Heterosis and combining ability analysis in Tetraploid Cotton (G. hirsutum and G. barbadense L.)

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Abstract
The present investigation was carried out with a view to study the heterosis, combining ability and gene action for seed cotton yield, yield attributing traits, ginning outturn and important fibre quality parameters in tetraploid cotton (G. hirsutum L. and G. barbadense L.). A set of 31 genotypes consisting of 21 (HxB) hybrids, seven lines of G. hirsutum, three testers of G. barbadense and one check hybrid DCH 32 was grown at Rasi Seeds Research and Development Farm, Attur. The hybrids were developed adopting Line x Tester mating design. Analysis of variance showed significant differences among the parents and hybrids for all the characters indicating presence of genetic variability. Combining ability analysis indicated that both additive and non additive gene effects were important in the inheritance of all the traits. The ratio of variance due to GCA to that of SCA was less than one for all the characters under study indicating importance of dominance gene effects in the inheritance of these characters. The parents CG 64 (hirsutum), CG 67 (hirsutum) and CG 45SB (barbadense) were good general combiner for the seed cotton yield per plant and number of bolls per plant. CG 45SB was also a good combiner for the 2.5 per cent span length. The cross CG 64 x CG 45 SB recorded the highest per se performance and standard heterosis for seed cotton yield. Two crosses viz., CG 64 x CG 45SB and CG 67 x CG 45SB registered significant per se performance, positive sca effects along with significant positive standard heterosis for seed cotton yield and majority of yield components and fibre quality traits.

Key words: Cotton, Lx T analysis, heterosis, combining ability, gene action

Introduction
Cotton, the king of fibre, is one of the most momentous and important cash crops of the country. It is the most important commercial crop contributing nearly 65 per cent of the total raw material needs of the textile industry in our country. Cotton is cultivated in an area of 115.53 lakh hectares with the production of 375 lakh bales (Anonymous, 2014). Among the four cultivatied species of cotton, the varieties and hybrids belonging to G. hirsutum, G. barbadense, hirsutum X hirsutum and hirsutum X barbadense hybrids were widely cultivated in India. In India, around 7 – 9 lakh bales of Extra long staple cotton is needed for the textile mills but the production is only around 5.0 lakh bales. The inter specific hybrids (G. hirsutum X G. barbadense), which are one of the source for ELS cotton production, is to be exploited to meet the demand. Several workers reported higher heterosis in case of interspecific hybrids. Exploitation of heterosis (G. hirsutum XG.barbadense) on commercial scale and systemic varietal improvement through hybridization are the main tools to increase ELS cotton production. Study of combining ability is important for selecting parents for hybridization. Sprague and Tatum (1942), proposed the concepts of general combining ability (gca) and specific combining ability (sca). According to them, GCA variance is due to additive variance and SCA variance is due to non-additive variance, both act as an important diagnostic tool in selection of suitable parents and cross combination. Among the various design used for combining ability analysis, Line x Tester analysis (Kempthorne, 1957) has been extensively used to assess the combining ability of parents and crosses for different quantitative characters as well as to study the extent of heterosis for yield, yield contributing characters and fibre quality traits in cotton.

Materials and Methods
The present investigation was carried out at Research and Development Farm of Rasi Seeds, Attur during winter, 2009. The experimental materials consisted of 21 hybrids (hirsutum Xbarbadense) obtained by crossing seven lines (hirsutum) viz., CG62, CG64, CG67, CG91, CG92, CG150 and CG163 and three testers (barbadense) viz., CG45SB, CG45E and CG305. The hybrids and parents were evaluated in randomized block
design with two replications. Each treatment was raised in four rows of 6.8 m length spaced at 1.2 m apart with plant to plant distance of 75 cm. All the recommended agronomical practices and plant protection measures were followed as and when required to raise a good crop of cotton. Observations were recorded for number of bolls per plant, boll weight (g), seed cotton yield per plant (g), number of seeds per boll, ginning outturn (per cent), lint index (g), seed index (g), 2.5 span length (mm), uniformity ratio (per cent), fibre strength (g/ tex), Micronaire and elongation percentage. Data were recorded on five random competitive plants from each entry from all replications and mean of five plants was taken for further analysis. Observations were recorded on number of bolls per plant, boll weight (g), seed cotton yield per plant (g), ginning outturn (per cent), lint index (g), seed index (g), 2.5 per cent span length (mm), uniformity ratio (per cent), fibre strength (g/tex), Micronaire (10^6 g/inch) and elongation. Data were recorded on five random competitive plants from each entry from all replications and mean of five plants was taken for further analysis. Combining ability analysis were estimated as per Kempthorne (1957). Standard heterosis was estimated as per the procedure suggested by Shull (1948) and Liang et al. (1971).

Results and Discussion

Analysis of variance showed highly significant differences due to genotypes for all the traits indicating the presence of sufficient variability in the experimental materials (Table 1). Parents and hybrids showed significant differences for all the characters studied. Significance of variance in parents and hybrids provides adequacy for comparing the heterotic expression for all the characters except lint index. The ratio of variance due to GCA to that of SCA was lesser than one for all the characters which shows the predominance of dominant gene action for all the characters under study indicating the exploitation of heterosis by hybrid development is the most suitable method of breeding. These findings are in agreement with those obtained by Simon et al. (2013).

Information on the per se performance and nature of general combining ability effects (gca) of characters is necessary for selection of suitable parents for developing hybrids. The gca effects of the parents along with their mean performance for various characters are given in Table 2 and 3. Based on the per se performance, the hirsutum line CG163 (217.6 g), was superior for the seed cotton yield per plant followed by CG91 (217.15 g) and CG150 (207.9 g). The barbadense genotype CG45E was superior for 2.5 span length (41.10 mm) and CG45 SB was superior for fibre strength (36.9 g/tex). The parents viz., CG 45SB (37.87 g), CG 64 (31.94 g) and CG 67 (29.19 g) were good combiners for the seed cotton yield per plant. These parents also recorded significant gca effects of 25.48, 24.90 and 19.57 for number of bolls per plant, respectively. The genotype CG150 recorded the highest significant gca effect (0.24) for boll weight, number of seeds per boll (1.45), ginning outturn (2.96) and lint index (1.26). For the character 2.5 per cent span length, the genotypes CG 45SB and CG 62 recorded the highest significant gca effects (1.03). The genotype CG 67 registered the highest significant gca effect (2.63) followed by CG 62 (2.30) and CG 45SB (1.41) for fibre strength. These results are in agreement with the findings of Rao and Gopinath (2013) and Amir et al. (2012).

The sca effects of the hybrids along with their mean performance for various characters are given in Table 4. The specific combining ability (sca) effect alone may not be the appropriate choice for exploitation of heterosis because the hybrid with low mean value may also possess high sca effect. Hence, the cross combinations were to be identified based on two criteria viz., per se performance and the gene action involved in the crosses for further exploitation. In the present investigation, based on the per se performance, the cross combination CG64 x CG 45SB was found to be the best based on superior for seed cotton yield (353.4 g), number of bolls per plant (166.5), boll weight (4.4 g) and number of seeds per boll (25.5). This cross combination also recorded the highest significant sca effects for boll weight (0.45), number of seeds per boll (3.31) and elongation percentage (0.66). The hybrid combination CG150 x CG45E was superior for ginning outturn which recorded 33.55 per cent of mean performance of ginning outturn. For lint index, CG 150 x CG 45E was superior based on per se performance (6.9 g) and sca effect (0.41). Regarding the fibre quality traits, the cross combination CG64 x CG 45SB for 2.5 per cent span length (39.8 mm) followed by CG 64 x CG 45SB (39.45 mm) showed maximum mean value than grand mean. For the fibre strength, the hybrid CG 64 x CG 45SB was superior for mean performance (35.7 g/tex) and significant sca effect (1.72). Similar results were earlier reported by Vineela et al. (2012) and Amir et al. (2012).

A summarized account of the best parent per se, best general combiner, best F₁ per se, most heterotic crosses and best specific combination...
for various characters studied in the present investigation are presented in Table 5. The cross CG 64 x CG 45SB recorded the highest per se performance for seed cotton yield per plant (353.40 g) and standard heterosis of 49.81 per cent, number of bolls per plant (166.50) and standard heterosis of 129.66 per cent, number of seeds per boll (25.50) and standard heterosis 2.00 per cent, uniformity ratio (47.15) and standard heterosis 9.65 per cent followed by the CG 67 x CG 45 SB for seed cotton yield, number of bolls per plant and fibre quality traits. All the parents involved in these crosses are having good general combining ability for seed cotton yield per plant and number of bolls per plant. The heterosis in this cross might have resulted from interaction of dominant gene contributed by both good combining parents. Pathak and Kumar (1975) reported close relationship between gca effects of parents and sca effect of their resultant crosses. In case of fibre quality properties, the cross CG 64 x CG 45 SB recorded 39.45 mm of 2.5 per cent span length, and 33.15 g/tx of fibre strength and standard heterosis of 8.45 and 21.21 per cent, respectively with the positive significant sca effects. The respective parents are also having significant positive gca effects for the 2.5 per cent span length and fibre strength. The next overall best hybrid CG 67 x CG 45 SB recorded high per se performance and standard heterosis for 2.5 per cent span length, fibre strength but negative sca effect for 2.5 per cent span length. Both the parents involved in this cross were having good general combining ability. Marked negative sca effect for 2.5 per cent span length in the cross CG 67 x CG 45 SB could be attributed to the lack of co-adaptation between favorable alleles of the parents involved. Gururaj Rao et al. (1977) reported that this was probably due to mutual cancellation of components of heterosis. The results are in agreement with the research findings of Patel et al. (2012) and Sekharet et al. (2012).

In the present investigation, the parent CG 64, CG 67 and CG 45 SB were found to be promising due to their high yield potential as well as significant and positive general combining ability effects for yield and its contributing characters and for 2.5 per cent span length and fibre strength. Therefore, these three parents could be effectively used for hybrid breeding programme as well as introgression breeding. The cross combinations having high mean yield, high heterosis and desirable sca effects is of immense importance for hybrid cotton breeding programme. For seed cotton yield and major yield attributes as well as important fibre quality parameters the hybrids viz., CG 64 x CG 45SB and CG 67 x CG 45 SB showed positive and significant per se, standard heterosis and sca effects. Consequently, these two hybrids appeared promising for commercial release after thorough testing. The results are in conformity with the reports of Maisuria et al. (2007) and Sekharet et al. (2012).

References
Anonymous . 2014. All India Coordinated Cotton Improvement Project, Coimbatore, Tamilnadu, India.

http://ejplantbreeding.com

Table 1. Analysis of variance for combining ability for twelve characters in cotton

<table>
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<tr>
<th>Source of variation</th>
<th>DF</th>
<th>Number of bolls per plant</th>
<th>Boll Weight (g)</th>
<th>Seed cotton yield per plant (g)</th>
<th>Number of seeds per boll</th>
<th>Ginning outturn (per cent)</th>
<th>Lint Index (g)</th>
<th>Seed Index (g)</th>
<th>2.5 Span Length (mm)</th>
<th>Uniformity Ratio (per cent)</th>
<th>Fibre Strength (g/tex)</th>
<th>Micronaire</th>
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* Significant at 5% probability level, ** Significant at 1% probability level.
Table 2. Mean Performance of Lines and testers for twelve characters in cotton

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<th>Seed cotton yield per plant (g)</th>
<th>Number of seeds per boll</th>
<th>Ginning outturn (per cent)</th>
<th>Lint Index (g)</th>
<th>Seed Index (g)</th>
<th>2.5 Span Length (mm)</th>
<th>Uniformity Ratio (per cent)</th>
<th>Fibre Strength (g/tex)</th>
<th>Micronaire</th>
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* Significant at 5 % probability level, ** Significant at 1 % probability level.
Table 3. Estimates of general combining ability (gca) effects of Lines and testers for twelve characters in cotton

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<th>PARENTS</th>
<th>Number of bolls per plant</th>
<th>Boll Weight (g)</th>
<th>Seed cotton yield per plant (g)</th>
<th>Number of seeds per boll</th>
<th>Ginning outturn (per cent)</th>
<th>Lint Index (g)</th>
<th>Seed Index (g)</th>
<th>2.5 Span Length (mm)</th>
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<th>Micronaire</th>
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* Significant at 5 % probability level, ** Significant at 1 % probability level.
Table 4. Per se performance and estimates of specific combining ability (sca) effects of hybrids for twelve characters in cotton

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<th>CROSS</th>
<th>Number of bolls per plant</th>
<th>Boll weight (g)</th>
<th>Seed cotton yield per plant (g)</th>
<th>Number of seed per boll</th>
<th>Ginning outturn (per cent)</th>
<th>Lint index (g)</th>
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Mean of hybrids 109.6 4.0 270.6 22.8 29.9 5.5
CD 5% 2.97 0.1 3.5 1.7 0.2 0.2
CD 1% 4.05 0.2 4.8 2.4 0.3 0.28

* Significant at 5% probability level, ** Significant at 1% probability level.

Contd.,
### Table 4, contd.

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<th>Fibre Strength (g/tex)</th>
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Mean of hybrids 12.8 37.6 44.4 30.2 3.2 5.3 0.2 0.3 0.2 0.2
CD 5 % 0.2 0.3 0.1 0.2 0.1 0.1
CD 1 % 0.2 0.5 0.2 0.3 0.2 0.2

* Significant at 5 % probability level, ** Significant at 1 % probability level.
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<td>CG62 X CG45SB</td>
<td>39.80</td>
<td>CG163 X CG305</td>
<td>1.08</td>
<td>CG62 X CG45SB</td>
<td>8.45</td>
<td>CG62 (1.03) X CG45SB (1.03)</td>
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<td>CG64 X CG45SB</td>
<td>39.45</td>
<td>CG91 X CG45E</td>
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<td></td>
<td>CG67 X CG45SB</td>
<td>39.30</td>
<td>CG150 X CG45SB</td>
<td>0.94</td>
<td>CG67 X CG45SB</td>
<td>7.08</td>
<td>CG64(0.16) X CG45SB (1.03)</td>
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<td>9.</td>
<td>Uniformity Ratio (per cent)</td>
<td>CG64 X CG45SB</td>
<td>47.15</td>
<td>CG150 X CG305</td>
<td>1.39</td>
<td>CG64 X CG45SB</td>
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<td>CG64 (1.08) X CG45SB (0.81)</td>
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<td>CG163 X CG45SB</td>
<td>46.65</td>
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<td>10.</td>
<td>Fibre Strength (g/tex)</td>
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<td>CG62 X CG45SB</td>
<td>1.72</td>
<td>CG62 X CG45SB</td>
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<td>CG67 X CG45SB</td>
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<td>CG150 X CG305</td>
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11. Micronaire

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<td>18.46</td>
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<td>CG91(0.14)X CG45SB (-0.11)</td>
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12. Elongation

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*Figures in parenthesis indicates gca effects*