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Research Article

# Combining ability and heterosis for yield contributing and fibre quality traits in the hybrids of *Gossypium hirsutum* L.

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**Abstract**
The present study was investigated in thirty five hybrids of *Gossypium hirsutum* L. for combining ability and heterosis for ten yield and fibre contributing traits. These hybrids were obtained by the crosses made between seven lines and five testers. None of the crosses was superior for all the traits studied for the mean performance. The hybrid TCH 1199 × GTHV 323 showed the highest mid and better parent heterosis for the lint index and the hybrid TCH 1828 × RHC 1409 exhibited the highest significant mid and better parent heterosis for ginning outturn. The characters *viz.,* boll weight and single cotton yield per plant were identified to have the highest significant mid and better parent values in the hybrid BSH 18 × RHC 1409. For yield contributing traits *viz.,* the number of sympodial branches per plant and the number of bolls per plant out numbered in the hybrid CO 14 × KC 3 with the maximum standard heterosis among the thirty five hybrids. Combining ability analysis exhibits the dominance of non- additive gene action in all yield and fibre quality contributing traits. Among the lines CO 14 and TCH 1828 were estimated as the best combiners for yield and quality traits, respectively. Among the testers, KC 2 and KC 3 were found to be the best among all the five testers. The hybrid BSH 18× RHC 1409 exhibited the highest *sca* for the boll weight and seed cotton yield per plant and the hybrid BSH 18 × GISV 323 exhibited the highest *sca* for the quality traits *viz*., ginning out turn and upper half mean length; TCH 1828 × KC 3 and CO 14 × KC 2 best performed hybrids for *sca* values for the quality traits *viz.,* elongation length and micronaire values.

**Keywords:** Cotton, $F_1$ hybrids, heterosis, combining ability.

## INTRODUCTION

Cotton (*Gossypium* spp.) is the most important fiber and major cash crop in India and has high commercial value to increase the income of millions of farmers all over the world. India is one of the largest producers of cotton (*Gossypium* spp.) around the world and the production was 26%. The yield per kilogram of a hectare (459 kgs/ha) is still decreasing against the world average yield of about 757 kg/ha (AICCIP Annual Report, 2019-2020). Among the four cotton species, *Gossypium hirsutum* derived cultivars give the highest production, which accounts for 90%. Even though upland cotton has wider adaptability and increased productivity, the low quality of its fiber products requires novel improvements and advances in spinning technology as suggested by Sarfraz *et al*. (2021). The most important genetic tool in boosting the yield of self as well as cross pollinated crops is only the phenomenon of heterosis which has been proven to be the most important genetic tool as reported by Chakholoma *et al*. (2021). It is considered to provide the major breakthrough in the field of crop improvement. Due to easy hand emasculation and pollination, the exploitation of hybrid vigour in cotton on commercial scale has become feasible and economical.

Line × Tester analysis provides a systematic approach for the detection of appropriate parents and crosses in terms of investigated traits. The first step in a successful breeding programme is the selection of better parents. The parents should be with the good combining ability (GCA) and parental combinations with high specific combining ability (SCA) effects and with distant genetic divergence for different kinds of high economical characters (Kumaresan,1999). The Line × Tester analysis (Kempthorne,1957) provides a methodical approach for the evaluation of suitable parents and cross combinations for most of the yield depending traits. The main purpose of the present investigation was carried out to identify the suitable parents with good combining ability and superior hybrids with specific combing ability between thirty five crosses acquired by crossing seven lines and five testers in Line × Tester fashion for eight biometrical characters to enhance yield and fibre quality in cotton (*Gossypium hirsutum* L.).

## MATERIALS AND METHODS

The present research work was carried out during *Rabi*, 2019-2020 in the experimental field at the Department of Cotton, Centre for Plant Breeding and Genetics (CPBG), Tamil Nadu Agricultural University (TNAU), Coimbatore. Thirty-five $F_1$ hybrids were obtained from the crosses between seven lines *viz*., BSH 18, MCU 5, CO 14, TCH 1828, CO 17, TCH 1199 and Suraj and five testers *viz*., KC 2, KC 3, GTHV 15-34, GISV 323 and RHC 1409 in L×T fashion. Randomized Block Design (RBD) was used for each entry with two replications in two rows with the spacing of 90× 45 cm. Five plants from each replication were randomly tagged for the observation of yield, quality and its contributing traits namely, plant height (cm), the number of sympodial branches, the number of bolls per plant , boll weight (g), lint index (g), single cotton yield per plant (g), ginning outturn (%), upper half mean length (mm), elongation length (%) and micronaire value (µg per inch) and the characters were studied. Heterosis studies were carried out by comparing the $F_1$ with better parent and the check (SVPR 1). The hybridization programme was done for 45 days to get a sufficient quantity of crossed bolls. Each randomly tagged five plants per replication were harvested separately and ginned to obtain $F_1$ seeds. Simultaneously, parental seeds were also produced by selfing selected plants same as the procedure followed by Monicashree *et al*. (2017).The statistical analysis was done by using all biometrical mean data over five randomly tagged plants in each replication using the TNAUSTAT software package tool.

## RESULTS AND DISCUSSION

Mean performance acts as an important criterion as it reveals the true value of the hybrids as reported by Udaya *et al*. (2020). The mean performance of 35 $F_1$ hybrids for seed cotton yield and their associated traits in *Gossypium hirsutum* L. were studied. The genotypic values in the mean square value in **Table 1**, illustrated showed highly significant values for all the traits under study. None of the crosses was superior for all the traits studied which was in accordance with the report of Ranganatha *et al*. (2013). From the study, BSH 18 × KC 3 showed the highest mean value for the plant height (138.25 cm) followed by MCU 5 × KC 2 (136.02 cm) **(Table 2)**. The minimum mean value for the plant height was found in the cross CO 17×GISV 323 (83.45 cm) followed by the cross CO 14×RHC 1409 (85.25 cm). The range of mean for the sympodial branches was between 36.68 and 23.86. The maximum value was showed by the hybrid MCU 5 × KC 3 and the minimum mean value was found in the cross CO 17 × GISV 323. MCU 5 × KC 2 showed the highest mean value for the trait, the number of bolls per plant (40.07) and the next to it stands the hybrid MCU 5 × KC 3 (39.59). The lowest mean values for the number of bolls were exhibited by the cross TCH 1828 × RHC 1409 (28). The boll weight mean values ranged between 5.15 g and 3.3 g. The maximum mean boll weight was observed in the hybrid MCU 5 × KC 3 and

**Table1. Analysis of variance for cotton yield and quality traits in *Gossypium hirsutum***

| SOURCE | DF | PH | S | NBPP | BW | LI | GOT | SCYPP | UHML | EL | MIC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Replication | 1 | 19.5606 | 0.4862 | 0.123 | 0.0143 | 0.0102 | 0.5363 | 2.9244 | 0.0297 | 0.0151 | 0.0478 |
| Genotypes | 46 | 444.0442** | 29.2533** | 27.9032** | 0.5536** | 0.2504** | 9.3686** | 794.6763** | 5.2202** | 0.1709** | 0.8767** |
| Cross | 34 | 448.255 | 32.6452 | 30.5531 | 0.6042 | 0.2197 | 7.8744 | 780.0231 | 3.1115 | 0.1591 | 0.9281 |
| Lines | 6 | 400.4493 | 22.0356 | 20.5266 | 0.4409 | 0.1155 | 5.4354 | 453.5236 | 10.4898 | 0.2019 | 0.8285 |
| Testers | 4 | 790.1184 | 131.2153 | 115.1564 | 1.1531 | 0.1017 | 9.3225 | 892.1933 | 14.5798 | 0.1148 | 0.1026 |
| Parets | 11 | 254.3131 | 19.9028 | 21.7982 | 0.4188 | 0.334 | 9.3225 | 872.5852 | 11.1532 | 0.208 | 0.6685 |
| Lines vs Testers | 24 | 403.2292 | 18.8692 | 18.9592 | 0.5536 | 0.2654 | 9.6281 | 842.9529 | 3.4103 | 0.1557 | 1.0905 |
| Cross vs parents | 1 | 2387.922 | 16.7851 | 4.9621 | 0.3134 | 0.3743 | 60.6794 | 435.8847 | 11.6521 | 0.1632 | 1.4212 |
| ERROR | 46 | 19.4831 | 0.9502 | 0.0659 | 0.0084 | 0.0106 | 1.1898 | 8.985 | 0.0929 | 0.0069 | 0.0432 |

** Significant at 1 per cent level

PH: Plant height, S: Number of sympodial branches, NBPP: Number of bolls per plant, BW: Boll weight, LI: Lint index, GOT: Ginning outturn, SCYPP : Seed cotton yield per plant, UHML: Upper Half Mean Length, EL: Elongation per cent, MIC: Micronaire value.

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**Table 2. Mean performance of 35 $F_1$ hybrids for seed cotton yield and their associated traits in *Gossypium hirsutum* L.**

| Crosses | PH | S | NB | BW | LI | GOT | SCYPP | UHML | EL | MIC |
|---|---|---|---|---|---|---|---|---|---|---|
| BSH 18× KC 2 | 114.54 | 33 | 36.11 | 3.93 | 4.3 | 37.05 | 123.8 | 31.41 | 5.92 | 4.46 |
| BSH 18× KC 3 | 138.25 | 36.14 | 39.35 | 4.83 | 4.3 | 33.99 | 105.62 | 29.75 | 5.08 | 4.38 |
| BSH 18× GTHV 15-34 | 96.1 | 27.03 | 29.65 | 4.27 | 4.15 | 36.43 | 134.51 | 30.67 | 5.68 | 4.28 |
| BSH 18× GISV 323 | 123.7 | 33.92 | 38.27 | 4.64 | 4.99 | 40.82 | 146.17 | 32.33 | 6.02 | 4.39 |
| BSH 18× RHC 1409 | 119 | 32.76 | 35.65 | 4.88 | 4.86 | 38.08 | 153.72 | 32.06 | 5.95 | 3.5 |
| MCU 5× KC 2 | 136.02 | 36.51 | 40.07 | 4.84 | 5.13 | 39.25 | 139.44 | 32.2 | 6.01 | 4.84 |
| MCU 5× KC 3 | 104 | 36.68 | 39.59 | 5.15 | 4.69 | 40.81 | 150.74 | 32.51 | 6.07 | 4.37 |
| MCU 5× GTHV 15-34 | 97 | 29 | 31.27 | 3.67 | 4.43 | 38.13 | 115.6 | 31.48 | 6.02 | 4.17 |
| MCU 5× GISV 323 | 125.95 | 34.49 | 37.49 | 4.61 | 4.41 | 34.57 | 124.49 | 29.41 | 5.85 | 4.16 |
| MCU 5× RHC 1409 | 86.45 | 24.61 | 27.45 | 3.33 | 4.92 | 36.82 | 104.74 | 31.16 | 6.1 | 4.2 |
| CO 14× KC 2 | 104 | 35.6 | 38.6 | 4.82 | 4.12 | 33.02 | 151.99 | 32.61 | 5.88 | 4.23 |
| CO 14× KC 3 | 115.1 | 36.87 | 39.35 | 4.36 | 4.41 | 38.65 | 137.18 | 32.6 | 6.03 | 3.95 |
| CO 14× GTHV 15-34 | 90.05 | 29.96 | 33.44 | 3.62 | 4.3 | 38.19 | 113.88 | 32.25 | 6.06 | 3.53 |
| CO 14× GISV 323 | 117.7 | 32.58 | 35.2 | 4.38 | 4.77 | 36.02 | 122.97 | 33.14 | 5.9 | 4.22 |
| CO 14× RHC 1409 | 85.25 | 34.72 | 38.18 | 3.48 | 4.37 | 35.31 | 147.12 | 33.13 | 6.02 | 4.01 |
| TCH 1828× KC 2 | 120.92 | 33.23 | 36.09 | 4.47 | 5.06 | 36.75 | 140.81 | 32.55 | 5.44 | 4.61 |
| TCH 1828× KC 3 | 102.7 | 36.61 | 39.61 | 4.97 | 4.52 | 35.4 | 156.72 | 32.62 | 6.11 | 4.3 |
| TCH 1828× GTHV 15-34 | 86.85 | 24.72 | 28.6 | 3.52 | 4.73 | 34.32 | 110.88 | 32.84 | 5.08 | 4.31 |
| TCH 1828× GISV 323 | 116.12 | 33.03 | 36.34 | 4.34 | 4.27 | 39.08 | 98.93 | 29.83 | 6.12 | 3.38 |
| TCH 1828× RHC 1409 | 87.25 | 24.81 | 27.51 | 3.34 | 4.5 | 39.44 | 100.28 | 32.46 | 5.92 | 4.41 |
| CO 17× KC 2 | 115.52 | 35.77 | 38.24 | 4.22 | 5 | 39.02 | 121.94 | 32.42 | 5.21 | 3.9 |
| CO 17× KC 3 | 98.9 | 33.33 | 36.36 | 5.04 | 4.15 | 37.25 | 158.92 | 32.52 | 5.99 | 3.87 |
| CO 17× GTHV 15-34 | 115.5 | 30.82 | 34.17 | 4.43 | 4.43 | 36.98 | 139.71 | 32.48 | 5.9 | 4.39 |
| CO 17× GISV 323 | 83.45 | 23.86 | 28.4 | 3.43 | 4.21 | 34.51 | 108.04 | 31.44 | 5.97 | 4.27 |
| CO 17× RHC 1409 | 92.65 | 26.16 | 30.11 | 3.69 | 4.58 | 36.39 | 97.57 | 29.56 | 5.43 | 4.88 |
| TCH 1199× KC 2 | 117.5 | 33.88 | 36.1 | 4.38 | 4.73 | 36.59 | 137.82 | 31.39 | 5.67 | 4.36 |
| TCH 1199× KC 3 | 92.95 | 32.13 | 34.61 | 3.41 | 4.18 | 37.42 | 107.58 | 29.34 | 5.52 | 4.58 |
| TCH 1199× GTHV 15-34 | 95.75 | 26.94 | 29.66 | 3.77 | 5.3 | 38.55 | 118.76 | 30.78 | 5.47 | 4.65 |
| TCH 1199× GISV 323 | 96.74 | 27.19 | 30.89 | 3.8 | 4.56 | 36.32 | 90.84 | 32.29 | 5.76 | 3.82 |
| TCH 1199× RHC 1409 | 104.2 | 30.55 | 33.43 | 4.01 | 4.29 | 37.01 | 126.16 | 32.47 | 5.77 | 3.84 |
| Suraj× KC 2 | 90.9 | 31.23 | 32.23 | 3.64 | 4.58 | 38.69 | 109.51 | 32.41 | 5.75 | 3.1 |
| Suraj× KC 3 | 96.1 | 36.1 | 38.65 | 3.78 | 5.16 | 39.97 | 124.07 | 32.44 | 5.73 | 3.13 |
| Suraj× GTHV 15-34 | 123.38 | 33.85 | 36.44 | 4.53 | 4.24 | 37.75 | 142.86 | 31.38 | 5.84 | 3.39 |
| Suraj× GISV 323 | 111.5 | 33.27 | 35.26 | 4.2 | 4.45 | 36.5 | 132.46 | 28.53 | 5.78 | 3.93 |
| Suraj× RHC 1409 | 94.6 | 26.65 | 30.4 | 3.74 | 4.17 | 39.51 | 90.26 | 28.5 | 5.8 | 4.28 |
| Mean | 105.61 | 31.66 | 34.65 | 4.16 | 4.55 | 37.3 | 125.32 | 31.60 | 5.8 | 4.12 |
| SEd | 3.84 | 0.87 | 0.25 | 0.09 | 0.10 | 0.89 | 2.92 | 0.29 | 0.08 | 0.23 |
| CD (0.05) | 7.73 | 1.75 | 0.51 | 0.18 | 0.21 | 1.80 | 5.87 | 0.59 | 0.17 | 0.47 |
| CV % | 4.98 | 3.06 | 1.18 | 2.22 | 2.25 | 2.96 | 2.42 | 1.01 | 1.44 | 4.74 |

PH: Plant height, S: Number of sympodial branches, NBPP: Number of bolls per plant, BW: Boll weight, LI: Lint index, GOT: Ginning outturn, SCYPP : Seed cotton yield per plant, UHML: Upper Half Mean Length, EL: Elongation per cent, MIC: Micronaire value.

the minimum mean value was observed in the hybrids *viz*., TCH 1828 × RHC 1409 and MCU 5 × RHC 1409. TCH 1199 × GTHV 15-34 was found to exhibit the highest mean lint index of 5.3 and the lowest mean value of 4.12 was observed in the cross CO 14 × KC 2. The maximum mean yield of 158.92 g per plant was measured in the hybrid CO 17 × KC 3 and the lowest mean value of 90.26 g was found in the cross Suraj × RHC 1409. The ginning outturn is high in BSH 18 × GISV 323 (40.82%) and low in CO 14 × KC 2 (33.02 %) was recorded. The upper half mean length which is an important trait that determines the quality of cotton, which was found to show the maximum mean value in the cross CO 14 × GISV 323 which was about 33.14 mm and the lowest mean value of 28.5 mm was found in the cross Suraj × RHC 1409. The elongation percentage was high in TCH 1828 × GISV 323(6.12 %) was observed. The micronaire value of 35 hybrids mean ranged between 3.10 µg per inch and 4.88 µg per inch. The maximum value was recorded in the cross between CO 17×RHC 1409 and the minimum value was found in the hybrid cross between Suraj and KC 2.

Heterobeltiosis studies are useful for the identification of cotton hybrids that can be identified for commercial production which will be superior to the best parent in the cross (Mendez-Natera *et al.,*2012). Among the thirty five hybrids studied each showed a different degree of heterosis as the similar results suggested by Reddy *et al*. (2017) and Giri *et al*. (2021). From T**able 3**, the cross TCH 1828 × GTHV 15-34 exhibited the lowest mid parent value (-38.37%) for the trait plant height and the cross Suraj × KC 2 recorded the lowest value for the same trait for the better parent value (-36.38%). Standard heterosis was found to be the lowest (-32.89%) in the cross CO 17 × GISV 323 for the plant height observed among the thirty five hybrids. The maximum values of mid parent and the better parent heterosis for the traits *viz.*, the number of sympodial branches (18.25%, 9.80%) and the number of bolls per plant (18.44%, 9.59%) were found in the cross Suraj × GTHV 15-34. CO 14 × KC 3 observed the highest value of standard heterosis for the traits *viz.,* sympodial branches (35.83%) and the number of bolls per plant (31.73%). The trait the number of bolls per plant being the most important and direct yield contributing trait can be exploited from this cross combination as suggested by Abro *et al.*(2009). BHS 18 × RHC 1409 hybrid was found to have the maximum mid and better parent values for the traits *viz*., boll weight (29.19%, 25.61%) and seed yield per plant (58.86% , 58.95%). MCU 5 × KC 3 cross showed a maximum standard heterosis for the boll weight trait among the thirty five hybrids studied. The highest standard heterosis value was observed for the trait seed cotton yield per plant in the cross CO 17 × KC 3 (68.72%). The trait lint index showed maximum mid (12.11%) and better parent value in the cross TCH 1199 × GTHV 15-34 (10.53 %). The cross TCH 1828 × RHC 1409 recorded the highest better (15.19%) and mid parent heterosis (20.94%) for the trait ginning out turn. The hybrid BSH

**Table 3. Heterotic effects of 35 $F_1$ hybrids for yield and quality traits in cotton ( in per cent)**

| Crosses | PH | | | NB | | | SCYPP | | | BW | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | di | dii | diii | di | dii | diii | di | dii | diii | di | dii | diii |
| BSH 18 × KC 2 | -8.86 * | -15.17 ** | -0.01 | 3.54 ** | -3.45 ** | 19.11 ** | 4.75 * | -12.06 ** | 31.44 ** | -5.47 ** | -15.39 ** | 8.41 ** |
| BSH 18 × KC 3 | 12.19 ** | 3.01 | 25.07 ** | 14.36 ** | 7.88 ** | 29.35 ** | 0.07 | -8.55 ** | 12.14 ** | 17.75 ** | 6.63 ** | 33.10 ** |
| BSH 18 × GTHV 15-34 | -24.56 ** | -28.04 ** | -19.51 ** | -2.19 | -8.33 ** | -0.38 | 34.81 ** | 29.39 ** | 42.81 ** | 12.29 ** | 8.51 ** | 17.79 ** |
| BSH 18 × GISV 323 | 8.13 * | 8.02 | 9.68 * | 12.09 ** | 6.47 ** | 22.12 ** | 29.10 ** | 11.71 ** | 55.18 ** | 23.73 ** | 21.15 ** | 28.00 ** |
| BSH 18× RHC 1409 | 8.61 * | 3.13 | 4.71 | 5.20 ** | 0.62 | 18.31 ** | 59.86 ** | 58.95 ** | 63.21 ** | 29.19 ** | 25.61 ** | 34.62 ** |
| MCU 5 × KC 2 | 17.10 ** | 4.10 | 22.71 ** | 5.29 ** | 3.50 ** | 30.56 ** | -1.54 | -2.12 | 48.04 ** | 9.94 ** | 4.20 * | 33.52 ** |
| MCU 5 × KC 3 | -16.63 ** | -26.83 ** | -11.16 ** | 5.31 ** | 2.26 * | 31.10 ** | 16.87 ** | 5.81 ** | 60.04 ** | 18.60 ** | 13.81 ** | 42.07 ** |
| MCU 5 × GTHV 15-34 | -19.98 ** | -27.19 ** | -18.56 ** | -6.66 ** | -19.23 ** | 6.07 * | -6.17 ** | -18.85 ** | 22.74 ** | -9.33 ** | -11.78 ** | 1.24 |
| MCU 5 × GISV 323 | 16.11 ** | 10.59 * | 12.06 ** | 0.42 | -3.16 ** | 23.97 ** | -8.90 ** | -12.62 ** | 32.17 ** | 15.39 ** | 10.82 ** | 27.17 ** |
| MCU 5 × RHC 1409 | -23.18 ** | -23.36 ** | -29.72 ** | -25.96 ** | -29.10 ** | -8.26 ** | -12.42 ** | -26.48 ** | 11.20 ** | -17.34 ** | -20.07 ** | -8.28 ** |
| CO 14 × KC 2 | -19.02 ** | -24.63 ** | -11.16 ** | 4.71 ** | 3.22 ** | 27.59 ** | 4.42 * | 1.09 | 61.37 ** | 3.60 * | 3.32 | 33.10 ** |
| CO 14 × KC 3 | -9.77 ** | -17.16 ** | 0.58 | 8.10 ** | 7.88 ** | 31.73 ** | 3.21 | -8.76 ** | 45.65 ** | -5.27 ** | -6.75 ** | 20.14 ** |
| CO 14 × GTHV 15-34 | -30.56 ** | -33.76 ** | -25.91 ** | 3.51 ** | -7.95 ** | 9.20 ** | -10.44 ** | -24.26 ** | 20.90 ** | -15.98 ** | -22.59 ** | -0.28 |
| CO 14 × GISV 323 | 1.88 | 1.77 | 3.33 | -2.60 * | -3.11 ** | 17.72 ** | -12.53 ** | -18.21 ** | 30.56 ** | 3.06 | -6.21 ** | 20.83 ** |
| CO 14 × RHC 1409 | -28.41 ** | -32.03 ** | -30.99 ** | 6.42 ** | 5.11 ** | 24.70 ** | 19.09 ** | -2.15 | 56.19 ** | -18.64 ** | -25.48 ** | -4.00 |
| TCH 1828 × KC 2 | -9.35 ** | -9.45 * | 6.74 | -6.53 ** | -9.39 ** | 19.86 ** | 8.31 ** | 0.02 | 49.49 ** | -1.38 | -3.77 | 23.31 ** |
| TCH 1828 × KC 3 | -26.81 ** | -27.96 ** | -12.53 ** | 3.82 ** | -0.55 | 30.89 ** | 33.53 ** | 31.44 ** | 66.38 ** | 11.24 ** | 9.94 ** | 37.24 ** |
| TCH 1828 × GTHV 15-34 | -38.37 ** | -39.88 ** | -29.30 ** | -16.02 ** | -28.19 ** | -7.93 ** | -0.64 | -7.00 ** | 17.72 ** | -15.74 ** | -20.36 ** | -2.90 |
| TCH 1828× GISV 323 | -7.13 | -13.56 ** | 1.66 | -4.10 ** | -8.77 ** | 19.20 ** | -20.87 ** | -24.38 ** | 5.04 | 5.21 ** | -1.81 | 19.72 ** |
| TCH 1828 × RHC 1409 | -31.90 ** | -39.52 ** | -28.87 ** | -26.88 ** | -30.92 ** | -7.60 * | -7.13 ** | -15.90 ** | 6.46 * | -19.57 ** | -24.43 ** | -7.86 ** |
| CO 17 × KC 2 | -0.69 | -14.29 ** | 1.03 | 3.04 ** | 2.27 * | 28.14 ** | -12.78 ** | -13.38 ** | 29.46 ** | 6.90 ** | -9.15 ** | 16.41 ** |
| CO 1 7× KC 3 | -19.37 ** | -31.27 ** | -16.55 ** | -0.81 | -1.30 | 20.18 ** | 24.97 ** | 14.47 ** | 68.72 ** | 29.77 ** | 11.49 ** | 39.17 ** |
| CO 17 × GTHV 15-34 | 2.33 | -9.69 * | 1.00 | 4.92 ** | -7.26 ** | 11.99 ** | 15.08 ** | 0.63 | 48.32 ** | 23.45 ** | 12.71 ** | 22.34 ** |
| CO 17 × GISV 323 | -28.19 ** | -33.77 ** | -32.89 ** | -21.97 ** | -22.91 ** | -10.70 ** | -19.87 ** | -22.18 ** | 14.71 ** | -3.11 | -10.44 ** | -5.38 * |

**Table 3. continued**

| Crosses | PH | | | NB | | | SCYPP | | | BW | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | di | dii | diii | di | dii | diii | di | dii | diii | di | dii | diii |
| CO 17 × RHC 1409 | -13.10 ** | -15.82 ** | -23.16 ** | -16.69 ** | -18.28 ** | -3.20 | -17.16 ** | -29.72 ** | 3.59 | 3.29 | -5.15 * | 1.66 |
| TCH 1199 × KC 2 | -1.59 | -12.52 ** | 3.12 | 5.14 ** | -3.45 ** | 21.96 ** | 20.69 ** | -2.10 | 46.32 ** | 6.45 ** | -5.81 ** | 20.69 ** |
| TCH 1199 × KC 3 | -27.59 ** | -36.45 ** | -22.85 ** | 2.17 * | -5.10 ** | 16.28 ** | 5.93 * | -6.86 * | 14.21 ** | -15.68 ** | -24.53 ** | -5.79 * |
| TCH 1199 × GTHV 15-34 | -21.28 ** | -28.37 ** | -19.88 ** | -0.42 ns | -5.19 ** | -0.67 | 23.98 ** | 14.24 ** | 26.08 ** | 0.40 | -4.19 | 4.00 |
| TCH 1199 × GISV 323 | -15.90 ** | -19.90 ** | -18.84 ** | -8.10 ** | -14.06 ** | 0.13 | -16.83 ** | -30.57 ** | -3.55 | 2.50 | -0.91 | 4.69 |
| TCH 1199 × RHC 1409 | -2.66 | -2.88 | -10.95 ** | 0.22 | -5.64 ** | 11.11 ** | 36.88 ** | 30.45 ** | 33.94 ** | 7.37 ** | 3.09 | 10.48 ** |
| Suraj × KC 2 | -31.15 ** | -36.38 ** | -25.01 ** | -8.76 ** | -13.81 ** | 13.31 ** | -16.86 ** | -22.21 ** | 16.26 ** | -13.25 ** | -21.74 ** | 0.28 |
| Suraj × KC 3 | -27.28 ** | -33.71 ** | -19.51 ** | 10.86 ** | 5.96 ** | 29.22 ** | 4.19 | 1.15 | 31.72 ** | -8.47 ** | -16.46 ** | 4.28 |
| Suraj × GTHV 15-34 | 3.25 | -2.24 | 9.34 * | 18.44 ** | 9.59 ** | 21.86 ** | 26.08 ** | 16.47 ** | 51.67 ** | 18.25 ** | 15.25 ** | 25.10 ** |
| Suraj × GISV 323 | -3.84 | -4.49 | -3.23 | 1.90 | -1.92 | 19.99 ** | 4.51 * | 1.24 | 40.63 ** | 11.17 ** | 9.79 ** | 16.00 ** |
| Suraj × RHC 1409 | -17.48 ** | -21.06 ** | -21.10 ** | -11.49 ** | -14.21 ** | -1.60 | -17.71 ** | -26.42 ** | -4.18 | -1.84 | -3.73 | 3.17 |
| SE | 3.8226 | 4.414 | 2.6808 | 0.3562 | 0.4113 | 0.6155 | 2.5959 | 2.9975 | 2.039 | 0.0792 | 0.0914 | 0.0634 |

**Table 3. continued**

| Crosses | S | | | LI | | | GOT | | | UHML | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | di | dii | diii | di | dii | diii | di | dii | diii | di | dii | diii |
| BSH 18 × KC 2 | 1.75 | -4.53 | 21.57 ** | -19.00 ** | -19.87 ** | -16.60 ** | 2.35 | -2.14 | -4.70 * | 1.06 | -3.83 ** | -3.55 ** |
| BSH 18 × KC 3 | 12.06 ** | 5.67 | 33.14 ** | -17.94 ** | -19.78 ** | -16.50 ** | -9.07 ** | -10.20 ** | -12.54 ** | -4.18 ** | -8.59 ** | -8.82 ** |
| BSH 18 × GTHV 15-34 | -4.69 | -10.79** | -0.42 | -18.17 ** | -22.48 ** | -19.32 ** | 0.85 | -3.75 | -6.26 ** | -1.75 | -6.82 ** | -5.90 ** |
| BSH 18 × GISV 323 | 8.13 ** | 4.55 | 24.98 ** | 1.63 | -6.81 ** | -3.01 | 15.17 ** | 10.47 ** | 7.59 ** | 9.24 ** | 8.78 ** | -0.63 |
| BSH 18× RHC 1409 | 5.27 | 2.58 | 20.67 ** | 2.91 | -9.33 ** | -5.63 ** | 10.65 ** | 0.61 | -2.02 | 14.76 ** | 8.74 ** | -1.51 |
| MCU 5 × KC 2 | 2.97 | 0.44 | 34.50 ** | 3.06 | -2.10 | -0.29 | 13.04 ** | 12.43 ** | 0.98 | -0.78 | -1.33 | -1.05 |
| MCU 5 × KC 3 | 3.97 | 0.89 | 35.11 ** | -4.67 * | -8.40 ** | -8.93 ** | 13.65 ** | 10.56 ** | 5.00 * | 0.13 | -0.16 | -0.41 |
| MCU 5 × GTHV 15-34 | -7.58 ** | -20.21** | 6.85 * | -6.78 ** | -7.51 ** | -13.88 ** | 10.01 ** | 9.21 ** | -1.92 | -3.41 ** | -4.27 ** | -3.33 ** |
| MCU 5 × GISV 323 | 0.26 | -5.12 | 27.06 ** | -4.03 * | -6.57 ** | -14.37 ** | -0.75 | -0.96 | -11.05 ** | -5.41 ** | -9.15 ** | -9.90 ** |
| MCU 5 × RHC 1409 | -27.90 ** | -32.28** | -9.32 ** | 11.75 ** | 4.24 | -4.47 * | 11.75 ** | 5.47 | -5.27 * | 6.16 ** | -3.53 ** | -4.33 ** |
| CO 14 × KC 2 | 1.98 | 0.99 | 31.15 ** | -13.78 ** | -21.54 ** | -20.10 ** | -5.39 | -6.39 * | -15.04 ** | 0.46 | -0.03 | 0.25 |
| CO 14 × KC 3 | 6.18 * | 4.60 | 35.83 ** | -6.37 ** | -13.87 ** | -14.37 ** | 7.07 ** | 4.70 | -0.57 | -2.49 ** | -2.70 ** | -2.95 ** |
| CO 14 × GTHV 15-34 | -2.82 | -14.99 ** | 10.39 ** | -5.55 ** | -10.43 ** | -16.60 ** | 9.63 ** | 8.26 * | -1.74 | -1.03 | -1.85 | -0.89 |
| CO 14 × GISV 323 | -3.77 ns | -7.59 ** | 20.00 ** | 8.67 ** | 6.60 ** | -7.48 ** | 2.86 | 2.11 | -7.32 ** | -6.39 ** | -10.14 ** | -10.77 ** |
| CO 14 × RHC 1409 | 3.35 | -1.52 | 27.89 ** | 4.11 | 1.51 | -15.24 ** | 6.57 * | 0.09 | -9.16 ** | 5.96 ** | -3.77 ** | -4.44 ** |
| TCH 1828 × KC 2 | -6.02 * | -8.08** | 22.42 ** | 4.07 * | -3.62 | -1.84 | 6.87 * | 6.41 * | -5.45 * | -0.77 | -3.70 ** | -3.43 ** |
| TCH 1828 × KC 3 | 4.08 | 1.27 | 34.87 ** | -5.74 ** | -11.72 ** | -12.23 ** | -0.50 | -4.10 | -8.93 ** | 3.32 ** | 0.54 | 0.29 |
| TCH 1828 × GTHV 15-34 | -21.00 ** | -31.63** | -8.95 ** | 2.10 | -1.36 | -8.16 ** | -0.01 | -0.25 | -11.72 ** | 3.39 ** | -0.00 | 0.98 |
| TCH 1828× GISV 323 | -3.70 | -8.63** | 21.68 ** | -4.59 * | -4.59 | -17.18 ** | 13.25 ** | 12.40 ** | 0.53 | -1.53 | -3.11 ** | -8.56 ** |
| TCH 1828 × RHC 1409 | -27.10 ** | -31.36** | -8.58 * | 5.08 * | 0.56 | -12.72 ** | 20.94 ** | 15.19 ** | 1.47 | 13.75 ** | 5.73 ** | -0.22 |
| CO 17 × KC 2 | 3.28 | 3.08 | 31.77 ** | -1.48 | -4.77 * | -3.01 | 6.90 * | 1.42 | 0.40 | -0.27 | -0.30 | -0.02 |
| CO 1 7× KC 3 | -3.25 | -3.95 | 22.79 ** | -17.02 ** | -18.85 ** | -19.32 ** | -1.19 | -3.20 | -4.17 | -0.33 | -0.57 | -0.35 |
| CO 17 × GTHV 15-34 | 0.85 | -11.18** | 13.54 ** | -8.57 ** | -9.50 ** | -13.98 ** | 1.48 | -3.90 | -4.86 * | -0.44 | -0.82 | 0.16 |
| CO 17 × GISV 323 | -28.92 ** | -31.22** | -12.08 ** | -9.98 ** | -13.89 ** | -18.16 ** | -5.75 * | -10.30 ** | -11.20 ** | 0.79 | -3.67 ** | -3.46 ** |

**Table 3. continued**

| Crosses | S | | | LI | | | GOT | | | UHML | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | di | dii | diii | di | dii | diii | di | dii | diii | di | dii | diii |
| CO 17 × RHC 1409 | -21.46 ** | -24.60 ** | -3.61 | 1.89 | -6.54 ** | -11.17 ** | 4.77 | -5.43 | -6.38 ** | -0.07 | -9.62 ** | -9.42 ** |
| TCH 1199 × KC 2 | 7.64 ** | -2.00 | 24.79 ** | -4.49 * | -9.82 ** | -8.16 ** | 0.18 | -5.00 | -5.87 * | 2.81 ** | -3.89 ** | -3.62** |
| TCH 1199 × KC 3 | 2.71 | -6.04 * | 18.38 ** | -14.42 ** | -18.26 ** | -18.74 ** | -0.78 | -2.84 | -3.73 ns | -3.85 ** | -9.89 ** | -10.12** |
| TCH 1199 × GTHV 15-34 | -1.67 | -5.06 | -0.76 | 12.11 ** | 10.53 ** | 2.91 | 5.73 * | 0.08 | -0.84 | 0.37 | -6.47 ** | -5.55 ** |
| TCH 1199 × GISV 323 | -10.61 ** | -16.22 ** | 0.15 | -0.11 | -2.15 | -11.46 ** | -0.87 | -5.70 * | -6.56 ** | 11.15 ** | 8.65 ** | -0.76 |
| TCH 1199 × RHC 1409 | 1.32 | -4.32 | 12.54 ** | -1.89 | -7.94 ** | -16.70 ** | 6.52 * | -3.89 | -4.77 * | 19.37 ** | 15.16 ** | 0.44 |
| Suraj × KC 2 | -4.50 | -9.66 ** | 15.03 ** | -3.28 | -12.77 ** | -11.17 ** | 11.85 ** | 11.66 ** | -0.46 s | 9.94 ** | -0.66 | -0.38 |
| Suraj × KC 3 | 11.03 ** | 5.56 | 32.99 ** | 10.55 ** | 0.78 | 0.19 | 11.70 ** | 8.28 ** | 2.83 | 10.37 ** | -0.03 | -0.29 |
| Suraj × GTHV 15-34 | 18.25 ** | 9.80 ** | 24.68 ** | -5.99 ** | -11.68 ** | -17.77 ** | 9.33 ** | 8.93 ** | -2.89 | 5.93 ** | -4.59 ** | -3.65 ** |
| Suraj × GISV 323 | 5.16 | 2.53 | 22.56 ** | 2.59 | -0.34 | -13.50 ** | 5.18 | 5.01 | -6.08 * | 5.04 ** | -0.94 | -9.51 ** |
| Suraj × RHC 1409 | -15.05 ** | -16.52 ** | -1.81 | 0.60 | -0.95 | -18.93 ** | 20.39 ** | 14.03 ** | 1.65 | 7.67 ** | 7.59 ** | -12.78** |
| SE | 0.8442 | 0.9748 | 0.6155 | 0.2595 | 0.2997 | 0.075 | 0.0892 | 0.103 | 0.6282 | 0.2639 | 0.3048 | 0.2059 |

**Table 3. continued**

| Crosses | EL | | | MIC | | |
|---|---|---|---|---|---|---|
| | di | dii | diii | di | dii | diii |
| BSH 18 × KC 2 | 2.60 * | -3.11 * | 2.42 | -2.78 | -8.51 | 13.49 * |
| BSH 18 × KC 3 | -6.53 ** | -6.62 ** | -12.11 ** | 25.52 ** | 10.46 * | 37.02 ** |
| BSH 18 × GTHV 15-34 | 8.09 ** | 4.60 ** | -1.73 | -15.91 ** | -19.32 ** | 8.91 |
| BSH 18 × GISV 323 | 8.18 ** | 5.61 ** | 4.15 ** | -10.22 ** | -10.50 * | 11.70 |
| BSH 18× RHC 1409 | 9.58 ** | 9.58 ** | 2.94 | -27.46 ** | -28.21 ** | -10.94 |
| MCU 5 × KC 2 | -0.91 | -1.64 | 3.98 * | 19.58 ** | 12.56 * | 23.16 ** |
| MCU 5 × KC 3 | 5.93 ** | 0.83 | 5.02 ** | 16.40 ** | 15.02 ** | 11.07 |
| MCU 5 × GTHV 15-34 | 8.47 ** | 0.00 | 4.15 ** | -8.24 * | -21.30 ** | 6.23 |
| MCU 5 × GISV 323 | -0.26 | -2.91 * | 1.12 | -4.37 | -15.19 ** | 5.85 |
| MCU 5 × RHC 1409 | 6.55 ** | 1.33 | 5.54 ** | -1.87 | -11.94 ** | 7.00 |
| CO 14 × KC 2 | -2.08 | -3.76 ** | 1.73 ns | 23.76 ** | 21.74 ** | 33.21 ** |
| CO 14 × KC 3 | 6.35 ** | 2.20 | 4.33 ** | 0.45 | -5.05 | 0.51 |
| CO 14 × GTHV 15-34 | 10.38 ** | 2.71 | 4.84 ** | -25.30 ** | -33.36 ** | -10.05 |
| CO 14 × GISV 323 | 1.72 | 0.00 | 2.08 | 15.17 ** | 6.42 | 32.82 ** |
| CO 14 × RHC 1409 | 6.27 ** | 2.03 | 4.15 ** | -10.24 * | -16.02 ** | 2.04 |
| TCH 1828 × KC 2 | -9.93 ** | -10.97 ** | -5.88 ** | -3.81 | -12.70 ** | 17.18 ** |
| TCH 1828 × KC 3 | 7.10 ** | 2.35 | 5.71 ** | -4.23 | -18.48 ** | 9.41 |
| TCH 1828 × GTHV 15-34 | -8.05 ** | -14.91 ** | -12.11 ** | 0.28 | -0.00 | 34.99 ** |
| TCH 1828× GISV 323 | 4.88 ** | 2.51 | 5.88 ** | -33.60 ** | -35.92 ** | -13.99 * |
| TCH 1828 × RHC 1409 | 3.86 ** | -0.84 | 2.42 | 7.66 * | 2.56 | 37.66 ** |
| CO 17 × KC 2 | -14.25 ** | -14.81 ** | -9.95 ** | -5.45 | -9.30 | -0.76 |
| CO 1 7× KC 3 | 4.45 ** | -0.66 | 3.63 * | 1.11 | -2.03 | -1.53 |
| CO 17 × GTHV 15-34 | 6.30 ** | -2.07 | 2.16 | -5.02 | -17.15 ** | 11.83 |
| CO 17 × GISV 323 | 1.79 | -1.00 | 3.29 * | 19.14 ** | 7.54 | 34.22 ** |

Table 3. continued

| Crosses | E | | | MIC | | |
|---|---|---|---|---|---|---|
| | di | dii | diii | di | dii | diii |
| CO 17 × RHC 1409 | -5.24 ** | -9.95 ** | -6.06 ** | 11.75 ** | 2.09 | 24.05 ** |
| TCH 1199 × KC 2 | -4.79 ** | -7.20 ** | -1.90 | -7.38 | -14.76 ** | 10.94 |
| TCH 1199 × KC 3 | -1.78 | -4.83 ** | -4.50 ** | 3.97 | -10.36 * | 16.67 ** |
| TCH 1199 × GTHV 15-34 | 0.55 | -5.69 ** | -5.36 ** | -10.75 ** | -12.35 ** | 18.32 ** |
| TCH 1199 × GISV 323 | 0.17 | -0.69 | -0.35 | -23.75 ** | -25.32 ** | -2.80 |
| TCH 1199 × RHC 1409 | 2.76 * | -0.52 | -0.17 | -22.24 ** | -24.83 ** | -2.16 |
| Suraj × KC 2 | -0.86 | -5.89 ** | -0.52 | -39.95 ** | -43.76 ** | -29.52 ** |
| Suraj × KC 3 | 4.85 ** | 4.37 ** | -0.87 | -27.35 ** | -36.35 ** | -20.23 ** |
| Suraj × GTHV 15-34 | 10.50 ** | 6.38 ** | 1.04 | -33.63 ** | -36.00 ** | -13.61 * |
| Suraj × GISV 323 | 3.31 * | 1.40 | 0.00 | -20.04 ** | -20.20 ** | 0.00 |
| Suraj × RHC 1409 | 6.23 ** | 5.65 ** | 0.35 | 8.87 * | 7.21 | 34.35 ** |
| SE | 0.0718 | 0.0829 | 0.0615 | 0.18 | 0.2078 | 0.1684 |

PH: Plant height, S: Number of sympodial branches, NBPP: Number of bolls per plant, BW: Boll weight, LI: Lint index, GOT: Ginning outturn, SCYPP : Seed cotton yield per plant, UHML: Upper Half Mean Length, EL: Elongation per cent, MIC: Micronaire value.
** Significant at 1 per cent level, * Significant at 5 per cent level

18× GISV 323 had a maximum standard heterosis value for the trait ginning out turn (7.59%). Therefore, the yield components have a direct positive impact on yield with some sacrifice of ginning outturn as given by Khan *et al*. (2015). The highest mid parent and better parent value was observed for the trait upper half mean length in the cross TCH 1199 × RHC 1409 (19.37%, 15.16%). The cross CO 14 × GTHV 323 had a maximum mid parent value (10.38%) for the elongation length and the cross TCH 1828 × GISV 323 was found to have the highest standard heterosis for the elongation length trait (5.88%). The cross BSH 18 × KC3 ( 25.52%, mid parent value), CO 14 × KC 2 ( 21.74%, better parent) and the cross TCH 1828 × RHC 1409 showed maximum values (37.66%, standard heterosis) for the trait of micronaire value. Similar results for most of the traits were suggested by Adsare *et al*. (2017).

**Table 4. General combining ability effects for various traits in *Gossypium hirsutum***

| Parents | PH | S | NBPP | BW | LI | GOT | SCYPP | UHML | EL | MIC |
|---|---|---|---|---|---|---|---|---|---|---|
| **LINES** | | | | | | | | | | |
| BSH18 | 12.70 ** | 0.91 ** | 1.16 ** | 0.35 ** | -0.03 | 0.17 | 7.45 ** | -0.13 | -0.07 * | 0.09 |
| MCU 5 | 4.27 ** | 0.60 * | 0.52 ** | 0.16 ** | 0.17 ** | 0.61 * | 1.69 | -0.04 | 0.21 ** | 0.04 |
| CO 14 | -3.20 * | 2.29 ** | 2.30 ** | -0.03 | -0.16 ** | -1.06 ** | 9.31 ** | -0.03 | 0.18 ** | 0.08 |
| TCH 1828 | -2.85 * | -1.18 ** | -1.02 ** | -0.03 | 0.06 | -0.31 | -3.79 ** | 0.47 ** | -0.06 * | 0.29 ** |
| CO 17 | -4.41 ** | -1.67 ** | -1.20 ** | 0.01 | -0.08 * | -0.47 | -0.08 | 0.33 ** | -0.10 ** | 0.15 * |
| TCH 1199 | -4.19 ** | -1.52 ** | -1.71 ** | -0.29 ** | 0.06 | -0.13 | -9.09 ** | -0.08 | -0.16 ** | -0.06 |
| SURAJ | -2.32 | 0.56 * | -0.06 | -0.18 ** | -0.03 | 1.18 ** | -5.49 ** | -0.52 ** | -0.02 | -0.61 ** |
| SE | 1.2164 | 0.2763 | 0.0812 | 0.0287 | 0.0338 | 0.2844 | 0.924 | 0.0934 | 0.0278 | 0.0746 |
| **TESTERS** | | | | | | | | | | |
| KC2 | 8.58 ** | 2.52 ** | 2.13 ** | 0.17 ** | 0.15 ** | -0.11 | 6.87 ** | 0.63 ** | -0.10 ** | 0.00 |
| KC3 | 1.24 | 3.75 ** | 3.57 ** | 0.35 ** | -0.06 * | 0.34 | 9.09 ** | 0.14 | -0.01 | -0.08 |
| GTHV 15-34 | -4.96 ** | -2.75 ** | -2.76 ** | -0.18 ** | -0.04 | -0.11 | -0.15 | 0.34 ** | -0.07 ** | -0.06 |
| GISV 323 | 5.12 ** | -0.47 | -0.10 | 0.04 | -0.03 | -0.33 | -7.61 ** | -0.81 ** | 0.12 ** | 0.00 |
| RHC 1409 | -9.99 ** | -3.05 ** | -2.83 ** | -0.38 ** | -0.02 | 0.21 | -8.20 ** | -0.30 ** | 0.06 * | 0.14 * |
| SE | 1.028 | 0.2335 | 0.0686 | 0.0243 | 0.0286 | 0.2403 | 0.7809 | 0.0789 | 0.0235 | 0.0631 |

** Significant at 1 per cent level, * Significant at 5 per cent level
PH: Plant height, S: Number of sympodial branches, NBPP: Number of bolls per plant, BW: Boll weight, LI: Lint index, GOT: Ginning outturn, SCYPP : Seed cotton yield per plant, UHML: Upper Half Mean Length, EL: Elongation per cent, MIC: Micronaire value.

**Table 5. Specific combining ability effects for various traits in *Gossypium hirsutum***

| Crosses | PH | S | NBPP | BW | LI | GOT | SCYPP | UHML | EL | MIC |
|---|---|---|---|---|---|---|---|---|---|---|
| BSH 18× KC 2 | -12.36 ** | -2.09 ** | -1.83 ** | -0.75 ** | -0.38 ** | -0.32 | -15.83 ** | -0.46 * | 0.29 ** | 0.06 |
| BSH 18× KC 3 | 18.69 ** | -0.18 | -0.02 | -0.03 | -0.16 * | -3.82 ** | -36.23 ** | -1.63 ** | -0.64 ** | 1.06 ** |
| BSH 18× GTHV 15-34 | -17.26 ** | -2.79 ** | -3.40 ** | -0.06 | -0.33 ** | -0.93 | 1.89 | -0.91 ** | 0.02 | -0.06 |
| BSH 18× GISV 323 | 0.26 | 1.82 ** | 2.57 ** | 0.09 | 0.50 ** | 4.67 ** | 21.01 ** | 1.89 ** | 0.17 ** | -0.02 |
| BSH 18× RHC 1409 | 10.67 ** | 3.23 ** | 2.68 ** | 0.75 ** | 0.36 ** | 0.40 | 29.16 ** | 1.11 ** | 0.16 * | -1.04 ** |
| MCU 5× KC 2 | 17.55 ** | 1.74 ** | 2.77 ** | 0.35 ** | 0.27 ** | 1.44 * | 5.57 ** | 0.24 | 0.10 | 0.49 ** |
| MCU 5× KC 3 | -7.12 * | 0.66 | 0.85 ** | 0.48 ** | 0.03 | 2.56 ** | 14.65 ** | 0.93 ** | 0.07 | 0.10 |
| MCU 5× GTHV 15-34 | -7.93 ** | -0.50 | -1.14 ** | -0.47 ** | -0.24 ** | 0.32 | -11.25 ** | -0.19 | 0.08 | -0.11 |
| MCU 5× GISV 323 | 10.95 ** | 2.70 ** | 2.42 ** | 0.25 ** | -0.28 ** | -3.02 ** | 5.10 * | -1.11 ** | -0.28 ** | -0.19 |
| MCU 5× RHC 1409 | -13.45 ** | -4.60 ** | -4.89 ** | -0.62 ** | 0.23 ** | -1.30 * | -14.07 ** | 0.13 | 0.03 | -0.28 |
| CO 14× KC 2 | -7.00 * | -0.86 | -0.48 * | 0.52 ** | -0.43 ** | -3.11 ** | 10.49 ** | 0.64 ** | 0.00 | 0.84 ** |
| CO 14× KC 3 | 11.44 ** | -0.83 | -1.17 ** | -0.12 | 0.08 | 2.07 ** | -6.53 ** | 0.12 | 0.06 | -0.36 * |
| CO 14× GTHV 15-34 | -7.41 ** | -1.23 | -0.75 ** | -0.33 ** | -0.06 | 2.07 ** | -20.61 ** | 0.57 ** | 0.16 * | -0.79 ** |
| CO 14× GISV 323 | 10.16 ** | -0.90 | -1.65 ** | 0.21 ** | 0.40 ** | 0.11 | -4.04 | -1.40 ** | -0.20 ** | 0.83 ** |
| CO 14× RHC 1409 | -7.18 * | 3.82 ** | 4.06 ** | -0.27 ** | -0.00 | -1.14 | 20.69 ** | 0.08 | -0.02 | -0.52 ** |
| TCH 1828× KC 2 | 9.57 ** | 0.23 | 0.33 | 0.17 * | 0.29 ** | -0.14 | 12.41 ** | -1.02 ** | -0.19 ** | 0.00 |
| TCH 1828× KC 3 | -1.31 | 2.38 ** | 2.41 ** | 0.50 ** | -0.03 | -1.94 ** | 26.11 ** | 0.64 ** | 0.38 ** | -0.22 |
| TCH 1828× GTHV 15-34 | -10.96 ** | -3.01 ** | -2.27 ** | -0.43 ** | 0.16 * | -2.57 ** | -10.50 ** | 0.66 ** | -0.58 ** | 0.77 ** |
| TCH 1828× GISV 323 | 8.23 ** | 3.02 ** | 2.81 ** | 0.17 * | -0.32 ** | 2.41 ** | -14.97 ** | -1.20 ** | 0.27 ** | -1.22 ** |
| TCH 1828× RHC 1409 | -5.53 * | -2.62 ** | -3.28 ** | -0.41 ** | -0.09 | 2.24 ** | -13.05 ** | 0.92 ** | 0.13 * | 0.67 ** |
| CO 17× KC 2 | 5.73 * | 3.26 ** | 2.66 ** | -0.11 | 0.37 ** | 2.30 ** | -10.17 ** | 0.19 | -0.40 ** | -0.56 ** |
| CO 17× KC 3 | -3.54 | -0.41 | -0.66 ** | 0.53 ** | -0.26 ** | 0.08 | 24.60 ** | 0.58 ** | 0.30 ** | -0.51 ** |
| CO 17× GTHV 15-34 | 19.25 ** | 3.58 ** | 3.47 ** | 0.46 ** | -0.01 | 0.26 | 14.62 ** | 0.54 * | 0.28 ** | -0.01 |
| CO 17× GISV 323 | -22.87 ** | -5.66 ** | -4.95 ** | -0.78 ** | -0.23 ** | -1.99 ** | -9.58 ** | 0.54 * | 0.15 * | 0.81 ** |
| CO 17× RHC 1409 | 1.43 | -0.78 | -0.52 ** | -0.10 | 0.13 | -0.65 | -19.47 ** | -1.85 ** | -0.33 ** | 0.27 |
| TCH 1199× KC 2 | 7.49 ** | 1.22 | 1.04 ** | 0.33 ** | -0.03 | -0.48 | 14.72 ** | -0.53 * | 0.13 * | 0.11 |
| TCH 1199× KC 3 | -9.72 ** | -1.75 ** | -1.89 ** | -0.81 ** | -0.37 ** | -0.10 | -17.74 ** | -2.09 ** | -0.11 | 0.41 * |
| TCH 1199× GTHV 15-34 | -0.72 | -0.44 | -0.52 ** | 0.08 | 0.73 ** | 1.48 * | 2.67 | -0.85 ** | -0.09 | 0.46 ** |
| TCH 1199× GISV 323 | -9.81 ** | -2.49 ** | -1.95 ** | -0.12 | -0.03 | -0.53 | -17.77 ** | 1.80 ** | 0.00 | -0.43 * |
| TCH 1199× RHC 1409 | 12.76 ** | 3.46 ** | 3.32 ** | 0.51 ** | -0.30 ** | -0.37 | 18.13 ** | 1.67 ** | 0.07 | -0.55 ** |
| Suraj× KC 2 | -20.98 ** | -3.51 ** | -4.49 ** | -0.51 ** | -0.10 | 0.31 | -17.19 ** | 0.93 ** | 0.07 | -0.93 ** |
| Suraj× KC 3 | -8.44 ** | 0.13 | 0.49 ** | -0.55 ** | 0.70 ** | 1.15 | -4.85 * | 1.45 ** | -0.04 | -0.49 ** |
| Suraj× GTHV 15-34 | 25.04 ** | 4.38 ** | 4.61 ** | 0.74 ** | -0.25 ** | -0.63 | 23.17 ** | 0.19 | 0.13 * | -0.25 |
| Suraj× GISV 323 | 3.08 | 1.52 * | 0.76 ** | 0.18 ** | -0.04 | -1.65 * | 20.24 ** | -0.52 * | -0.12 | 0.23 |
| Suraj× RHC 1409 | 1.29 | -2.52 ** | -1.37 ** | 0.14 * | -0.32 ** | 0.82 | -21.38 ** | -2.06 ** | -0.04 | 1.44 ** |
| SE | 2.7199 | 0.6178 | 0.1815 | 0.0643 | 0.0756 | 0.6359 | 2.0661 | 0.2088 | 0.0622 | 0.1668 |

** Significant at 1 per cent level, * Significant at 5 per cent level
PH: Plant height, S: Number of sympodial branches, NBPP: Number of bolls per plant, BW: Boll weight, LI: Lint index, GOT: Ginning outturn, SCYPP : Seed cotton yield per plant, UHML: Upper Half Mean Length, EL: Elongation per cent, MIC: Micronaire value.

Parents showing high mean values for the combining ability in crosses are considered to have good general combining ability (*gca*) and if they have enough potential to combine well with only a particular cross, they are considered to have good specific combining ability (*sca*) as given by Monicashree *et al*. (2017). Among the lines from **Table 4**, BHS 18 showed a highly significant *gca* value for the trait boll weight (0.35) and MCU 5 showed a highly significant *gca* value for the traits *viz*., lint index (0.17) and the elongation length (0.21). The line CO 14 exhibited a highly significant *gca* values for the traits *viz*., the number of sympodial branches (2.29), the number

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of bolls per plant (2.30) and seed cotton yield per plant (9.31). A highly significant *gca* value for the trait upper half mean length (0.47) and the micronaire value (0.29) were found to be the highest in the line TCH 1828. The lowest significant *gca* value was observed in the line CO 17 (-4.14). Among the testers, KC 2 was found to have the highly significant *gca* value for the traits *viz*., lint index and upper half mean length (0.63) and KC 3 exhibited a highly significant *gca* value for the traits *viz*., the number of sympodial branches (3.75), the number of bolls (3.57) and boll weight (0.35). RHC 1409 exhibited the lowest significant *gca* value for the plant height (-9.99) and a significant positive value for the trait micronaire value. GISV 323 showed a highly significant positive value for the trait elongation length (0.12).

Among the 35 hybrids in **Table 5**, Suraj × GTHV 15-34 was found to have highly significant *sca* values for the traits namely the number of sympodial branches per plant and the number of bolls per plant. BSH 18 × RHC 1409 was observed to have highly significant *sca* values for the traits namely boll weight and seed yield of cotton. Similar results were concluded by Rauf *et al*.(2005). Suraj × KC 3 showed a highly significant *sca* value for the trait lint index . BSH 18 × GISV 323 was found to have a highly significant *sca* value for the trait ginning out turn and upper half mean length. A highly significant negative value was observed for the plant height in the cross Suraj × KC 2. A highly significant positive *sca* value was observed for the trait elongation length and micronaire value in the cross TCH 1828 × KC 3 and CO 14 × KC2, respectively. Hence, among the available genotypes, these genotypes were recognized as the best parental material and hence can be used as parents in hybridization programmes as reported by Sawarkar *et al*. (2015).

From the heterosis and combining ability studies, the results revealed that many hybrids have outperformed the standard check variety for yield and its contributing traits and also for the quality parameters studied. Hence, these hybrids paves way for the improvement of the yield along with the quality traits in cotton, further enhances the spinning and weaving qualities of the cotton for industrial purposes. These genotypes may be evaluated over different locations for exploiting their superiority and conformational studies as suggested by Naik *et al*. (2020).

Identification of parents for breeding programme based on either *per se* performance or *gca* effects alone was misleading in the selection programme. The parents showing a positive relationship between *per se* performance and *gca* effects may have more number of additive genes. They also contribute for the accumulation of favorable genes in a varietal development programme. Combining ability analysis exhibits the dominance or non- additive gene action in all yield and fibre quality contributing traits. The findings of Sivia *et al*. (2017), Monicashree *et al*. (2017) and Khokhar *et al*. (2018) also confirmed the non-additive gene action that was appeared to be dominant in the traits *viz*., the number of sympodia per plant, the number of bolls per plant, boll weight and seed cotton yield per plant as suggested by Gnanasekaran *et al*. (2021). Non-additive gene action results due to the lack of association between *per se* performance and the *gca* effects of parents *i.e.,* either having values of high mean with low *gca* effects or *vice versa*. An attempt could be made for selecting desirable hybrids through multiple crosses for yield and fibre quality traits in the segregating generations, as no parent was found to be a good combiner for all the traits.

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