity. Anuradha and Reddy (2008b) found that seed yield and yield traits like number of primary branches, seeds per capsule, thousand seed weight, biological yield and harvest index advocated the importance of dominance variance, while plant height, capsules on main stem, capsules on primary branches registered importance of additive gene action. Raghunaiah et al. (2008) revealed that days to 50 percent flowering might be conditioned by both additive and non-additive gene action. Sumathi and Muralidharan (2008) found that SCA variances was higher than GCA variances for the traits days to 50 percent flowering, days to maturity, number of capsules, capsule length, number of seeds per capsule. 100 seed weight, seed yield per plant and oil content suggested the predominant role of non-additive component, whereas plant height and number of branches shown predominant of GCA variances indicating role of additive component. Kuselan and Thirugnana Kumar (2009) observed that variance due to SCA was higher than variance due to GCA for all the seven characters. The variance due to dominance was much pronounced than that of additive genetic variance. Prajapati et al. (2009) found that non-additive
gene action was predominantly responsible for inheritance of quality traits. Praveen Kumar (2009) studied combining ability variance and recorded the predominance of dominance variance than additive variance for the characters like plant height, days to 50 percent flowering, days to maturity, capsules per plant, capsule length, seeds per capsule, 1000 seed weight, oil content and yield per plant. Yamunara and Nadaf (2009) indicated that character, 1000 seed weight had a fixable additive genetic variance which can be improved by simple selection, whereas characters viz., plant height, days to 50 percent flowering, days to maturity, length of capsule, total number of capsules per plant, oil content, seed yield per plant and seed yield per ha showed predominance of non-additive gene action which can be improved by bi-parental mating. Parameshwarappa and Salimath (2010) observed that general and specific combining ability variances showed major contribution of additive gene action for all the nine characters studied except number of seeds/capsule. Shekhat et al. (2011) revealed that both additive and non-additive type of gene actions were involved in the inheritance of most of the traits studied with preponderance of non-additive gene actions for all the characters. Praveen Kumar et al. (2012) revealed that general and specific combining ability (GCA and SCA) variances showed major contribution of non-additive gene action for all the characters except days to maturity.

5.5 GENOTYPE X ENVIRONMENT (G X E) INTERACTION/STABILITY ANALYSIS

5.5.1 Influence of environments on quantitative characters

Earliness to days to flower initiation and days to 50 percent flowering were observed in summer season followed by kharif and rabi season. Minimum days required for maturity in summer seasons, while maturity delayed in kharif season followed by rabi season. For plant height kharif season was the most favorable environments, whereas summer season was most unfavourable. Character plant height for first capsule was minimum during summer season followed by rabi, whereas kharif season
was most favorable with increased plant height for first capsule. Capsule bearing plant height was shown higher expression in *kharif* season, followed by *rabi* and summer season. More primary branches per plant observed during *kharif* season, followed by *rabi* and summer season. Internode distance and capsule length expressed higher expression in *kharif* season, followed by *rabi* and summer season. Number of nodes on main stem was more in *rabi* season, followed by *kharif* and summer season. In *kharif* season more nodes for first capsule observed in comparison to *rabi* season, whereas summer season was the most unfavorable season. For number of capsules on main stem *rabi* season was the most favorable, followed by summer and *kharif* season. Number of capsules per plant observed more during *rabi* season, followed by *kharif* and summer season. In *kharif* season, more number of seeds per capsule recorded, followed by summer and *rabi* season. For seed yield per plant *rabi* season was the most favorable environment followed by *kharif* season, whereas summer season recorded lower seed yield per plant. Higher expression of 1000 seed weight was observed during *kharif* season followed by summer and *rabi* season. Higher oil content was observed in *kharif* season, followed by *rabi* and summer season.

Srivastava *et al.* (1998) found that genotypes which have poor yield potential under non-stress condition are more resistance to moisture stress. Mahto and Verma (2001) observed that based on environment indices, monsoon 1989 (environment I) was the most favourable for expression of all characters. Subbaraman and Jebbaraj (2001) evaluated the twenty five sesame genotypes for stability of seed yield in three different locations; the summer season was identified as best environment for growing the present set of genotypes. Anuradha and Reddy (2005) revealed that Peddapuram location was most favoured location for sesame production. Suvarna *et al.* (2011) identified promising genotypes in different location based on actual seed yield.

### 5.5.2 Analysis of variance
Analysis of variances for quantitative traits revealed significant differences among genotypes in all the environments for all the characters except days for flower initiation, days for 50 percent flowering, days to maturity, capsule length and number of seeds per capsule. This indicates presence of substantial amount of variability among the genotypes for most of the traits.

5.5.3 Pooled analysis of variance

The pooled analysis of variance revealed that mean sum of square (MSS) due to genotypes were highly significant for all the characters except number of seeds per capsule indicating the large amount variability in the material selected for the study. The MSS due to environments was also significant for all the traits indicating the validity of conducting experiment in these environments. The MSS due to genotype x environment interaction were significant for all the characters when tested against either pooled error or pooled deviation, except for days to 50 percent flowering, days to maturity and number of seeds per capsule indicating considerable interaction between genotypes and environments for these characters. The MSS due to environment + (genotype x environments) was significant for all the traits when tested against either pooled error or pooled deviation indicates that these characters were unstable and fluctuated in their expression with change in environment. MSS due to environment (linear) was significant for all the characters indicating that environment effects are additive and differed significantly and quite diverse with respect to their effects on performance of genotypes for quantitative traits. Further, MSS. due to environment (linear) was higher in magnitude than M.S.S. due to genotype x environment (linear) indicating that MSS due to environment (linear) accounted for major part of total variation in genotypes for all the characters. MSS due to genotype x environment (linear) was significant for all the traits when tested against either pooled error or pooled deviation except days to 50 percent flowering, days to maturity, number of seeds per capsule indicating that genotypes differed from each other with respect to
their linear response and prediction of performance in different environments was possible for these traits. Similarly, significant MSS due to pooled deviation observed for all the traits except days to flower initiation, days to 50 percent flowering, days to maturity, number of seeds per capsule, 1000 seeds weight and oil content indicating that non linear component of G x E interaction was predominant and deviation from linear regression also contributed substantially towards the differences in stability of genotypes. Thus, both linear (predictable) and non-linear (un-predictable) components significantly contributed to genotype x environmental interactions for these traits and part of variation in these characters was unpredictable. In case of characters capsule length and number of nodes for first capsule MSS due to genotype x environment (linear) was non-significant, however MSS due to pooled deviation was significant indicating that variation in the genotypes for these characters was entirely unpredictable. Characters viz., days to 50 percent flowering, days to maturity and number of seeds per capsule recorded significant MSS due to environments (linear), however MSS due to genotype x environment (linear) and MSS due to pooled deviation were non-significant indicating that variation in genotypes for these characters was entirely due to change in environment.

Kumar (1988) revealed the presence of genotype x environment interaction and large portion of these accounted for linear component. Non-linear component was also significant yet magnitude smaller than the linear component. Mahdy et al. (1988) revealed highly significant effects of environments and genotype x environment interaction for seed yield per plant, seed oil percentage, capsules per plant, capsule length, capsule breadth, plant height, first capsule height and branches per plant. Osman (1989b) tested the material for stability with hypothesis that $b_i=1$ and $S^2di=0$. The material studied differed significantly for seed yield and genotype x environment (G x E) interaction. Quijada and Layrisse (1995) observed a large genotype x location interaction for all traits, suggesting
that hybrids should be produced for specific location. Singh et al. (1998) observed genotype x environment interaction for all the traits. Linear as well as non-linear components accounted for the interaction for all the characters except number of primary branches; however the former component contributed to a greater extent. Laurentin and Montilla (1999) and Subbaraman and Jebbaraj (2001) determined genotype x environment interaction and stability by regression, principal component axis (PCA) and additive main and multiplicative interaction (AMMI) model. Mahto and Verma (2001) observed significant differences among genotypes and environments. Kumaresan and Nadarajan (2002) revealed that the analysis of mean square due to genotypes x environment (linear) and non-linear deviation were significant for all the character studied. 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. Kumar et al. (2004) observed sufficient G x E interaction for all the characters of interest; however characters differed regarding the contribution of linear and non-linear components of G x E interaction. Anuradha and Reddy (2005) observed that substantial portion of the interaction was due to linear component. Kumaresan and Nadarajan (2005) found that analysis of mean square due to genotype x environment (linear) and non-linear deviation were significant for all the characters studied. Raghuwanshi and Duhoon (2005) observed that genotype x environment interaction had significant effect on seed yield. Velu and Shunmugavalli (2005) found differential response of characters to varied environments effects. Significant genotype x environment interaction effects were observed for all characters except capsule length. Adebisi and Ajala (2006) found that genotypes differed significantly for seed yield and genotype x environment (G x E) interaction. Kumar et al. (2008) found that the sufficient G x E interaction was exhibited by all the genotypes for 1000 seed weight and seed yield. The contribution of linear and non-linear
components of G x E interaction was differed for different traits of interest. Adebisi et al. (2009) observed significant genotype x environment interaction for quality traits. Mekonnen and Mohammad (2010) studied the stability for oil content and revealed highly significant differences between genotypes, location and G x E interaction, suggesting differential response of genotypes across testing locations and need for stability analysis. Bhandarkar and Kumar et al. (2010) observed highly significant differences among genotypes for all the characters. The significant G x E interaction was recorded for primary branches and seed yield. Environment (linear) interaction component was significant for all the traits, while the linear component of genotype x environment interaction was significant only for plant height. The variance due to pooled deviation (non-linear) was highly significant for seed yield only, which reflects considerable genetic diversity in seed yield.

5.5.4 Stability analysis of genotypes for the quantitative characters

After the pooled analysis of variances stability of genotypes studied for the characters those recorded significant genotype x environment interaction. The ability of genotype to produce a narrow range of phenotype in different environments can be called as stable (Lewis, 1954). Eberhart and Russell (1966) defined a stable genotype as the one which showed high mean, regression co-efficient (bi) around unity and deviation from regression near to zero. Accordingly, the mean and deviation from regression of each genotype were considered for stability, whereas linear regression used for testing the varietal response or sensitivity to environmental changes. Genotypes with high mean, \( bi = 1 \) with non-significant \( \delta^2 di \) are suitable for general adaptation, i.e., suitable over all environmental conditions and they are considered as stable genotypes. Genotypes with high mean, \( bi > 1 \) with non-significant \( \delta^2 di \) are highly sensitive to changing environments and considered as below average in stability. Such genotypes tend to respond favourably to better environments but give poor yield in unfavourable environments; hence, they are suitable
for favourable environments. Genotypes with low mean, $b_i < 1$ with non-significant $\delta^2di$ do not respond favorably to improved environmental conditions and hence, it could be regarded as specifically adapted to poor environments; however if accompanied with high mean suitable to unfavourable environment or stress condition. Genotypes with any $b_i$ value with significant $\delta^2di$ are unstable and performance could not be predicted. On the basis of above stability parameters stability of genotypes was discussed herewith for quantitative traits.

5.5.4.1 Days to flower initiation (Fig. 5.1)

Days to flower initiation registered earliness during summer season (environment index -1.92), whereas flower initiation delayed in Rabi season (environment index 2.94). Hybrid IC-413208 x SI-331517 was ideal genotype and adapted over the environments, whereas hybrid IC-413209 x S-0434, IC-413209 x Lalguda local and IC-413202 x KMS-5-343 were stable and suitable for general adaptation. Twenty genotypes were highly sensitive to environmental change and out of them parent IC-413204 and hybrids IC-413204 x KMR 116 and IC-413208 x KMR 116 were suitable for favourable environment as showing high mean. Parents ES-111-284 and IC-413202 and hybrids IC-413209 x KMS-5-343, IC-413204 x KMS-5-343, IC-413209 x KMR 116, IC-413208 x KMS-5-873 and IC-413209 x Lalguda local were above average stable and not suitable for favourable environments, however were specifically adapted to poor environments. Hybrids ES-111-284 x Lalguda local and IC-413208 x KMS-5-343 were unstable genotypes and performance could not be predicted.

5.5.4.2 Days to 50 percent flowering (Fig. 5.2)

Days to 50 percent flowering, recorded earliness in summer season (environment index -1.81), whereas delayed in rabi season (environment index 3.05). Parent IC-413202 and five hybrids viz. IC-413202 x KMS-5-343, IC-413204 x KMS-5-343, IC-413209 x KMR 116, IC-413208 x KMS-5-873 and IC-413209 x Lalguda local were stable genotypes for earliness and suitable for general adaptation. Parent IC-413204 and hybrids IC-413204 x KMR-116, IC-413204 x KMS-5-873, ES-111-284 x SI-331517,
Fig. 5.1 Relationship between the regression coefficient (b) and days to flower initiation

**Stable Genotypes**
14. IC-413208 x SI-331517
29. IC-413209 x S-0434
30. IC-413209 x Lalguda local
31. IC-413202 x KMS-5-343
Fig. 5.2 Relationship between the regression coefficient ($b_i$) and days to 50 percent flowering

**Stable Genotypes**
- 16. IC-413208 x KMS-5-873
- 19. IC-413204 x KMS-5-343
- 27. IC-413209 x KMR 116
- 30. IC-413209 x Lalguda local
- 31. IC-413202 x KMS-5-343
- 54. IC-413202
IC-413204 x SI-331517 were highly sensitive for change in environments, however they tend to early in favourable environments. Parents ES-111-284 and IC-413208 and eight hybrids viz., ES-111-284 x KMR 116, IC-413209 x KMS-5-873, IC-413209 x SI-331517, IC-413209 x KMS-343, IC-413202 x KMS-5-873, IC-413231 x SI-331517, IC-413209 x S-0434, IC-413202 x KMS-5-343 were above average stable genotypes and will not respond to favourable environment and specifically adapted to poor environments. Hybrid SI-3218 x KMS-5-873 and IC-413208 x KMS-5-343 were unstable genotypes and performance could not be predicted.

Kumaresan and Nadarajan (2002) studied the stability for the days to 50 percent flowering among sixty four genotypes comprising 48 hybrids and 16 parents.

5.5.4.3 Days to maturity (Fig. 5.3)

Environment indices revealed that summer season (-6.83) was the most favourable averment for early maturity, whereas kharif season (4.39) was the most unfavourable environment which exhibited late maturity. Hybrids IC-413208 x Lalguda local and IC-413231 x KMR 116 were stable genotypes for early maturity and suitable for diverse range of environments. Parent IC-413202 and hybrids IC-413202 x S-0434, IC-413209 x S-0434 and IC-413202 x KMS-5-343 were sensitive for fluctuation in environmental condition and will not suitable for unfavourable environmental condition, however they will respond favourably to better environments. Parent IC-413209 and IC-413204; hybrids IC-413231 x KMS-5-343, ES-111-284 x S-0434 and IC-413204 x SI-331517 were specifically adapted for poor or stress conditions but will not respond favourably to better environments.

Elizondo-Barron (1997) studied the stability for maturity and found that the early maturity Peludo Canastilla and Iguala 200-SI-R77 and the medium maturity Criollo de Llera showed general environmental adaptability. The medium maturity Iguala 267-T72 had the best adaptability to favorable environments. In addition, the early maturity Chino II and the
Fig. 5.3 Relationship between the regression coefficient ($b_i$) and days to maturity

Stable Genotypes
9. IC-413231 x KMR 116
18. IC-413208 x Lalguda local
medium maturity Instituto 7 consistently performed well in unfavorable conditions.

5.5.4.4 Plant height (cm) (Fig. 5.4)

Plant height is one of the major yield components affecting the seed yield per plant. Plant height recorded wide range over the environments, however highest plant height observed in kharif season as being the most favourable environment (environment index 26.45), whereas lower plant height observed in summer season (environment index -20.75). Parents IC-413208 and five hybrids viz. IC-413204 x SI-331517, IC-413231 x Lalguda local, IC-413208 x S-0434, IC-413204 x KMS-5-343 and GSM-22 x Lalguda local were stable genotypes and suitable over wide environmental conditions. Parent KMS-5-343 and hybrids IC-413208 x KMS-5-343, IC-413208 x KMR-116 with low mean were average stable and poorly adapted over the environments. Parent IC-413231 and four hybrids viz. GSM-22 x SI-331517, IC-413204 x Lalguda local, IC-413231 x S-0434 and IC-413231 x KMR 116 were having high mean and regression coefficient more than unity, were sensitive to environmental changes, however tend to respond favourably to better environments. Parents SI-3218, GSM-22 and hybrids GSM-22 x KMS-5-343, SI-3218 x Lalguda local were above average stable and may not respond to rich environments, however specifically adapted to poor or stress environments. Parents KMR 116, SI-331517 and ES-111-284 and eight hybrids were unstable genotypes with significant S^2d. Hybrids IC-413204 x S-0434, GSM-22 x SI-331517, GSM-22 x KMR-116, ES-111-284 with high mean were unstable and fluctuates in their performances.

Mahdy et al. (1988) found that introduced genotypes were stable in yield and other traits including plant height. Kumar et al. (2006) and Bhandarkar and Kumar (2010) studied the stability for plant height across three environments. Bhandarkar and Kumar et al. (2010) found that TKG-22 was stable for plant height, however in current study TKG-22 shown poor plant height than overall mean in each environment.

5.5.4.5 Plant height for first capsule (cm) (Fig. 5.5)
Fig. 5.4 Relationship between the regression coefficient ($b_i$) and plant height (cm)

**Stable Genotypes**
12. IC-413231 x Lalguda local
17. IC-413208 x S-0434
19. IC-413204 x KMS-5-343
20. IC-413204 x SI-331517
42. GSM-22 x Lalguda local
51. IC-413208
Change in environments influenced the expression of plant height for first capsule and mean varied from 19.74 to 49.18. Summer season had highest desirable environment index (-11.14) whereas lowest shown by kharif season (18.30). Parent KMS-5-343 and check TKG-22 and hybrids IC-413231 x KMR 116, IC-413208 x S-0434 and IC-413209 x S-0434 were stable genotypes and suitable over diverse environments. Hybrids IC-413202 x KMR 116, IC-413231 x KMS-5-873, IC-413231 x Lalguda local and IC-413208 x Lalguda local with high mean were highly sensitivity to changes in environments, and tend to respond better in favourable environment. Parents IC-413202, KMR 116 and IC-413209 and eight hybrids viz. IC-413204 x KMR 116, IC-413202 x S-0434, IC-413209 x SI-331517, IC-413209 x KMS-5-343, IC-413202 x KMS-5-343, IC-413204 x KMS-5-343, ES-111-284 x KMR-116 and IC-413208 x KMS-5-343 were above average stable genotypes and specifically adapted for stress or unfavourable environments, however may not perform in rich environment. Parents SI-331517, ES-111-284, GSM-22 and Lalguda local and sixteen hybrids were unstable as shown significant S^2di and includes genotypes viz.,IC-413208 x KMR-116, IC-413209 x KMS-5-873, IC-413202 x SI-331517, IC-413202 x KMS-5-873 with high mean.

Mahdy et al. (1988) observed that introduced genotypes were stable in yield and first capsule height along with other yield traits.

**5.5.4.6 Capsule bearing plant height (cm) (Fig. 5.6)**

Stability analysis revealed that kharif season (environment index 6.75) was the most favourable season for capsule bearing plant height, whereas low expression observed in summer season (environment index - 9.07). Hybrids ES-111-284 x Lalguda local and IC-413231 x KMS-5-343 were stable genotype and suitable for general adaptation as less sensitive to environment change and produce narrow range of phenotype over the environments. Two hybrids IC-413204 x KMS-5-873 and IC-413209 x KMR-116 were poorly adapted over the environments with low mean. Parent IC-413231 and five hybrids viz. IC-413204 x KMS-5-343, IC-
Fig. 5.5 Relationship between the regression coefficient ($b_i$) and plant height for first capsule (cm).

Stable Genotypes:
- IC-413231 x KMR 116
- IC-413208 x S-0434
- IC-413209 x S-0434
- KMS-5-343
- TKG-22

Average stability:
- Below average stability
- Average stability
- Above average stability
Fig. 5.6 Relationship between the regression coefficient ($b_i$) and capsule bearing plant height

Stable Genotypes
6. ES-111-284 x Lalguda local
7. IC-413231 x KMS-5-343
413208 x KMS-5-343, IC-413204 x Lalguda local, IC-41208 x S-0434, ES-111-284 x KMS-5-343 were highly sensitive to changes in environments as regression coefficient more than unity, however these genotypes tend to perform better in rich environments or favourable environments. Four hybrid viz., IC-413231 x SI-331517, IC-413202 x Lalguda local, ES-111-284 x KMR 116 and IC-413202 x SI-331517 were above average stable and not suitable for favourable environments, however these are specifically adapted to poor or stress environments. Six Parents viz., Lalguda local, IC-413208, KMR 116, IC-413202, SI-331517 and S-0434 and twenty one hybrids were unstable genotypes, out of these IC-413231 x KMR-116, IC-413231 x S-0434, IC-413204 x SI-331517, IC-413204 x S-0434 and GSM-22 x SI-331517 were having high mean.

5.5.4.7 Number of primary branches (Fig. 5.7)

Number of primary branches is major yield components and kharif season (environment index, 0.56) was the most favourable season for this trait, whereas low expression observed during kharif season (-0.53). Parent KMS-5-343 and hybrid GSM-22 x KMS-5-343 with high mean were suitable over diverse environmental conditions. Hybrids ES-111-284 x SI-331517, SI-3218 x KMS-5-343, IC-413231 x S-0434 and IC-413204 x S-0434 with regression coefficient more than unity were highly sensitive for change in environment, however tend to perform better in favourable environments and performance increases with improvement in environment index. Hybrid IC-413204 x SI-331517, IC-413208 x S-0434 and GSM-22 x SI-331517 were above average stable and not suitable for favourable or rich environments, however specifically adapted to poor environment. Four parents viz., IC-413231, S-0434, SI-3218 and GSM-22 and twenty two hybrids were unstable genotypes as shown significant $S^2_{di}$, including genotypes viz., GSM-22 x KMS-5-873, GSM-22 x S-0434, SI-3218 x Lalguda local, GSM-22, SI-3218 and S-0434 with high mean.

Mahdy et al. (1988) found that introduced genotypes were stable in yield and branches per plant along with other traits. Singh et al. (1998)
Fig. 5.7 Relationship between the regression coefficient ($b_i$) and number of primary branches

Stable Genotypes
37. GSM-22 x KMS-5-343
57. KMS-5-343
revealed that entries TC-25 and TC-13 were stable for most of the characters including number of primary branches. Kumaresan and Nadarajan (2002) studied the genotypic stability and phenotypic stability for number of branches within sixty four genotypes. Bhandarkar and Kumar (2010) studied the stability for number of primary branches per plant for six genotypes over there environments. Bhandarkar and Kumar et al. (2010) observed that genotypes TKG-22, RT-46 and TKG-21 were stable for number of primary branches.

### 5.5.4.8 Internode distance (cm) (Fig. 5.8)

Summer season (environment index -0.08) was favourable environment for minimum internode distance, whereas expression enhanced during kharif season (environment index 0.14). Parents GSM-22 and hybrids ES-111-284 x KMS-5-343 and IC-413204 x KMS-5-343 were ideal genotype as per the stability parameters i.e. low mean, bi=1 and S2d around zero. These genotypes produced narrow range of phenotype over the range of environments. Parent IC-413204 and four hybrids viz., IC-413231 x SI-331517, GSM-22 x SI-331517, IC-413209 x KMS-5-873 and IC-413204 x Lalguda local were below average stable genotypes and suitable for rich or favourable environments which reduces the expression of trait. Parents SI-3218, IC-413208 and TKG-22 and hybrids viz., SI-3218 x Lalguda local, IC-413231 x Lalguda local, IC-413202 x Lalguda local, GSM-22 x KMS-5-873 and ES-111-284 x SI-331517 were above average genotypes and specifically adapted to poor environments, which enhances the internode distance. Parent Lalguda local and thirteen hybrids were unstable genotypes as exhibited significant S2di, including genotypes ES-111-284 x Lalguda local, IC-413231 x KMS-5-343 and IC-413204 x S-0434 with low mean.

### 5.5.4.9 Capsule length (cm) (Fig. 5.9)

Capsule length shown increased performance during kharif season (0.05), whereas expression suppressed during summer (-0.05) followed by rabi season (-0.001). None of the genotype was stable over the environments. Parents IC-413208, SI-3218 and KMR 116 and five hybrids
Fig. 5.8 Relationship between the regression coefficient ($b_i$) and internode distance (cm)

Stable Genotypes
1. ES-111-284 x KMS-5-343
19. IC-413204 x KMS-5-343
55. GSM-22
viz., IC-413208 x KMS-5-343, ES-111-284 x KMS-5-343, IC-413209 x KMR 116, IC-413208 x KMS-5-873 and GSM-22 x S-0434 were highly sensitive to change in environments and tend to respond favourably to better environments, however will not perform better in poor environments. Hybrids GSM-22 x SI-331517, SI-3218 x KMS-5-343, IC-413202 x S-0434 and ES-111-284 x KMR-116 were specifically adapted to poor or stress environments, however may not respond favourably in better environments. Parent KMS-5-343 and nine hybrids were unstable genotypes as expressed significant $S^2_{di}$, out of them ES-111-284 x SI-331517, ES-111-284 x S-0434, IC-413231 x KMR-116 and KMS-5-343 were having high mean.

Mahdy et al. (1988) observed that introduced genotypes were stable in yield and capsule length along with other traits, and average stability observed in six promising local cultivar for most of the traits.

5.5.4.10 Number of nodes on main stem (Fig. 5.10)

Wide fluctuations were observed over the environments in expression of character; however rabi season (environment index 3.98) was the most favourable environment. Hybrid IC-413208 x S-0434 was stable genotypes and suitable for wide range of environment. Hybrid IC-413209 x SI-331517 was average stable and poorly adapted to all the environments. Parents IC-413208, SI-3218 and IC-413231 and hybrids IC-413231 x Lalguda local, IC-413231 x S-0434, IC-413202 x Lalguda local, IC-413209 x Lalguda local and IC-413204 x KMS-5-343 were highly sensitive to change in environment, however tend to perform favourably in better or rich environments. Hybrids IC-413204 x S-0434, GSM-22 x SI-331517 and IC-413231 x SI-331517 were above average stable and specifically adapted to unfavourable or stress environment, however may not respond better in rich or favourable environment. Parents GSM-22, ES-111-284, IC-413204, KMR-116 and fourteen hybrids were unstable genotypes as shown significant $S^2_{di}$, out of them genotype IC-413231 x KMS-5-873, IC-413204 x Lalguda local, IC-413209 x S-0434 and GSM-22 x Lalguda local, SI-3218 x Lalguda local and IC-413204 were having high mean.
Fig. 5.9 Relationship between the regression coefficient ($b_i$) and capsule length (cm)

Capsule length (cm)

Below average stability

Average stability

Above average stability

Stable Genotypes
None
Fig. 5.10 Relationship between the regression coefficient ($b_i$) and number of nodes on main stem.
5.5.4.11 Number of nodes for first capsule (Fig. 5.11)

Number of nodes for first capsule is earliness related trait and summer season (environment index -0.88) was favourable environments for this trait. Hybrid IC-413231 x KMS-5-873 and IC-413202 x KMR 116 were stable genotypes and suitable for general adaptation. Hybrids IC-413202 x S-0434, IC-413209 x S-0434 and IC-413204 x KMS-5-873 were suitable for favorable environments. Five parents *viz.*, KMS-5-873, SI-331517, KMS-5-343, IC-413202 and KMR-116 and hybrids IC-413209 x SI-331517, IC-413202 x KMS-5-873, IC-413209 x KMR 116, IC-413209 x KMS-5-873 were specifically adapted for poor or environment and highly desirable. Parents IC-413204, IC-413209, Lalguda local, ES-111-284 and twelve hybrids were unstable genotypes as shown significant $S^2$di, includes genotypes IC-413231 x Lalguda local, IC-413208 x SI-331517, IC-413208 x Lalguda local, IC-413202 x SI-331517 and IC-413209 showing low mean.

5.5.4.12 Number of capsules on main stem (Fig. 5.12)

Highest environment index for *rabi* season (4.79) indicates that it’s most favourable environment for expression of number of capsule per plant. Hybrids IC-413208 x S-0434 and IC-413231 x SI-331517 were stable genotypes and produce narrow range of phenotype and suitable over all environmental conditions. Hybrid IC-413209 x KMR-116 was exhibited average stability and poorly adapted to all environments. Parents SI-3218, KMR 116 and Lalguda local and seven hybrids *viz.* IC-413204 x KMS-5-343, IC-413231 x S-0434, IC-413231 x KMS-5-343, IC-413209 x KMS-5-873, IC-413202 x Lalguda local, IC-413231 x Lalguda local and SI-3218 x Lalguda local were below average stable genotypes and highly sensitive to change in environment, however tend to respond favourably to better environments but poor performer in unfavourable or stress environment. Hybrids GSM-22 x Lalguda local, IC-413204 x S-0434 and GSM-22 x SI-331517 were specifically adapted to stress or unfavourable environments and best suited for *kharif* and summer season. Parents IC-413231, GSM-22,
Fig. 5.11 Relationship between the regression coefficient ($b_i$) and number of nodes for first capsule

- Stable Genotypes
  - 10. IC-413231 x KMS-5-873
  - 25. IC-413209 x KMS-5-343
  - 33. IC-413202 x KMR 116

- Below average stability
- Average stability
- Above average stability

Number of nodes for first capsule
Fig. 5.12 Relationship between the regression coefficient ($b_i$) and number of capsules on main stem

Stable Genotypes
8. IC-413231 x SI-331517
17. IC-413208 x S-0434
ES-111-284, IC-413202 and fourteen hybrids were unstable genotypes as expressed significant $S^2_{di}$, these list include hybrids viz., ES-111-284 x Lalguda local, IC-413231 x KMR-116, IC-413231 x KMS-5-873, IC-413204 x Lalguda local and IC-413231 having high mean.

5.5.4.13 Number of capsules per plant (Fig. 5.13)

Number of capsule per plant experienced wide variation over the environments and *rabi* season (environment index 26.96) was most favourable and summer season (environment index -25.88) unfavourable for expression. Hybrid SI-3218 x Lalguda local was stable genotype and suitable for wider adaptation. Parent IC-413202 was average stable and poorly adapted to all environments. Parent IC-413231 and hybrids ES-111-284 x SI-331517, IC-413231 x S-0434 and IC-413231 x Lalguda local were highly sensitive to change in environments, however suitable for favourable or rich environments and tend to respond better with improvement in environment. Hybrids SI-3218 x KMS-5-343 and IC-413208 x S-0434 were highly desirable because of their specific adaption to poor or stress environments. Seven parents viz., ES-111-284, GSM-22, SI-3218, KMS-5-343, KMR-116, S-0434 and Lalguda local and twenty seven hybrids were unstable genotypes as shown significant $S^2_{di}$, out of them ES-111-284 x KMS-5-343, IC-413204 x S-0434, IC-413204 x Lalguda local, GSM-22 x Lalguda local, SI-3218 x S-0434, SI-3218 and S-0434 were registered high mean.

Mahdy *et al.* (1988) found that introduced genotypes were stable in yield and some other traits including capsule per plant, whereas six promising local genotypes were average stable for most of the traits. Kang Bo *et al.* (2000) observed sesame varieties with high cultural stabilities by comparing several yield components under different environments and found that genotypes shown more stable regression coefficient values for number of capsules per plant. Kumaresan and Nadarajan (2002) studied the stability among sixty four genotypes comprising 48 hybrids and 16 parents for number of capsule.
Fig. 5.13 Relationship between the regression coefficient \( b_i \) and number of capsules per plant

Stable Genotype
48. SI-3218 x Lalguda local
5.5.4.14 Number of seeds per capsule (Fig. 5.14)

Performance varied over the seasons; however *kharif* season (1.75) was the most favourable environment for expression. Hybrid IC-413209 x KMS-5-343 was stable genotype and suitable for wider adaptation. TKG-22 and hybrids SI-3218 x SI-331517 and SI-3218 x Lalguda local were suitable for favourable or rich environments, however poor performer in unfavourable or stress environment. Parents SI-3218 and hybrids ES-111-284 x SI-331517, IC-413231 x KMR 116, IC-413208 x KMR 116 and SI-3218 x KMS-5-343 were above average stable and specifically adapted to poor or stress environments. Four hybrids *viz.*, IC-413204 x S-0434, ES-111-284 x S-0434, SI-3218 x S-0434 and IC-413208 x KMS-5-343 were unstable genotypes as shown significant $S^2_{di}$, out of them ES-111-284 x S-0434 and SI-3218 x Lalguda local were expressed high mean.

Mahdy *et al.* (1988) studied the stability for number of seeds per capsule. Kang Bo *et al.* (2000) observed that genotypes shown more stable regression coefficient values for number of seeds per capsule.

5.5.4.15 Seed yield per plant (g) (Fig. 5.15)

Seed yield per plant is the complex trait and experience high genotype x environment interaction. Sesame is cultivated all over the India during all seasons *i.e.* *kharif*, semi-*rabi*, *rabi* and summer seasons and stability for seed yield is the major issue. Dahoon (2004) reported that, large gap existed in the heterosis reported in experimental hybrids at a single location or two locations and their average performance in multi-location trials at larger plots indicating high genotype x environmental interaction. In present investigation wide range of variation observed for seed yield per plant over the season, however *rabi* season (environment index 2.96) was the most favourable season for expression of seed yield per plant, whereas expression suppressed during summer season (environment index -3.62) followed by *kharif* season (environment index 0.67). Six parents GSM-22, SI-3218, KMS-5-343, KMR-116, S-0434 and Lalguda local; thirty two hybrids were unstable genotypes as exhibited significant $S^2_{di}$, including
Fig. 5.14 Relationship between the regression coefficient ($b_i$) and number of seeds per capsule

Stable Genotype
25. IC-413209 x KMS-5-343
genotypes viz., ES-111-284 x KMS-5-343, ES-111-284 x Lalguda local, IC-413204 x S-0434, IC-413204 x Lalguda local, IC-413209 x Lalguda local, IC-413202 x Lalguda local, GSM-22 x Lalguda local, SI-3218 x S-0434 and GSM-22 with high mean. Twenty seven hybrids were highly sensitive to change in environment as regression coefficient more than unity. None of the genotype showed desirable stable performance; however parents IC-413204 and IC-413202 were average stable and poorly adapted to the all environments. Parent IC-413231 and Hybrids SI-3218 x Lalguda local and IC-413231 x S-0434 were shown below average stability and suitable for favourable or rich environments, and tend to perform better with improvement in environment; however these genotypes were not suitable for stress or poor environments. These genotypes could be used in rabi and kharif season. Hybrids IC-413208 x S-0434 and GSM-22 x KMS-5-873 with high mean were above average stable genotypes and specifically adapted to stress or poor environments and should be tested in drought prone areas or summer season with supplemented irrigation. Further, these genotypes with suitability for favourable or unfavourable environments should be exploited for developing high yielding varieties and hybrids having specific adaptation.

Moneim Babu Fatih et al. (1983) observed that the local lines gave higher yields than the crosses, but showed no marked differences in stability. The high-yielding lines A/4/4, A/4/10, A/5/9 and A/2/15 had average stability. Kumar (1988) observed that strain 4-2 and T-13 were the most stable for seed yield in better environment whereas TC-171 and C-6 exhibited maximum yield in poor environment. Mahdy et al. (1988) observed that introduced genotypes were stable in yield and some other traits, but their yields were low. Giza 23 gave high seed yields and was the only stable local cultivar. Moreover, 6 of the promising local genotypes gave high stable seed yields with average stability for most of the studied traits. Farrokhi and Ahmadi (1998) evaluated 25 improved sesame cultivars for yield stability and genotype-environment interactions and found that Cv.
Fig. 5.15 Relationship between the regression coefficient ($b_i$) and seed yield per plant (g)

Seed yield per plant (g)

- Below average stability
- Stable Genotype
- Above average stability
- Average stability
- None
Moghan 11 and Moghan 18 produced the highest, stable yields. Singh et al. (1998) revealed that genotype MT-5 was characterised 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. Srivastava et al. (1998) suggested that on basis of wide range of yield stability index, breeding objective should be to combine the high yield potentiality of genotypes with stability. Arriel et al. (2000) found that CNPA 88-88 showed high productivity, adaptation to adverse conditions, responsiveness to improved environmental conditions and high stability of seed yield. Mahto and Verma (2001) revealed that 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. Subbaraman and Jebbaraj (2001) observed that genotypes EC 357017, EC 357020, EC 351905 and EC 357022 were stable across environments. Raghuwanshi et al. (2003) observed that genotype Uma, followed by RT-54 were 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. Kumar et al. (2004) observed that 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. Thus, these varieties could well be utilized to develop stable strains having wider adaptability in future breeding programme. Anuradha and Reddy (2005) observed that none of the genotypes exhibited stable performance for all the traits, however, genotypes EC 355653, EC 351882, EC 357312, EC358039, SI 1618, SI 75, YLM 17, DCB 1791 and NAC 8414 were stable for seed yield per plant. Kumaresan and Nadarajan (2005) revealed that parent’s viz., TNAU 28, TN 8467 and B 203 and the F₁ hybrids namely SI 42 x VRI 1 and B 203 x SVPR 1 were identified as stable genotypes with
Stable Genotypes
2. ES-111-284 x SI-331517
31. IC-413202 x KMS-5-343
32. IC-413202 x SI-331517
42. GSM-22 x Lalguda Local
58. SI-331517

Fig. 5.16 Relationship between the regression coefficient ($\beta_i$) and 1000 seed weight (g)
high yield and performance *per se*. Therefore, these genotypes can be recommended for varied environments to exploit their high yield potential. Adebisi and Ajala (2006) recorded regression coefficients from 0.65-1.25 and were statistically close to unity. Genotype, 530-3, with a regression coefficient value of 1.01 and smaller $S_2$ d 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.* (2008) found that genotypes viz., IVTS-05-04; IVTS-05-09 and IVTS-05-25 were have stability for seed yield. These genotypes can be utilized to develop stable varieties having wider adaptability in future breeding programme. Mekonnen and Mohammad (2009) evaluated 20 genotypes across six environments to estimate the nature and magnitude of $G \times E$ for seed yield and identify stable genotypes for general cultivation. Bhandarkar and Kumar *et al.* (2010) showed that genotypes RT-54, TKG-22, RT-46, TKG-55 and TKG-21 were stable for seed yield. Suvarna *et al.* (2011) observed significant differences for seed yield. Genotypes were identified as promising in different locations based on actual seed yield. Among fifty entries only three entries Kanakapura local, ST-3 and ST-16 identified as stable for seed yield.

5.5.4.16. **1000 seeds weight (g) (Fig. 5.16)**

Genotypes experienced fluctuation over the season for 1000 seed weight; however *kharif* season was the favorable season (0.41). Parent SI-331517 and four hybrids *viz.*, ES-111-284 x SI-331517, IC-413202 x KMS-5-343, IC-413202 x SI-331517 and GSM-22 x Lalguda local were stable genotype and suitable for wide range of environments. Parents IC-413231, KMS-5-343, IC-413209, IC-413208 and KMS-5-873 and TKG-22 and Sixteen hybrids *viz.* ES-111-284 x KMS-5-343, ES-111-284 x KMR 116, IC-413231 x KMS-5-343, IC-413231 x KMR116, IC-413208 x KMR 116, IC-413208 x KMS-5-873, IC-413204 x SI-331517, IC-413204 x KMS-5-873, IC-413208 x SI-331517, IC-413209 x KMS-5-343, IC-413209 x KMR-116,
Fig. 5.17 Relationship between the regression coefficient ($b_i$) and oil content (%)
ES-111-284 x KMS-5-873, IC-413231 x SI-331517, IC-413208 x KMS-5-343, IC-413204 x KMS-5-873 and IC-413202 x KMR-116 were suitable for favourable environments and tend to perform better with improvement in environment. Hybrid IC-413204 x Lalguda Local was above average stable and specifically adapted for unfavourable environment. Hybrid SI-3218 x SI-331517 was unstable as expressed significant $S^2_{di}$.

Kumar et al. (2008) studied the stability for 1000 seed weight.

5.5.4.17 Oil content (%) (Fig. 5.17)

Oil content recorded fluctuation with over the environments and kharif season is revealed high expression for oil content. Two hybrids IC-413202 x SI-331517 and IC-413204 x KMR-116 were stable genotypes and suitable for wider environments. Parent IC-413208 and hybrids IC-413209 x KMS-5-343, IC-413208 x SI-331517, IC-413204 x KMS-5-343, IC-413208 x KMR-116, IC-413202 x KMR-116 and IC-413231 x KMR-116 and IC-413208 x KMS-5-873 were below average stable and tend to respond favourably to better environments, however give poor performance in unfavourable environments. Nine parents viz. IC-413231, KMS-5-873, IC-413202, IC-413204, ES-111-284, IC-413209, SI-331517, KMR 116 and KMS-5-343; check TKG-22 and eight hybrids viz. ES-111-284 x KMR 116, ES-111-284 x SI-331517, IC-413204 x SI-331517, IC-413231 x KMS-5-343, IC-413231 x SI-331517, IC-413209 x SI-331517, IC-413209 x KMR116 and ES-111-284 x KMS-5-343 were desirable genotypes as specifically adapted to unfavourable or stress environments. Hybrids IC-413202 x KMS-5-873 and IC-413204 x S-0434 were unstable genotypes as shown significant $S^2_{di}$.

Mahdy et al. (1988), Adebisi et al. (2009) and Mekonnen and Mohammad (2010) were studied the stability for seed oil content.

5.6 INBREEDING DEPRESSION

Inbreeding defined as mating between closely related individual by ancestry. Inbreeding increases homozygosity and intentionally practiced in plant breeding to create genetically homozygous inbred lines for
hybridization. Self pollinated species are tolerant to inbreeding depression and upon self pollination there is no inbreeding depression in pure lines or homozygous lines. It may be defined as the reduction or loss in vigour and fertility as a result of inbreeding and due to fixation of unfavourable recessive genes. Heterosis and inbreeding depression are considered two aspects of the same phenomenon (Falconer, 1981). Inbreeding depression is the decline in fitness and vigor with decreased heterozygosity, whereas heterosis is the increase in fitness and vigor with increased heterozygosity. It is essential to study inbreeding depression along with heterosis to distinguish whether the observed vigor in F1 breaks down in F2 or not. In present study inbreeding depression studied in F2 generations of 48 F1 crosses for seventeen quantitative traits.

5.6.1 Days to flower initiation

Significant inbreeding depression observed in F2’s of 8 crosses, however IC-413208 x KSM-5-343 (18.64%) shown highest followed by ES-111-284 x KSM-5-343 (15.69%) and IC-413231 x Lalaguda local (10.42%). These crosses were expressed delayed flower initiation. Desirable negative inbreeding depression for days to flower initiation was exhibited by four F2’s of crosses viz., SI-3218 x KMR-116 (-18.75%), SI-3218 x S-0434 (-13.95%), ES-111-284 x KMR-116 (-13.33%) and IC-413208 x KMS-5-873 (-13.04%) and these should be utilized for isolating transgressive segregants with earliness to flower initiation.

Saraswathi (2003) reported positive residual heterosis for days to taken for flowering in brinjal. Kumar et al. (2005) studied the relative heterosis, heterobeltosis and standard heterosis in F2 population in bhendi for days to first flower.

5.6.2 Days to 50 percent flowering

Highest significant inbreeding depression shown by F2 IC-413202 x Lalaguda local (16.95%), followed by F2 IC-413231 x KMR-116 (11.11%) and F2 IC-413204 x KMS-5-873 (11.11%). Significant earliness to 50 percent flowering were observed in four F2’s viz., IC-413208 x KMS-5-873
(-54.90%), SI-3218 x KMR-116 (-17.86%), ES-111-284 x KMR-116 (-16.67%) and ES-111-284 x S-0434 (-14.29%). These crosses should be utilized for isolating high yielding and early flowering isolates in later segregating generations.

Gaikwad et al. (2009) and Gaikwad and Lal (2011) observed negative inbreeding depression for days to 50 percent flowering. Banerjee and Kole (2011) revealed that many of the crosses exhibited positive and significant inbreeding depression for all he flowering traits. In other crops, Pathak et al. (2002) revealed that low in magnitude but significant heterosis over better parent have been observed for days to 50 percent flowering in F$_2$ generation of Indian mustard (*Brassica juncea* L.). Patil et al. (2005) recorded negative residual heterosis for days to 50 percent flowering in rice.

5.6.3 Days to maturity

Desirable negative inbreeding depression or inbreeding vigor was recorded by twenty three crosses and significant inbreeding vigor was shown by two F$_2$’s GSM-22 x KSM-5-343 (-27.96%) and GSM-22 x KMR-116 (-23.96%). These crosses might be governed by additive x additive gene interaction and it’s possible to isolate early maturing and high yielding isolates in advance generations. Positive inbreeding depression observed in twenty two crosses and highest expressed by GSM-22 x S-0434 (14.16%).

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. Anuradha and Reddy (2008a) observed the inbreeding depression for days to maturity ranged from -28.60 to 7.00%. Gaikwad et al. (2009) and Gaikwad and Lal (2011) observed negative inbreeding depression for days to maturity. In other crops, Pathak et al. (2002) revealed that low in magnitude but significant heterosis over better parent have been observed for days to maturity in F$_2$ generation of Indian mustard (*Brassica juncea* L.).

5.6.4 Plant height (cm)
Inbreeding depression observed in nineteen crosses and highest inbreeding depression shown by GSM-22 x S-0434 (25.66%) followed by GSM-22 x SI-331517 (18.41%) and IC-413204 x KSM-5-343 (11.31%). In these crosses non-additive gene action may be predominant in the expression of plant height. Highest inbreeding vigor recorded by GSM-22 x KMR-116 (-66.67%) followed by ES-111-284 x KMR-116 (-30.43%) and ES-111-284 x KSM-5-343 (-29.03%) these crosses may be utilized for isolating transgressive segregants for plant height along with high seed yield.


**5.6.5 Plant height for first capsule (cm)**

Seven crosses shown positive inbreeding depression and IC-413208 x Lalguda local (30.43%) and IC-413204 x KMR-116 (25.00%) were significant, followed by IC-413204 x KMS-5-873 (19.17%). These crosses might be governed by non-additive gene action and transgressive segregants should be selected in delayed generations. Twenty seven crosses were expressed significant inbreeding vigor and highest exhibited by IC-413209 x KMS-5-873 (-154.00%).

**5.6.6 Capsule bearing plant height (cm)**
Negative inbreeding depression recorded significantly by seven crosses and SI-3218 x KMS-5-873 (-63.08\%) shown highest, followed by IC-413204 x S-0434 (-50.53\%) and IC-413204 x KMR-116 (-41.22\%) and these crosses may involve additive x additive gene action. Positive inbreeding depression observed in twenty crosses and ES-111-284 x S-0434 (24.35\%) expressed highest, followed by IC-413202 x KMR-116 (23.03\%) and SI-3218 x Lalguda local (20.97\%). Inbreeding depression may be due to non-additive gene action and bi-parental mating or diallel selective mating should be used for breaking the undesirable linkages and accumulate the favorable genes in homozygous condition.

5.6.7 Number of primary branches

Significant positive inbreeding depression expressed by eleven crosses and IC-413204 x SI-331517 (42.11\%) shown highest, followed by IC-413209 x SI-331517 (26.67\%) and IC-413202 x KMR-116 (21.05\%). Non-additive genetic effects may be important in these crosses. Recurrent selection method should be utilized for improvement in these crosses. Inbreeding vigor expressed significantly by thirty one crosses and GSM-22 x S-0434 (-135.29\%) exhibited highest, followed by IC-413231 x S-0434 (-94.74\%), SI-3218 x KMS-5-873 (-85.00\%) and IC-413209 x KMS-5-873 (-81.82\%). Additive x additive gene action may be resulted in inbreeding vigor in these crosses and simple pedigree methods should be utilized for improvement in these crosses.

Anuradha and Reddy (2008a) observed the inbreeding depression for primary branches ranged from -36.56 to 38.89\%. Banerjee and Kole (2010) recorded high inbreeding depression for branch number, indicating the predominance of non-additive genetic effects. In other crop, Pathak et al. (2002) revealed low but significant heterosis over better parent for number of branches (primary and secondary) in F2 generation of Indian mustard (Brassica juncea L.). Saraswathi (2003) also reported positive residual heterosis for primary branches number in brinjal. Kumar et al. (2005)
estimated the relative heterosis, heterobeltosis and standard heterosis in F$_2$ population in bhendi for branch number.

5.6.8 Internode distance (cm)

Internode distance exhibited both positive and negative inbreeding depression, however positive inbreeding depression desirable recorded by thirty three crosses and IC-413231 x KMR-116 (38.71%) shown highest, followed by SI-3218 x KSM-5-343 (30.28%) and IC-413204 x KMS-5-873 (20.83%). This may be due to non-additive genetic effects and selection should be delayed in later generations. Highest inbreeding vigor was shown by SI-3218 x S-0434 (-38.15%), followed by IC-413231 x SI-331517 (-22.52%) and GSM-22 x Lalguda local (-20.00%), these may be due to additive genetic effects.

5.6.9 Capsule length (cm)

Inbreeding depression and inbreeding vigor both were observed in F$_2$ generation of crosses. Twenty crosses were recorded inbreeding depression and GSM-22 x S-0434 (33.82%) expressed highest, followed by IC-413231 x KMR-116 (28.13%) and ES-111-284 x SI-331517 (24.73%). Cross IC-413204 x SI-331517 (-38.10%) was shown highest negative inbreeding depression, followed by IC-413202 x KMR-116 (-30.99%) and IC-413231 x KSM-5-343 (-20.83%). The reason for high inbreeding depression may be due to non-additive genetic effects and isolation of transgressive segregants should be delayed in later generations.

Anuradha and Reddy (2008a) observed the inbreeding depression for capsule length ranged from -27.66 to 47.08%.

5.6.10 Number of nodes on main stem

Most of the hybrids experienced the increase in number of nodes on main stem in F$_2$ generation and ES-111-284 x KSM-5-343 (-218.18%) exhibited highest, followed by IC-413209 x KSM-5-343 (-84.43%) and ES-111-284 x SI-331517 (-84.21%). The high inbreeding vigor may be due to involvement of high additive genetic effects and these crosses could be
exploited for isolating transgressive segregants with superior seed yield per plant.

5.6.11 Number of nodes for first capsule

Reduction in number of nodes for first capsule observed in eight hybrids up to extent of 16.92% by SI-3218 x SI-331517, followed by IC-413231 x KMR-116 (15.79%) and GSM-22 x KMS-5-873 (14.29%). These crosses could be exploited for isolating transgressive segregants for minimum nodes for first capsule along with high yield. Forty one crosses experience increase in number of nodes for first capsule.

5.6.12 Number of capsules on main stem

Thirteen hybrids were shown reduction in number of capsules per plant and highest inbreeding depression recorded by GSM-22 x S-0434 (89.19%) shown highest, followed by IC-413208 x KSM-5-343 (41.10%) and IC-413209 x KMS-5-873 (39.31%). Most of these crosses were expressed significant relative heterosis in F1 and inbreeding depression may be due to involvement of non-additive genetic effects which declined in F2 generation. Twenty one crosses were exhibited significant inbreeding vigor and ES-111-284 x KSM-5-343 (-108.33%) shown highest, followed by IC-413204 x KMR-116 (-107.55%) and SI-3218 x KMR-116 (-96.67%) inbreeding vigor. These crosses revealed negative heterosis in F1 generation; therefore additive genetic effects may be resulted in inbreeding vigor.

Ragiba and Reddy (2000) revealed that crosses showing non-allelic interaction demonstrated high inbreeding depression for capsules on main stem, primaries and secondaries. Anuradha and Reddy (2008a) observed the inbreeding depression for capsules on main stem ranged from -46.86 to 32.26%. In other crop, Kumar et al. (2005) estimated the relative heterosis, heterobeltosis and standard heterosis in F2 population in bhendi node number.

5.6.13 Number of capsules per plant
Most of the crosses experienced increase in number of capsule per plant in $F_2$ generation, may be due to increase in number of primary branches, reduced internode distance, increase number of nodes on mains stem and number of capsule on main stem. Thirty eight crosses recorded negative inbreeding depression and highest shown by SI-3218 x KMR-116 (-144.10%), followed by SI-3218 x KMS-5-873 (-106.41%) and SI-3218 x SI-331517 (-96.65%). These crosses were revealed negative relative heterosis in $F_1$ generation; therefore breeding methods like bi-parental mating or diallel selective mating should be used for isolating high yielding segregants in later generations.

Chavan et al. (1982) revealed that the low value for inbreeding depression associated with capsules/plant and plant height allows the selection for crop improvement. Zhan et al. (1990) found that $F_2$ hybrids appear inbreeding depression and still maintain a definite vigor for capsules per plant. Anuradha and Reddy (2008a) observed the inbreeding depression for capsules per plant ranged from -54.44 to 38.59%. Gaikwad et al. (2009) and Gaikwad and Lal (2011) observed considerable inbreeding depression for capsules per plant in $F_2$ generation. Banerjee and Kole (2010) recorded high inbreeding depression for capsules per plant, indicating the predominance of non-additive genetic effects.

5.6.14 Number of seeds per capsule

Inbreeding depression for number of seeds per capsule observed in twenty eight crosses up to extent of 33.82% in GSM-22 x S-0434, followed by IC-413231 x KMR-116 (28.13%) and ES-111-284 x SI-331517 (24.73%). Significant inbreeding vigor recorded by IC-413204 x SI-331517 (-38.10%), IC-413202 x KMR-116 (-30.99%) and IC-413202 x KSM-5-343 (-18.55%). Additive genetic effects could be responsible for inbreeding vigor, whereas inbreeding depression may due to non-additive genetic effects.

Zhan et al. (1990) found that $F_2$ hybrids appear inbreeding depression and still maintain a definite vigor for seeds per capsule.
Anuradha and Reddy (2008a) observed the inbreeding depression for seeds per capsule ranged from -54.40 to 34.47%.

### 5.6.15 1000 seed weight (g)

Twenty six crosses revealed positive inbreeding depression. Cross IC-413231 x KSM-5-343 (21.95%) was recorded highest inbreeding depression, followed by IC-413231 x KMS-5-873 (13.62%) and GSM-22 x S-0434 (8.73%). Non-additive genetic effects might be involved in these hybrids.

Gokmen (1997) found that 1000-grain weight decreased significantly in the F$_2$ generation of single crosses, followed by three way and double crosses and composite varieties. Banerjee and Kole (2010) observed highest inbreeding depression for 1000 seed weight after seed yield. In other crops, Pathak et al. (2002) observed heterotic responses in Indian mustard (Brassica juncea L.) at the F$_2$ level for yield for 1000-grain weight considerably. Patil et al. (2005) observed high level of residual heterosis (positive and significant) for 1000-grain weight.

### 4.6.16 Oil content (%)

Inbreeding depression was prevalent in F$_2$ generation for oil content up to extent of 33.19%, indicating role of non-additive gene action in expression of trait. Cross SI-3218 x KMR-116 (33.19%) revealed highest negative inbreeding depression, this might be due to involvement of additive genetic effects. Similar results were also reported by Banerjee and Kole (2011).

### 5.6.17 Seed yield per plant (g)

Seed yield per plant is the complex trait and affected directly and indirectly by yield components. Negative inbreeding depression or inbreeding vigor is also referred as residual heterosis. In present study, substantial amount of inbreeding vigor was observe for characters like plant height, number of primary branches, number of nodes on main stem and number of capsule per plant. For seed yield per plant, twenty eight crosses were expressed significant inbreeding vigor in F$_2$ generation and SI-
3218 x KMR-116 (-161.54%) exhibited highest, followed by SI-3218 x KMS-5-873 (-111.65%) and SI-3218 x SI-331517 (-100.81%). Crosses ES-111-284 x SI-331517, ES-111-284 x KMS-5-873, IC-413231 x KMS-5-873, IC-413208 x KMS-5-873, IC-413204 x KMS-5-873, IC-413202 x Lalguda local, GSM-22 x SI-331517 and GSM-22 x KMS-5-873 with significant positive relative heterosis in F₁ generation were shown significant inbreeding vigor in F₂ generation. Additive genetic effects might be involved in these crosses and these crosses could be exploited by simple pedigree methods for isolating superior transgressive segregants in advanced generations. Inbreeding depression was observed in eleven crosses and highest recorded by IC-413202 x KMR-116 (43.64%) followed by IC-413208 x KSM-5-343 (32.45%) and IC-413202 x SI-331517 (30.15%). Five crosses viz., IC-413231 x Lalguda local, IC-413204 x S-0434, IC-413209 x KMS-5-873, IC-413202 x SI-331517 and GSM-22 x Lalguda local with significant positive relative heterosis experienced inbreeding depression in F₂ generation. This might be due to non-additive genetic effects, as non-additive genetic effect tends to decline in F₂ generations of crosses. Bi-parental or selective diallel mating method should be used exploitation of these crosses by breaking the linkages and accumulating the desirable genes in homozygous condition.

In F₂ generation, significant residual heterosis or negative inbreeding depression over parental mean and better parent revealed by twenty four crosses and fourteen crosses respectively. Hybrids with significant heterosis over better parent in F₂ generation, higher or even lower extent in comparison to F₁ generation but more than locally adapted variety could be exploited commercially as F₂ hybrid to reduce the price of hybrid seeds. However, there should not be significant difference in morphological characters of parents involved in cross especially in seed color. Residual heterosis is already reported by few authors in sesame and by several authors in other field crops and vegetables. In present study hybrids viz., SI-3218 x KMR-116 (-161.54%), SI-3218 x KMS-5-873 (-111.65%) and SI-
3218 x SI-331517 (-100.81%) with high negative inbreeding depression or inbreeding vigor could not be exploited commercially because these having parents with different seed color i.e. black x white and expressed segregation in F2 generation for seed color. However hybrids viz., IC-413231 x KMR-116 (-99.58%), IC-413208 x KMS-5-873 (-75.06%), IC-413208 x SI-331517 (-93.70%) and IC-413208 x SI-331517 (-66.45%) with substantial amount of inbreeding vigor could be exploited commercially as F2 hybrid, because parents have similar white colored seeds. Two crosses SI-3218 x S-0434 (-39.81%) and GSM-22 x S-0434 (-32.89%) could be exploited as F2 hybrids in black colored sesame, as both parents were have black colored seeds.

In sesame, Godawat and Gupta (1983) Observed the heterosis and inbreeding depression in all the crosses for most of the characters in different environments. Sodani and Bhatnagar (1990) observed that generally crosses with significant heterosis showed significant inbreeding depression in F2. Zhan et al. (1990) found that F2 hybrids appear inbreeding depression and still maintain a definite vigor for yield per plant, capsules per plant, 1000 seed weight and seeds per capsule. Karuppaiyan and Ramasamy (2001) observed that generally 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. Singh (2002) observed 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. Toprope (2009) observed that maximum limit for the residual heterosis in F2 and F3 was lower than that of heterosis in F1, however observed an appreciable amount of heterosis in F2 and F3. 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. Gaikwad et al. (2009) and Gaikwad and Lal (2011) observed that yield plant -1 and number of capsules plant -1 showed
considerable inbreeding depression in F₂ generation. Banerjee and Kole (2010) observed highest inbreeding depression for seed yield, B67 x Rama exhibited significant positive heterosis in F₁, but non-significant inbreeding depression in F₂ for seed yield. This cross can be utilized as basic material for identifying better pure lines.

In other crops, Rudas (1973) and Kanthaswamy and Balakrishnan (1989) studied residual heterosis in tomato. Sahoo and Mishra (1990) studied residual heterosis in chilli and found 72.6% residual heterosis for number of fruits per plant. Gokmen (1997) observed inbreeding depression in dent maize and found that except ear yield, most of the traits shown decrease in F₂ generation of single crosses, followed by three way crosses, double crosses and composite crosses. Subhashri and Natarajan (1999) studied residual heterosis in chilli and found that CA133 X CA 84 exhibited positive residual heterosis for number of fruits per plant and fruit weight. Pathak et al. (2002) noticed heterotic responses at the F₂ level for yield and yield components in Indian mustard (Brassica juncea L.). Saraswathi (2003) studied residual heterosis in segregating population of six brinjal crosses and residual heterosis for yield was expressed by WCGR x T. Naga (14.16%) and SM-6 x Erengere (1.55%). Li-Rulilian et al. (2004) reported on utilization of F₂ generation hybrid in cotton and observed that the F₂ hybrids have 10-15% higher yield than F₁. The F₂ generation showed better heterosis for yield, quality and pest resistance compared to the parent. Bhutto et al. (2005) evaluated six F₂ interspecific hybrids in wheat, observed 15.78 and 13.92 per cent increase over mid and better parents in kernel yield per plant. Kumar et al. (2005) estimated the relative heterosis, heterobelitosis and standard heterosis in F₂ population in bhendi, and positive heterosis over mid parent and better parent ranged from (6.77% & 13.99%) and (14.48 & 31.40%) for fruit yield by number and weight respectively. This might be due to low inbreeding depression. Patil et al. (2005) studied the residual heterosis in 6 F₂ hybrids of rice. High level of residual heterosis (positive and significant) was recorded for number of
productive tillers per plant, number of grains per panicle, 1000-grain weight and grain yield per plant. Negative residual heterosis was registered for number of days to 50 per cent flowering and pollen fertility. Manoj (2007) observed that residual heterosis in F2 generation of eggplant ranged from 57.22 [R-I/12 x 17 (4-41)] to 71.51 per cent (S.C.H.N. 18) in the population for yield per plant. Shi et al. (2011) indicated that heterosis was generally related to the heterozygosity at the population level but poorly correlated with heterozygosity at the individual level.

5.7 TECHNIQUE AND COST OF HYBRID SEED PRODUCTION

A number of attempts were made by several research workers to standardize method for producing hybrid seed production by hand emasculation & pollination technique. In present study it was found that emasculation in the day before in evening time (4-5 pm) and pollination in next day morning (7-9 am) found beneficial for good seed setting. It was found convenient, to plant one male and all female in same block instead of separate planting of male and female for each cross. Also after successful cross fertilization in few capsules upper part of the stem and branches trimmed to avoid the chances of self fruits and proper nutrition to for seed development in existing fertilized capsules. Sesame has advantage of epipetalous flower for easy emasculation, high number of seeds (40-50) produced per flower, low seed rate (2.0-2.5 kg/ha) and high multiplication ratio (1:150) for manual seed production. However, the cost incurred to produce 1 kg of hybrid seeds (Rs. 4826.12) was very high in comparison to seed prices of available varieties. This cost can be further reduced with help of utilization of cytoplasmic male sterility in hybrid seed production. Virmani et al. (1997) discussed that in the past adoption of hybrid technology in rice was considered impractical because of strict self pollinated nature of the crop and skepticism about the practical feasibility of producing hybrid seed on large commercial scale, fortunately rice breeders overcome this hurdle by developing usable system of cytoplasmic-genic male sterility and packages of efficient and economic hybrid seed
production. More than 50% of area of China is planted under hybrid seeds and many countries outside China developing and exploiting hybrid rice technology. Tu (1998) discussed heterosis in sesame, techniques for hybrid production, especially the improvement of populations, the origin and establishment of male sterile lines and methods of using male sterile lines in breeding and hybrid production. Bhuyan and Sarma (2003) concluded that with availability of CMS systems highly heterotic sesame hybrids can be developed in hybrid breeding programme and future studies for determining the extent of hybrid seed production under natural out crossing would be helpful to ascertain the prospects of the male sterile lines in commercial hybrid seed production. However, male sterility and restoration system in sesame is not established.

The hybrid seed cost could be reduced by exploitation of residual heterosis in F$_2$ hybrids. The hybrids having high heterosis in F$_1$ generation with positive inbreeding depression or inbreeding vigor in F$_2$ generation could be exploited as F$_2$ hybrids, with certain condition such as parents should have similar seed color and not having much difference in other morphological characters. In current study hybrids *viz*., IC-413231 x KMR-116, IC-413208 x KMS-5-873, IC-413208 x SI-331517, IC-413208 x SI-331517, SI-3218 x S-0434 and GSM-22 x S-0434 could be exploited as F$_2$ hybrids as having substantial amount of heterosis in F$_2$ generation over better parent and standard check. In case of hybrids showing high residual heterosis in F$_2$ generation, but parents differ for seed color dehulling may be good choice. Major part of export contained dehulling seeds (approx. 70%); therefore, these hybrids with different colored parents could be exploited commercially after dehulling. Kar and Swain (2003) concluded that in the absence of male sterile line in sesame, the practical possibility for commercial exploitation of heterosis is far reaching due to high cost of F$_1$ seeds produced through hand emasculation and pollination, and recorded the presence of residual heterosis up to 148.32% in F$_2$ for seed yield/plant over Uma, a widely cultivated check variety. These results advocate for
commercial exploitation of desirable crosses having substantial amount of residual heterosis in F_2. In other crops, Kumar (1999) found that in kenef (Hibiscus cannabinus L.), three crosses retained substantial amount of residual heterosis in F_2 generation that may be exploited and utilized commercially with lower cost of seed production. Siles et al. (2004) concluded that even if commercial production of F_1 hybrids is not economical viable, the level of heterosis observed for grain yield even at F_2 generation or other type of population with relative high percentage of heterozygous genotypes would provide a significant yield benefit over non-hybrid varieties.