5. DISCUSSION

Sorghum is the third important food crop after rice and wheat in dry land agriculture in India grown under rainfed conditions. It is a dual purpose crop as the grain is the staple food for millions throughout the world and straw is a principal fodder for milch and drought animals. Eventhough the crop is cultivated extensively, grain yield are not commensurable with the area, reflecting the low productivity levels. The great majority of traditional cultivars cultivated prior to advent of hybrids/high yielding varieties were pure lines highly localized, tall growing, with the late maturity, generally, photosensitive with a low harvest indices.

In India a major breakthrough resulting in green revolution in sorghum occurred with the advent of two hybrids CSH-1 and CSH-2, during 1964 and 1965. Later CSH-4 was added during 1970, as a result of outstanding research efforts of Rao, N.G.P. and his associates (1968,1970). This inputs proved the way for breeding high yielding sorghums and several hybrids/varieties have since been released for cultivation which have proved the test of time in several sorghum growing areas resulting increase in production.

The accelerated growth in the productivity of Khanj sorghum hybrids from CSH-1 to CSH-17 is due to an optimum plant type,
accumulating desirable genes for productivity, incorporating resistance in parental lines and exploiting better heterotic combinations. Though significant heterosis was observed for grain yield in *rabi* sorghum by various workers (Kaul and Rana, 1997), the productivity levels of *rabi* hybrids could not be realised due to biotic and abiotic stresses of *rabi* hybrids.

In the past it was difficult to demonstrate a high level of heterosis and perceptible yield advantage of hybrids over the land races in *rabi* sorghum, though *kharrif* hybrids are very heterotic and productive. The low level of heterosis is attributed to the use of land races germplasm which is non heterotic (Rao, 1970), low harvest index in male parental lines and use of *kharrif* based CMS lines. The intensive breeding effort under taken in the recent years has enabled the development of *rabi* based CMS lines as well as desirable male parents with different degrees of tolerance to biotic stresses. By using such *rabi* based lines, the hybrid CSH 15R was developed in 1997 and the hybrid SPH 1010 was recently released as CSH 19R in 2000 which found high grain yield in these *rabi* hybrids.

The present study is a step forward to examine the variability among recently bred parental lines (CMS and restorer lines) and their $F_1$ and $F_2$ generations derived from different types of crosses with respect to the *kharrif* and *rabi* types comparison as below:

5.1 **VARIABILITY AMONG THE PARENTS AND $F_1$ CROSSES**

The genetic variability in *rabi* sorghum is confined to Indian subcontinent in Southern plateau under receding soil moisture conditions. These land races have limited variability in panicle components though they
possess high biomass productivity. The variability has been induced through the hybridization between RxK types. Therefore efforts were made to compare the variability among the parents and F1's of Kharif and rabi origin. It could be possible to generate different types of hybrids among kharif and rabi parental lines such as KxK, KxR, RxD, RxD and RxD, where K and R pertain to the derived lines of kharif and rabi seasons while GS is referred to the rabi land races.

In the present studies, the kharif parental lines derived form temperate cultivars possessed long panicle length ranging from 21.67 to 31.67 cm, compared to the genetic stocks with panicle length ranging from 14.33 to 15.33 cm. However, hybridization between these two groups has resulted with a range of 17.83 to 29.07 cm. Therefore derived lines represent a variability form rabi to the kharif types. Rao and Rana (1982) reported that, the hybridization between tropical × temperate groups forms the basis of genetic improvement in sorghum. The kharif parental lines were specifically dwarf ranging from 140 to 153.33 cm in contrast to the genetic stocks ranging 189.7 to 221 cm and variability among the derived lines distributed from 129 cm in SPSFR 94006B to 224 cm in RS 615. The derived line RS 615 were taller than the rabi genetic stocks and RS 585, RS 647, RS 653 were moderate length than the rabi genetic stocks. This is possible since the height genes between temperate and tropical types are separately distributed and their recombination may result some of the forms taller than either of parental lines (Quinby and Karpar, 1954). These genotypes therefore, in further combination will enable height gene interaction and development of dual purpose hybrids. The matching height
of parental lines is important in hybrid seed production, since the dual
purpose tall hybrids were required for important CMS lines, such as 104 B,
116 B and 117 B possessed 152 to 174.7 cm plant height. Some of the
recently derived restorer lines such as R 354, RS 647 slightly taller than the
CMS lines, will be useful in the development of dual purpose hybrids. The
CMS lines such as 42 B, SPSFR 94006B, SPSFR 94016B with height ranging
129 to 159 cm are dwarf and match with relatively dwarf restorer lines such
as RS 680, ICSV 93028 and ICSV 95076 with the height ranging from 152.3
to 172.3 cm. The heterosis of the derivatives of temperate x tropical crosses
and demonstrated the superiority of derived dwarfs over original male
parents used in hybrid development in India (Rana et al., 1974).

The variability has been generated among parental lines ranging
from 65.7 to 80 days for days to 50 per cent flowering useful to bred early to
medium duration hybrid. *Khurif* based CMS lines flowered in 65.7 to 74.3
days, *khurif* restorer lines with the matching flowering such as RS 29,
RS 627, C43 and CS 3541 as well as *rabi* based CMS lines flowered in 67.3
to 71.3 days, *rabi* restorer lines with the matching flowering such as R 354,
RS 585, RS 615, RS 651, RS 653 and SPV 839 can be utilized in tandem
with CMS line 104 B as well as early CMS lines 42 B, 401 B and 116 B.
Pathak and Sanghi (1992) observed that the females exhibited greater
variability than the male with respect to days to flowering. The pattern of
variability indicated high seed number in *khurif* types as coupled with low
seed weight in *khurif* genotypes compare to low grain number and bold seed
in *rabi* types. A new variability has been created among the derivatives,
some of the possessed more number of grains transgressing the two parental
groups. Some of the derived parental lines possessed as much as 3.33 to 3.97 g per 100 seed, compared to 2.23 to 3.43 g in kharif parents and about 2.40 to 3.97 g in rabi types. This is an example of fixing of transgressive segregates in the derived parental lines. Similarly some of the derived lines are better than the rabi genetic stocks and at par with best kharif parental lines.

As kharif restorer lines viz., CS 3541, RS 29 and RS 673 are known to be heterotic, it is expected some of the derived parental lines of rabi x kharif restorer lines, will also be heterotic. Some of these rabi derivatives RS 647, 401 B, SPV 839, SPSFR 94016B and 116 B had high per se performance. For grain yield, the heterosis involving these lines would be examined in the later section.

5.1.1 Mean performance of parents, F1's, F2's and population bulks

The results are presented in Table 15. The mean values of days to 50% flowering in F1 hybrids were 69.40 compared to 71.96 days in parents, respectively. This result revealed that most of the hybrids attained days to 50% flowering earlier than either of their parents indicating the presence of dominance in the hybrids for earliness. Earliness is an important character since sorghum is grown mostly as rainfed crop wherein moisture stress is the limiting factor. Similar results were reported by Liang (1967), Kirby and Atkins (1968), Yestrebov and Tsybul-Ko (1971), Shankar Gouda et al. (1972), Giriraj and Goud (1981), Patel et al. (1982) and Jagadeshwar (1985).

The average plant height of the parents was 172.15 cm. The F1's were 234.82 cm tall than their average plant height of parents. In other
Table 15:  Mean performance of parents, F₁’s and their 7 corresponding F₂’s and population bulks in sorghum

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Genotypes</th>
<th>Days to 50% flowering</th>
<th>Plant height (cm)</th>
<th>Number of leaves</th>
<th>Leaf area at 50% flowering (Sq.cm²)</th>
<th>Panicle length (cm)</th>
<th>Panicle width (mm)</th>
<th>No. of primaries / panicle</th>
<th>No. of grains / panicle</th>
<th>Grain seed weight (g)</th>
<th>Harvest index (%)</th>
<th>Fodder weight/plant (g)</th>
<th>Protein content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Parents</td>
<td>71.96</td>
<td>172.13</td>
<td>10.87</td>
<td>1445.81</td>
<td>21.53</td>
<td>5.24</td>
<td>54.02</td>
<td>49.31</td>
<td>1421.64</td>
<td>44.79</td>
<td>2.99</td>
<td>43.26</td>
</tr>
<tr>
<td>2</td>
<td>F₁’s</td>
<td>69.40</td>
<td>224.82</td>
<td>10.00</td>
<td>1650.26</td>
<td>21.94</td>
<td>5.28</td>
<td>54.28</td>
<td>43.74</td>
<td>1457.26</td>
<td>53.14</td>
<td>3.27</td>
<td>42.86</td>
</tr>
<tr>
<td>3</td>
<td>F₂’s</td>
<td>71.05</td>
<td>223.71</td>
<td>9.29</td>
<td>1388.71</td>
<td>20.57</td>
<td>4.98</td>
<td>53.00</td>
<td>38.14</td>
<td>1226.90</td>
<td>49.99</td>
<td>3.03</td>
<td>40.23</td>
</tr>
<tr>
<td>4</td>
<td>Population bulks</td>
<td>67.89</td>
<td>253.56</td>
<td>9.23</td>
<td>1806.67</td>
<td>15.56</td>
<td>5.51</td>
<td>62.22</td>
<td>39.87</td>
<td>1159.56</td>
<td>38.27</td>
<td>3.30</td>
<td>40.00</td>
</tr>
<tr>
<td>5</td>
<td>G. Mean</td>
<td>70.63</td>
<td>207.31</td>
<td>10.28</td>
<td>1538.97</td>
<td>21.28</td>
<td>5.24</td>
<td>54.61</td>
<td>45.29</td>
<td>1400.11</td>
<td>48.41</td>
<td>3.12</td>
<td>42.58</td>
</tr>
<tr>
<td>6</td>
<td>Checks</td>
<td>65.50</td>
<td>230.66</td>
<td>10.67</td>
<td>2036.16</td>
<td>27.00</td>
<td>5.40</td>
<td>60.66</td>
<td>62.66</td>
<td>2122.66</td>
<td>62.23</td>
<td>3.48</td>
<td>46.00</td>
</tr>
</tbody>
</table>
studies, the crosses possessed intermediate plant height between their parents indicating the presence of partial dominance in hybrids. Dremlyuk (1972), Patel et al. (1982), Choudhari (1992) and Ghorade et al. (1997) also observed that hybrids possessing plant height in between their parental lines.

The number of leaves in F₁ hybrids was 10.0 compared to 10.87 in parents. The mean value of the parents was higher than that of the F₁ hybrid mean values indicating reduction in number of leaves in hybrids. Giriraj and Goud (1981) and Hussain Sahib et al. (1988) reported similar results. The average leaf area at 50% flowering increased in F₁ hybrids than that of the parental means values. Salunke and Pawar (1996) reported similar results and Liang (1967) reported increased leaf area in F₁ hybrids of sorghum.

The average panicle length of parents was 21.53 cm and 21.94 cm in F₁ hybrids. The panicle width of parents 5.24 cm and 5.28 cm in F₁ hybrids. The variation for panicle length and width was slightly higher in crosses compared to the parental lines indicating the existence of divergence among crosses for these characters. Thankey et al. (1981) observed maximum heterosis for both characters. Amsalu and Bapat (1990) observed superiority of many crosses over their parents for panicle girth. Most of the crosses of 27 A and 296 A had longer panicle length indicated that these two CMS lines were good combiners to produce long panicle hybrids.

The number of primaries per panicle was slightly high in most of the F₁ crosses than in parents and low in F₂ crosses due to inbreeding depression. Sodani and Chaturvedi (1978) also reported that hybrid may
had more number of primaries/panicle than parents. The number of average seeds/primaries was 49.31 in parents. It was high in case of parents, and low in F₁ and F₂ crosses indicating negative heterosis.

The number of grains per panicle 1226.9 in F₂ to 1457.36 in F₁ and were high in F₁ crosses than in parents (1421.64) and low in F₂ crosses (1226.9) due to inbreeding depression. Goud and Krishna Sastry (1974), Singhania (1980) and Swarnalata et al. (1996) reported similar results. Tomar and Peretz (1973) observed a constant degree of heterosis in yield over mid-parent due to higher number of seeds per panicle.

The grain yield per plant ranged from 38.27 g in bulks to 53.14 g in F₁. The average grain yield was 53.14 g in F₁ and in parents 44.79 g. A wide ranges among crosses for this character indicates the existence of considerable amount of genetic variations. Vasudeva Rao (1973) reported that there was substantial degree of heterosis for grain yield/plant in kharif crosses.

The 100 seed weight in different groups ranged from 2.99 to 3.27 g and was 3.27 g in F₁'s as compared to 2.99 g in parents. The 100-seed weight was higher in F₁ crosses compared to the parent mean values exhibited greater amount of heterosis over parents. Singhania (1980), Patel et al. (1982) and Geeta and Rana (1987) earlier reported presence of heterosis for this character also.

The harvest index was lowest in population bulks and F₂ crosses as compared to F₁ crosses. The harvest index in parents was 43.26 per cent higher than F₁’s was 42.86 per cent. It resulted negative heterosis.
Swarnalata and Rana (1988) and Salunke and Pawar (1996) reported similar results.

The fodder weight/plant in $F_1$ crosses was 73.11 g higher than parent mean values was 57.46 g. It resulted a wide range among crosses for this character indicates the existence of considerable amount of genetic variations. The per cent increase of $F_1$ hybrids over the parents is indicated valuable amount of heterosis. Lodhi et al. (1978) and Shreenivasa et al. (2000) reported standard heterosis for green fodder yield. The protein content in $F_1$ higher than parents mean values. It resulted positive heterosis and Nayeem and Bapat (1984) reported similar results.

5.1.2 Analysis of group means of $F_1$ hybrids

The results are presented in Table 16. The variability is distributed between kharif and rabi types. As rabi land races are bolded and low in seed number, the genetic improvement aimed to transfer high grain number from kharif types. High heterosis was reported in long panicle x compact headed vs. long x long panicles crosses brought out the superiority of better crosses for yield and yield components (Rana and Murthy 1978). Some of the popular hybrids (CSH 5, CSH 6, CSH 9 and CSH 16) are the instances released in subsequent years. In recent years long panicle CMS are bred in rabi placing them at par with kharif CMS lines. However differences in panicle length of kharif and rabi restorer lines have been described earlier. Present study examines it a fresh with recent derivatives using type of crosses KxK, RxK, RxR and RxGS where, K is kharif type parent, R is rabi type parent and GS was the genetic stock (rabi local land races). The rabi hybrids CSH 15R and CSH 19R represented, both hybrids a
### Table 16: Different types of group means of F_1 hybrids in sorghum

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Genotypes</th>
<th>Days to 50% flowering (days)</th>
<th>Plant height (cm)</th>
<th>Number of leaves</th>
<th>Leaf area at 50% flowering (Sq.cm)</th>
<th>Panicle length (cm)</th>
<th>Panicle width (cm)</th>
<th>No. of primaries / panicle</th>
<th>No. of seeds / primaries</th>
<th>No. of grains / panicle</th>
<th>Grain yield per plant (g)</th>
<th>100-seed weight (g)</th>
<th>Harvest Index (%)</th>
<th>Fodder weight / plant (g)</th>
<th>Protein content (%)</th>
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<tbody>
<tr>
<td>G-1</td>
<td>K x K</td>
<td>66.80</td>
<td>210.33</td>
<td>11.13</td>
<td>1908.00</td>
<td>29.07</td>
<td>5.93</td>
<td>61.80</td>
<td>58.13</td>
<td>2372.60</td>
<td>63.25</td>
<td>3.12</td>
<td>45.60</td>
<td>83.78</td>
<td>9.64</td>
</tr>
<tr>
<td>G-2</td>
<td>R x K</td>
<td>80.75</td>
<td>244.00</td>
<td>10.67</td>
<td>1897.00</td>
<td>21.50</td>
<td>5.19</td>
<td>47.92</td>
<td>45.66</td>
<td>1511.41</td>
<td>61.75</td>
<td>3.27</td>
<td>44.20</td>
<td>80.40</td>
<td>7.31</td>
</tr>
<tr>
<td>G-3</td>
<td>K x R</td>
<td>66.20</td>
<td>217.60</td>
<td>9.00</td>
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<td>42.00</td>
<td>58.38</td>
<td>7.02</td>
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<td>G-4</td>
<td>R x R</td>
<td>69.50</td>
<td>244.78</td>
<td>9.78</td>
<td>1762.50</td>
<td>20.95</td>
<td>5.53</td>
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<td>1049.67</td>
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<td>40.25</td>
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<td>209.00</td>
<td>10.67</td>
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<td>60.33</td>
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<td>3.53</td>
<td>46.90</td>
<td>80.40</td>
<td>7.83</td>
</tr>
</tbody>
</table>

K = Khurif;  
R = Rabi;  
GS = Genetic stock (local land races);  
G = Groups
Table 16: Different types of group means of F₁ hybrids in sorghum

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Genotypes</th>
<th>Days to 50% flowering</th>
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<th>Number of leaves</th>
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<th>Panicle length (cm)</th>
<th>Panicle width (cm)</th>
<th>No.of primaries / panicle</th>
<th>No.of seeds / primaries</th>
<th>No.of grams / panicle</th>
<th>Grain yield per plant (g)</th>
<th>100-seed weight (g)</th>
<th>Harvest index (%)</th>
<th>Fodder weight / plant (g)</th>
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<tr>
<td>G-1</td>
<td>K x K</td>
<td>66.80</td>
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<td>11.13</td>
<td>1908.00</td>
<td>29.07</td>
<td>5.93</td>
<td>61.80</td>
<td>58.13</td>
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</table>

K = Khari;  
R = Rabi;  
GS = Genetic stock (local land races);  
G = Groups
than check (CSH 19R). The KxK, RxE crosses were closer to CSH 17 and CSH 19R, respectively. There is a possibility of increasing yield potential of rabi hybrids, if the high grain number is increased in rabi restorer lines on the pattern of kharif restorer lines. This is a possible through increasing grain number per primaries and diversity brought in the form clustered grain in the primary branch (Rana & Murthy 1978). The cross combination rabi x kharif to produce the highest heterosis for grain yield and majority of yield components (Patil and Thomber 1986).

In RxR type of crosses, grain size of SPH 1077 (3.77g) was bolder seed than other type of combinations. The other groups of crosses with boldness were closer to checks, these are RxK and RxR hybrids. The 100-seed weight of KxK crosses was 3.12 g and thus lowest. In these crosses, where rabi types was one of the parent the seed weight was higher than typical kharif based hybrids. The distinction of high grain number per panicle in kharif hybrids and high grain weight in rabi based crosses still continuing and need to be bridged by improving rabi based restorer lines. The harvest index in KxK crosses was more than the other groups and 3.07 per cent higher than RxK crosses. Therefore, where one or both kharif parents were involved, the harvest index was higher. The rabi land races are known for low harvest index and that trend still continues.

The leaf area at 50 per cent flowering was highest in KxK crosses (1908 sq.cm) followed by RxK crosses (1897 sq.cm). It was low in case of RxR (1762.5 sq.cm) and RxGS crosses (1298 sq.cm) as compared to typical kharif type crosses. In case of kharif hybrids, 25% leaf area was reported in F1 than inbreds at panicle initiation stage (Rao et al., 1998). Thus kharif
parent in crosses contributes high leaf area. Breeding for dual-purpose type is targeted in sorghum and thus both high grain and fodder yield is required. The fodder yield was highest in SPH 1102 (120.40 g/plant) followed by dual-purpose hybrid CSH 13 (115 g/plant) while KxK crosses were on par with the both checks, the RxK and RxR crosses were closer to CSH 19R the level of fodder yield potential. It appears that some taller hybrids were not necessarily higher in fodder yield. Such situation happens when peduncle is too long. The protein content variation from 7.02 to 9.64 per cent among different type of crosses is in normal limits relatively high (9.64%) protein content was observed in KxK crosses followed by CSH 9 (10.53%) which was higher than the both standard checks, CSH 17 and CSH 19R.

5.1.3 Range of heterosis (%) over BP in different type of crosses

The results are presented in Table 17. Several workers reported the heterosis in sorghum. Kaul and Rana (1997) reported 39.3 to 44.3 per cent heterosis for grain yield in hybrids involving genetic stocks and KxK derivative restorer lines. The yield heterosis was also positively correlated with per se performance thus high yielding hybrids in rabi sorghum would have high heterosis. It is thus pertinent to study the variation in heterosis in different type of crosses KxK, KxR, RxK, RxR and RxGS where, K = kharif, R = rabi, and GS = genetic stock (local land race type parental lines) to make breeding strategy. Recently release of rabi hybrids CSH 13R was based on KxK, CSH 12R (KxR), CSH 15R and CSH 19R (RxR) type cross combination, he later being combining more desirable traits and CSH 13 most productive under protection from shoot fly both rabi and kharif season (Rao and Rana 1998). The present study brought out that for grain yield the heterosis per
Table 17: Range of heterosis (%) over better parent (BP) for fourteen characters in different types of crosses

<table>
<thead>
<tr>
<th>Character</th>
<th>Type of crosses and range of heterosis [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K x K Minimum</td>
</tr>
<tr>
<td>Days to 50% flowering</td>
<td>-7.17</td>
</tr>
<tr>
<td>Plant height (cm)</td>
<td>-2.00</td>
</tr>
<tr>
<td>No. of leaves</td>
<td>20.000</td>
</tr>
<tr>
<td>Leaf area at 50% flowering (sq cm)</td>
<td>27.84</td>
</tr>
<tr>
<td>Peduncle length (cm)</td>
<td>7.80</td>
</tr>
<tr>
<td>Peduncle width (cm)</td>
<td>23.26</td>
</tr>
<tr>
<td>No. of primaries/particle</td>
<td>22.48</td>
</tr>
<tr>
<td>Grain yield/plot (g)</td>
<td>13.59</td>
</tr>
<tr>
<td>100 seed weight (g)</td>
<td>0.09</td>
</tr>
<tr>
<td>Harvest index (%)</td>
<td>-15.01</td>
</tr>
<tr>
<td>Fodder weight/plot (g)</td>
<td>2.75</td>
</tr>
<tr>
<td>Protein content (%)</td>
<td>-8.04</td>
</tr>
</tbody>
</table>

K: Khart; R: Rab; CS: Genetic stock (Local land races)
cent ranged from 3.07 - 52.40 per cent in RxK crosses. In case of KxK and RxR crosses the maximum heterosis was 38.62 - 50.23 per cent but in other crosses it was found to be as low as 11.77 - 23.19 per cent. In KxK and RxK crosses all hybrids manifested positive heterosis for grain yield, but in other type of crosses, some hybrid expressed the negative heterosis. While KxK and RxK hybrids provide better option for heterosis.

Ghorade et al. (1997) defined the days to 50 per cent flowering economically important character for the hybrids. For days to 50 per cent flowering, the heterosis ranged from -10.59 to 22.50 per cent. The negative value indicated the heterosis for earliness in all cases. Such hybrids may be better adopted under higher moisture stress. In case of KxK, KxR and RxGS all crosses exhibited negative heterosis only. Variation for heterosis for plant height ranged from -34.66 to 48.77 per cent. In RxR crosses, the heterosis was maximum ranging from 0.59 to 48.77 per cent followed by RxGS cross combinations such hybrids have higher potential to bred dual purpose hybrids. Moderate heterosis was observed in KxK, KxR and RxK where kharif parent was involved. The heterosis ranged from -34.28 to 14.28 per cent, for panicle length. The maximum heterosis was observed from RxR followed by KxK crosses.

The range of heterosis for number of primaries per panicle was -29.14 to 11.04 per cent, maximum being in RxR crosses. In other crosses positive heterosis was low ranging from 0.61 to 2.45 per cent. Number of seeds per primaries also exhibited low heterosis except RxR crosses. The positive heterosis ranged from 7.38 to 27.46 per cent. Some of the crosses pertaining to KxK and RxK exhibited 7.38 to 13.98 per cent heterosis.
Earlier Quinby (1963), Kambel and Webster (1965), Tomar and Peretz (1973) and Swarnalata Kaul et al. (1996) reported seed number per panicle has been attributed responsible for increased grain yield. In KxK crosses all the hybrids manifested positive heterosis for number of grains per panicle. In case of RxK crosses, the heterosis was maximum range were 18.19 per cent. Other hybrids showed negative heterosis. Most of the hybrids for 100-seed weight in KxK, RxR followed by KxR type of crosses showed positive heterosis ranging from 0.96 to 35.52 per cent. In fodder weight KxK and RxK crosses showed positive heterosis value ranged from 2.75 to 113.52 per cent.

For protein content, the heterosis ranged from -19.07 to 21.93 per cent. The KxK crosses maximum heterosis was 21.93 per cent followed by RxR crosses 9.13 per cent heterosis. Nayeem and Bapat (1984) reported positive heterosis over better parent for this character.

### 5.1.4 Performance of hybrids for grain yield and yield components

It is identified above that KxK and RxK hybrids are much higher yielding than KxR, RxR and RxGS hybrids. But the range of heterosis for grain yield was highest (3.07 – 52.40%) in RxK crosses over better parent. Therefore, there is a possibility to identify high heterotic hybrids from RxK group of crosses. In general, four out of five KxK crosses were significantly superior to the rabi hybrid check, CSH 19R. Among these, CSH 13 was highest yielding (73.10 g/plant) followed by CSH 16 (64.0 g/plant). The CSH 13 hybrid has already been released for kharif and rabi seasons and has proved its high potential to break the yield plateau in both seasons (Rao and Rana 1998). However seed size (3.12 g) in the KxK hybrids and inadequate
resistance to shoot-fly could not make the impact. Hence hybrids involving one or both nubi based parent possessing bold grain could result in more acceptable hybrids. Some of these KxK crosses (CSH 9, CSH 13, CSH 16, SPH 999), RxK crosses (104A x ICSV 95076, SPH 1026, 104A x ICSV 93028), KxR crosses (SPH 733 and SPSFR 94006A x RS 585), RxR crosses (CSH 15R and SPH 922) and RxGS cross combination (SPH 1075) were significantly high yielding than the both checks, CSH 17 and CSH 19R. It is pertinent here that specific cross combination need to be examined to exploit individual cross superiority and different level of heterosis over high yielding check, CSH 17 and CSH 19 R (Plate No.3).

In general, the KxK hybrids can be characterized with high grain yield long panicle, more number of primary branches, number of seeds per primary branches, number of grains per panicle and high harvest index. Rao and Rana (1982) have earlier reported that such characteristics of temperate x tropical sorghum in contrast to local cultivars.

5.2 HETEROSIS

Heterosis successfully exploited by plant breeders in increasing the yield of cultivated crops. Many workers reported varying level of heterosis in relation to mid-parent, superior parent (heterobeltiosis) and high yielding check (standard heterosis) in sorghum hybrids.

In the present study the estimates for heterosis computed over mid-parent, superior parent and standard heterosis were found to be highly variable among different crosses for all the characters during kharif season.
Plate No.3: Commercial released hybrids utilised as checks

(a) CSH 17 (*kharif* hybrid)

(b) CSH 19 R (*rabi* hybrid)
a) CSH 17

b) CSH 19R
Days to 50 per cent flowering indicating negative heterosis over mid-parent, better parent and standard checks values in most of the hybrids. These results indicating the presence of non-additive gene action controlling this characters. Negative heterosis for days to 50 per cent flowering indicates earliness of the crosses which is one of the most desirable agronomic characters since sorghum is grown mostly as rainfed crop wherein moisture is the limiting factor. Late genotypes usually yield less under conditions of moisture stress. Liang (1967), Shankare Gowda et al. (1972) and Franca et al. (1986) also reported earliness of F₁ hybrids over the superior parent. Quinby (1963), Liang (1967) and Yestrebov and Tysbul-Ko (1971) observed earliness of flowering in F₁ hybrids of sorghum. Liang et al. (1972) and Giriraj and Goud (1981) also found heterosis to be negative for days to first flower. Significant heterosis in sorghum hybrids for earliness was reported by Kirby and Atkins (1968) and Shankare Gouda et al. (1972) also Indi and Goud (1981) reported low heterosis for days to 50% flowering in rabi sorghum.

Heterosis for plant height was positive and significant in all the crosses except one cross viz., SPH 733, which had negative value. Kulkarni and Shinde (1985) recorded high heterosis of 40.4 per cent in respect of plant height whereas in the present studies 69.26 per cent (42 A x RS 654) heterosis in plant height was recorded. Hirayoshi et al. (1956), Agrikar and Chavan (1957), Dremlyuk (1972), Vasudeva Rao (1973), Singhania (1980), Thankey et al. (1981), Patel et al. (1982), Kulkarni and Shinde (1985), Franca et al. (1986), Jebraj et al. (1988), Choudhari (1992), Dremble and Galiba 1993), Ghorade et al. (1997), Salunke and Deore (1998 a) and Shreenivasa
Heterosis for panicle length and width were found to be positively significant in some of the hybrids over mid parental and better parental values. Positive heterosis for panicle length and width is preferred as it results in plants with longer panicles and more breadth, which ultimately leads to increased yield per plant. These results are in conformity with the findings of Agrikar and Chavan (1957), Subramanian et al. (1962), Goud et al. (1973a), Vasudeva Rao (1973), Goyal and Joshi (1976), Singhania (1980), Thankey et al. (1981), Sarada Mani (1981), Patel et al. (1982), Rana et al. (1983), Franca et al. (1986), Jebraj et al. (1988), Nimbalkar et al. (1988), Hussain Sahib et al. (1988), Dremble and Galiba (1993), Swarnalata Kaul et al. (1996) and Salunke and Deore (1998 a).

Out of twenty-four crosses, four hybrids showed positively significant over mid parental values and seven hybrids exhibit positive heterosis over better parental values for number of primaries per panicle. This result indicated the existence of over dominance (non-additive gene action effects) controlling this character. Similar results obtained by several workers. Rana and Murthy (1978) reported the superiority of hybrids to their parents with respect to primary branches per panicle. Sodani and Chaturvedi (1978), Sarada Mani (1981), Geeta and Rana (1987) and Hussain Sahib et al. (1988) observed positive heterosis in the hybrid. Shahane (1980) and Patel et al. (1982) observed heterosis and heterobeltiosis for number of primary branches per panicle. Nimbalkar et al. (1988) observed high significant heterosis over mid parental values indicated a predominance of non-additive gene action. None of the hybrids exhibited significant standard heterosis over the both checks, indicated that the hybrids had significantly
less number of branches per panicle compared to the checks, CSH 17 and CSH 19R.

For number of seeds per primaries, few number hybrids have recorded positive and significant heterosis and heterobeltiosis in the present study. Rest of the hybrids expressed negative heterosis for this character. Rana et al. (1983) also reported heterosis for number of seeds in panicle branches at the bottom. This character was predominantly governed by additive gene.

Eight and six crosses out of 24 crosses exhibited positive and significant heterosis and heterobeltiosis for number of seeds per panicle, respectively. Similar results reported by different workers. Subramanian et al. (1962), Quinby (1963) and Kambel and Webster (1965) reported increased yield in hybrids was due to increased seed number per panicle. Franca et al. (1986) and Swarnalata Kaul et al. (1996) observed heterosis over better parent was positive for this character. Tomar and Pena (1972), Tomar and Peretz (1973), Vasudeva Rao (1973), Goud and Krishna Sastry (1974), Sodani and Chaturvedi (1978), Singhania (1980), Gao (1984), Salunke and Deore (1998 a) observed heterosis in the hybrids. Six hybrids exhibited positively significant standard heterosis over the check (CSH 19R). This result revealed that most of the hybrids had significantly less number of seeds per panicle as compared to the check (CSH 19R). The CSH 13 (296A x RS 29) exhibited highly significant and positive heterosis over the check. Hence, CMS line 296A were good combiners to produce heterotic hybrids for his character. The CMS line 296 A is a female parent of five released commercial hybrids.
For grain yield heterosis of 18 to 60 per cent and above was recorded in 16 hybrids, heterobeltiosis of 15 to 52 per cent was recorded in 15 hybrids and 11 to 44 per cent standard heterosis in two hybrids (over CSH 17) and six hybrids (over CSH 19R). Among different crosses CSH 16 in kharif type and CSH 15R in rabi type exhibited positive and very high heterosis 58.22 and 60.43 per cent and heterobeltiosis 50.23 and 38.63 per cent, respectively. All the three types of heterotic effects were exhibited positively and significantly heterosis. Heterosis for grain yield was reported by Agrikar and Chavan (1957), Kirby and Atkins (1968), Yestrebov and Tsybul-Ko (1971), Tomar and Pena (1972), Dremlyuk (1972), Collins and Pickett (1972), Goud et al. (1973a), Vasudeva Rao (1973), Goud and Krishnasastry (1974), Kaul and Rana (1977), Shinde (1977), Rao et al. (1978), Patel et al. (1982), Geeta and Rana (1987), Choudhari (1992), Shankarapandian et al. (1994), Ghorade et al. (1997) and Scapim et al. (1998).

over checks, CSH 17 and CSH 19R (a high yielding check) in some of the combinations.

For the character 100-seed weight, eleven hybrids had bolder seeds and have recorded heterosis, nine hybrids exhibited positive and significant heterobeltiosis while two hybrids over CSH 17 and six hybrids over CSH 19R recorded positively significant standard heterosis. Among the different hybrids CSH 13 (30.48%), 401A x SPV 839 (30%) and SPH 999 (24.36%) showed high heterosis and heterobeltiosis for 100-seed weight over respective checks (CSH 17 and CSH 19R). These results are in conformity with the studies carried out by Goyal and Joshi (1976), Singhania (1980), Patil et al. (1982), Patel et al. (1983), Geeta and Rana (1987) and Hussain Sahib et al. (1988). However, Shankargowda et al. (1972) reported low heterosis for 100-grain weight and Franca et al. (1986) noticed negative heterosis for this attribute. Agrikar and Chavan (1957), Subbarao et al. (1976 a, b), Sodani and Chaturvedi (1978), Harer and Bapat (1982), Nimbalkar et al. (1988) and Salunke and Deore (1998a) found heterosis for 1000-grain weight.

For the character harvest index, most of the hybrids were found to be exhibited negative heterosis and heterobeltiosis. Out of 24 crosses, one and six crosses exhibited positive and significant heterosis and heterobeltiosis, respectively. The SPSFR 94006A x RS 585 cross, showed significantly positive heterosis (18.91%) and positive heterobeltiosis (9.50%) for harvest index over other crosses. Rao and Rana (1998) also established hybrid superiority over inbred lines. Other workers like Swarnalata and
Rana (1988) and Salunke and Pawar (1996) reported moderate heterosis for harvest index.

In the present study, sixteen and thirteen crosses expressed positive and significant heterosis and heterobeltiosis for fodder yield per plant, respectively, while fourteen crosses recorded significant standard heterosis over check CSH 17. Hybrids CSH 13, CSH 16 and SPH 1102 exhibited high heterosis, high heterobeltiosis and standard heterosis over check, CSH 17 for this trait than the other crosses. Hirayoshi et al. (1956) and Lodhi et al. (1978) also reported positive heterosis for fodder yield in sorghum hybrids. Mal (1984) and Manickam and Vijendra Das (1995) observed higher heterosis and heterobeltiosis for green fodder yield while Shreenivas et al. (2000) exhibited good standard heterosis for this character.

Out of twenty for crosses, nine crosses showed positive and significant heterosis and remaining crosses showed negative heterosis for protein content. Liang (1967) also reported negative heterosis for protein content. Out of 24 crosses only eight crosses showed positive and significant heterobeltiosis for protein content. Kharif hybrids, CSH 9 and SPH 999 exhibited high heterosis and heterobeltiosis for this trait than the other crosses. Nayeem and Bapat (1984) also showed heterosis and heterobeltiosis for protein content.

5.3 INBREEDING DEPRESSION

The inbreeding depression has been reported as reverse phenomena of heterosis. The most striking observed consequence of
Plate No.4: Some of the hybrids showing segregation in $F_2$ generation

(a) CSH 13

(b) CSH 17

(c) CSH 19 R
a) CSH 13 ($F_2$ generation)

b) CSH 17 ($F_2$ generation)
c) CSH 19R (F₂ generation)
magnitude of inbreeding depression varied from 16.57 to 32.14 per cent in 
F2 generation. Similar variations in the magnitude of inbreeding depression 
for grain yield of sorghum has also been recorded by Kulkarni et al. (1977), 
Dangi and Paroda (1979), Goyal and Joshi (1984), Geeta and Rana (1987), 
Reddy and Joshi (1993) and Scapin et al. (1998) in F1 to F2 and F3 
generations. Rubaihaya and Mukumbi (1976) also reported significant 
inbreeding depression for grain yield.

In the present case, highest yielding hybrids showed high heterosis 
for panicle length, panicle width and 100-seed weight and the most heterotic 
F1 hybrid showed the most inbreeding depression in F2 generation. Similar 
results were obtained by Patil et al. (1983) showed high heterosis for these 
characters and the most heterotic F1 hybrids showed the most inbreeding 
depression in the F2 generation. In case of 100-seed weight all crosses 
exhibited non-significant inbreeding depression. Nimbalkar et al. (1988) also 
reported similar kinds of observation for 1000-grain weight.

Variation in inbreeding depression in component characters from 
F1 to F2 revealed complexities in the inheritance of grain yield in sorghum. 
Among the different component traits, number of grains per panicle showed 
moderate inbreeding depression in F2 generation (29.8%). The level of 
heterosis and inbreeding depression varied from cross to cross. In case of 
CSH 13 the high heterosis (54.39%) was coupled with low inbreeding 
depression (40.96%) which is an indication of more additive genetic variance 
in this cross coupled with low epistasis and dominance variances. The 
pattern in CSH 16 and SPH 1026 was similar to that of CSH 13 for number 
of grains per panicle. In case of CSH 19R, heterosis for number of grains per
panicle was low (2.98%) followed by high inbreeding depression (28.77%). There should be high dominance and epistasis variances acting in opposite direction in $F_1$, which drastically diminished in $F_2$, resulting in low heterosis and high inbreeding depression. The pattern in CSH 15R and SPH 922 was similar to that CSH 19R for this character.

Out of seven, four hybrids showed significant inbreeding depression for number of primaries/panicle. Nimbalkar et al. (1988) has also recorded significant inbreeding depression for number of primaries in panicle in some crosses. The number of whorls per panicle depicted significant inbreeding depression in $F_2$ and other generation also reported by Reddy and Joshi (1993).

For fodder yield, the inbreeding depression was correspondingly lower than heterosis, in all the seven crosses. Therefore, non-additive genetic variance might have played important role in $F_1$ resulting 22.40 to 118.55 per cent heterosis. The heterosis got diminished in different degrees resulting in 2.25 to 56.03 per cent inbreeding depression. Similar results for fodder yield of sorghum has also been recorded by Paroda et al. (1978), Jhorer and Paroda (1976) also reported least inbreeding depression in $F_2$ and $F_3$ generation.

Low inbreeding depression and heterosis was observed in days to 50% flowering and in plant height. Similar kind of results obtained by Liang et al. (1972). Rathore and Singhania (1987) also reported the inbreeding depression for plant height in sorghum.
5.4 CHARACTER ASSOCIATION

A knowledge about the degree and direction of association between yield and yield components is essential to initiate any selection programme. In the present investigation was therefore, conducted to determine the nature of associations by correlation and regression analysis for grain yield to develop a selection strategy in sorghum.

In general the genotypic correlations higher than their corresponding phenotypic correlations. This would probably due to modifying effect of environment on character association at genetic level. These results are conformity with that of Sindagi et al. (1970 b) who also found higher magnitude of genotypic correlations than phenotypic correlation values for most of the characters.

The grain yield (Table 7) was significantly and positively correlated with panicle length, panicle width, number of seeds/primaries, number of grains/panicle, leaf area at 50 per cent flowering, 100-seed weight, harvest index, fodder weight and protein percentage. This suggests that selection based on these traits would be very effective for realizing high yield potential.

The character day to 50% flowering, plant height, number of leaves per plant and number of primaries/panicle registered positive correlation with grain yield but were non-significant. These results were conformity with the findings of Kolhe (1951), Vishnuswarup and Chaugale (1962), Sindagi et al. (1970a), Pokle et al. (1973), Kambal and Abu-el-resim (1976), Goud and Asawa (1978), Patel et al. (1980), Dabhulkar et al. (1983), Navale et al. (2000) and Lata Chaudhary and Arora (2001).

In the present studies significant and positive association of days to 50% flowering with number of leaves was observed. Senthil and Palaniswamy (1995) also observed days to 50 per cent flowering were positively and significantly correlated with number of leaves. Rao et al. (1973) noticed days to 50% bloom was more important to yield than plant height in sorghum.

Usually the fodder weight indicates the vigorous plant and therefore the increasing the fodder weight, thought direct indication of the taller plant, could result in higher fodder yield. In present case significant correlation of fodder yield with plant height, leaf area at 50 per cent flowering, panicle width, number of grains per panicle and 100 seed weight was observed. These results are in conformity with the earlier workers of Vishnu Swarup and Chaugale (1962), Rohewal et al. (1964), Kulkarni and Sreekrumulu (1973), Patel et al. (1973) and in same case fodder yield were negatively correlated with harvest index. Swarnalata and Rana (1988) have also noticed that fodder yield was negatively correlated with harvest index.

The harvest index in combination of fodder weight can contribute a high grain yield and high fodder yield but the correlation between fodder
weight and harvest index is negligible and therefore in present case both these traits were to be independent. Therefore there is likelihood to select tall plant and high fodder yield genotypes with high harvest index, such genotypes were 116 B, SPV 839, CSH 16 and CSH 13.

The strong association of grain yield with panicle length, panicle width, number of seeds per primaries, number of grains per panicle, 100-seed weight, harvest index, fodder weight, protein content and leaf area at 50 per cent flowering are in conformity with the findings of Sindagi et al. (1970a), Badwal (1971), Kulkarni and Sreernamulu (1973), Pokle et al. (1973), Chauhan and Singh (1975), Cheralu and Rao (1989b), Dubey (1992), Veerabadhiran et al. (1994), Jayaprakash et al. (1997) and Kumaravadival and Amirathadevarathinam (2000). Test weigh (100-grain weight) association with grain yield was also reported by many workers including Kandaswamy and Subramanian (1980), Thomber et al. (1982), Heinrich et al. (1983) and Sayeed et al. (1986). Negatively relationship was observed between 100-seed weight and number of grains per panicle. These results are in accordance with the findings of Rao and Rana (1998).

5.5 REGRESSION ANALYSIS

The information on association between grain yield with their components is prerequisite for breeding programme amid at high yielding genotypes. In this method it is possible to identify the variable that is most important contributor for ultimate grain yield. As per the data (Table 8) the variable i.e., 100-grain weight had maximum regression coefficient of 9.6465 units with $R^2$ of 9.726 was functional.
Hence, it may be conducted that for grain yield alone could contribute maximum than other characters. Therefore, simultaneous selection for this character is expected to improve the grain yield. The character viz., panicle length, panicle width, number of seeds per primaries, number of grains per panicle, leaf area at 50 per cent flowering, harvest index, fodder yield and protein content have least contribution for grain yield. Thus, these associations could provide valuable guidelines for the development of high yielding varieties as well as hybrids for future breeding programmes.

5.6 OFFSPRING-PARENT REGRESSION

Heritability has been described as proposition of heritable variation to the total phenotypic variation and can be defined as the ratio of additive genetic variance to phenotypic variance (Falconer, 1960). Heritability of a matrix character happened to be one of its most important properties. This will also determine degree of resemblance between relatives and can play a predictive role. Expression of the variability of the phenotypic value is a guide to the breeding value.

Various studies have reported heritability estimate in broad sense and narrow sense. Usually estimates based on analysis of variance of one or more location gives higher heritabilities such as observed in the present case. Broad sense heritability ranged from 66 to 99 per cent. Similar reports made by other workers. However, in this case genotypic variation is taken, as indicative of heritable variation and therefore the estimates of broad sense heritability for predicting genetic advance may be unreliable.
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Based on offspring-parent regression, the heritability of grain yield in F₁ was 66 per cent and in F₂ it was 18 per cent. Earlier also heritability of grain yield in similar range have been reported by Ross et al. (1981), Potdukhe et al. (1994) and Gururaja Rao and Patil (1996). Therefore, grain yield is high heritable character when parents and F₂'s are considered. However, it increased in F₁ since that dominance gene interaction played important role to reflect high grain yield in F₁'s.

As regarded the panicle width, heritability was moderately high in F₁'s and F₂'s. It was 34 per cent and 35 per cent, respectively. Moderate heritability value were also reported for panicle width by Wankhade et al. (1985) and Singh (1994). The number of seeds per primaries (80%) and number of grains/panicle (92%) has exhibited high heritability in F₁ and low heritability in F₂ since high breeding value to phenotypic value have been expressed in F₁. Both characters showed high heritability due to specific combinations in F₁, which might have dissipated in F₂. There is a possibility that dominance gene interaction might have played important role to reflect the high number of grains in F₁. High heritability estimates recorded by Spivakov (1990), Birader et al. (1996), Gururaja Rao and Patil (1996), Amit Dadheech et al. (1999) and Narkhade et al. (2000) for number of grains per panicle.

In case of 100-seed weight the heritability in F₁ (19%) and in F₂ (52%) were recorded. Similar range recorded by George et al. (1968). Herefore 100-seed weight is a low heritable character when parents and F₁'s are considered. Additive gene effects seemed to have a minor contribution to e inheritance for 100-seed weight.
The percentage of protein content found to be highly heritable as 78 per cent and 53 per cent heritability in F₁ and F₂ is a good indicator of high heritability. High heritability estimates also recorded by Ross et al. (1981), Ross and Hookstra (1983) and Phul and Allah Rang (1986).

5.7 GENETIC VARIABILITY

In the present investigation, most of the plant characters showed a wide range of phenotypic variation. The magnitude of the phenotypic variation, however, does not reveal the relative amounts of genetic and non-genetic components of the variation. This was ascertained with the help of some genetic parameters such as genotypic and phenotypic coefficient of variation (GCV/PCV), heritability estimates and genetic advance.

High values of GCV and PCV were obtained for number of grains per panicle, leaf area at 50 per cent flowering, fodder weight per plant, grain yield per plant, number of seeds per primaries, panicle length, plant height and number of primaries per panicle indicating that variation in these characters contributed markedly to the total variability. It is also evident that there is great scope for improvement of these characters either by direct selection among the collections of genotypes or by improving carefully chosen parents in hybridization. Similar kind of observations also reported by Goud et al. (1980), Kumar and Singh (1986), Potdukhe et al. (1994), Birader et al. (1996) and Lata Chaudhary et al. (2001).

All the characters studied showed moderate to high estimates of broad-sense heritability. The heritability estimates of more than 80 per cent indicates that environmental variation may not reduce the high heritability
of the phenotypic values an indication of genotypic value of these characters. This also indicates the major role of additive gene action for these characters. High heritability estimates were also recorded by Panchal et al. (1979), Patil et al. (1980), Phul and Allah Rang (1986), Cheralu and Rao (1989a), Birader et al. (1996), Gururaja Rao and Patil (1996), Narkhede et al. (2000b) and Lata Chaudhary et al. (2001) for many of these characters. High value of heritability of polygenically controlled traits such as panicle length, number of primaries per panicles, number of seeds per primaries, number of grains per panicle and grain yield are useful to plant breeders, for making effective selection for these traits on phenotypic basis.

The components of grain yield like number of grains per panicle, leaf area, fodder weight, plant height, panicle length and number of seeds per primaries exhibited high genetic advance over mean coupled with high estimates of broad-sense heritability values indicating that variation in them are attributable to high level of additive effects. Similar reports were published by Potdukhe et al. (1994) and Birader et al. (1996). Earliness showed low estimates of genetic advance coupled with high estimates of broad-sense heritability. It may be due to the presence of non-additive gene effects and high genotype environment interaction. Similar kind of observations made by Narkhede et al. (2000b).

5.8 GENETIC DIVERSITY AMONG PARENTS, HYBRIDS (F₁'S AND F₂'S) AND POPULATION BULKS

The choice of parents, play an important role in breeding programme. Parents selected from genetically divergent groups are expected to be more heterotic. The multivariate analysis (D₂-statistic) for selection of
parents has an important bearing on the assessment of genetic divergence for use in conventional breeding programme (Bhatt, 1970). The present study investigated the genetic divergence between 60 sorghum genotypes and its relation to heterosis.

The all genotypes fell into eleven distinct groups on the basis of genetic diversity for yield and yield contributing characters. The clustering pattern obtained in the present study revealed that genetic diversity was not necessarily associated with geographical diversity. The most of the genotypes developed at one station at NRC for Sorghum, Hyderabad station were also grouped in different clusters (Table 11). This indicated that there was no association between clustering pattern and eco-geographical distribution of the genotypes which is contrary to the finding out of Sabharwal et al. (1995) and Asthana et al. (1998) in sorghum. The studies on genetic divergence conducted by Biradar et al. (1997), Narkhede et al. (2000a) and Gurpreet singh et al. (2001) in sorghum indicated that geographical diversity was not necessarily related to genetic diversity, which confirmed the present findings.

The hybridization involving genetically diverse parents belonging to different clusters separated by high inter-cluster values is suggested for achieving desirable heterosis/or for isolating recombinants (Malm, 1968; Rana and Murthy, 1978). In present studies groups the parents and some of their hybrids in the same cluster though lack of distinctness between parental lines and their hybrids may be the important reason for grouping together. It may, defeat the criteria of selecting divergent parents for hybrids breeding except in few instances. In this respect crossing between lines of
clusters I and VI, and III and VI will exhibit high heterosis and maximum transgressive segregants. Keeping this in view, the divergence between cluster I is considered than CMS line 296 A can be selected as a female parent and genotypes like RS 647, RS 653 and RS 654 can be selected as the restorer lines. The another opportunity will be selection of restorer lines like R 354, RS 627 and C 43 and utilizing CMS lines such as 27 A and 42 A from cluster III. These lines are presently being utilized in experimental hybrids. Similarly CMS lines such as 104 A, AKMS 14A and 401 A and restorer lines such as CS 3541 and RS 680 from cluster VI were identified as promising parents for developing superior hybrid programme.

In the present study, the fourteen hybrids showing significant and positive heterosis over better parent (out of these, nine superior hybrids showed in Table 18 and two hybrids over standard check CSH17, respectively, for grain yield indicated that parents of each hybrid fell into different groups (Table 18) except for cross 27A x C43 (CSH16). Similar observation was made by He Zhong-hu (1991) among wheat lines where in he observed that, in some crosses, standardized potence (heterosis) in not dependent on genetic distance, but on the specific combinations.

These observations clearly indicate that, in general, crossing genetically diverse parents could give high heterotic performance in hybrids. It is thus suggested that parents from diverse groups should be selected for hybrid breeding programme in sorghum.
Table 18: Superior hybrids over better parent, commercial check (heterosis %) and their parental clusters.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Hybrids</th>
<th>Parental clusters</th>
<th>Characters</th>
<th>Grain yield/plant (g) BP</th>
<th>Fodder yield/plant (g) BP</th>
<th>Protein content (%) BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>104 A x ICSV 93028</td>
<td>VI x IV</td>
<td></td>
<td>52.40**</td>
<td>-3.30</td>
<td>34.60**</td>
</tr>
<tr>
<td>2</td>
<td>CSH 16 (27 A x C 43)</td>
<td>III x III</td>
<td></td>
<td>50.23**</td>
<td>-2.38</td>
<td>113.52**</td>
</tr>
<tr>
<td>3</td>
<td>104 A x ICSV 95076</td>
<td>VI x XI</td>
<td></td>
<td>41.04**</td>
<td>-11.08**</td>
<td>43.00**</td>
</tr>
<tr>
<td>4</td>
<td>CSH 15R (104 A x RS 585)</td>
<td>VI x II</td>
<td></td>
<td>38.62**</td>
<td>-12.60**</td>
<td>77.05**</td>
</tr>
<tr>
<td>5</td>
<td>CSH 13 (796 A x RS 29)</td>
<td>I x VIII</td>
<td></td>
<td>30.30**</td>
<td>11.48**</td>
<td>98.10**</td>
</tr>
<tr>
<td>6</td>
<td>SPH 999 (AKMS 14A x RS 627)</td>
<td>VI x III</td>
<td></td>
<td>29.20**</td>
<td>-20.38**</td>
<td>2.75</td>
</tr>
<tr>
<td>7</td>
<td>SPH 1102 (116 A x RS 680)</td>
<td>VII x VI</td>
<td></td>
<td>28.18**</td>
<td>29.02**</td>
<td>83.81**</td>
</tr>
<tr>
<td>8</td>
<td>SPH 922 (117 A x RS 385)</td>
<td>IV x II</td>
<td></td>
<td>25.14**</td>
<td>-3.60</td>
<td>58.03**</td>
</tr>
<tr>
<td>9</td>
<td>SPH 1026 (116 A x RS 647)</td>
<td>VII x I</td>
<td></td>
<td>23.50**</td>
<td>4.16</td>
<td>61.67**</td>
</tr>
</tbody>
</table>

* Heterosis (%) over better parent and commercial check (CSH 17)
BP: Better parent; CC: Commercial check