Combining ability estimates and heterosis analysis on major yield attributing traits and lint quality in American cotton (*Gossypium hirsutum* L.)

S. Mudhalvan¹*, S. Rajeswari², L. Mahalingam², P. Jeyakumar³, M. Muthuswami⁴ and N. Premalatha²

¹Department of Genetics and Plant Breeding, CPBG, TNAU, Coimbatore, 641003.
²Department of Cotton, CPBG, TNAU, Coimbatore, 641003.
³Department of Plant Physiology, TNAU, Coimbatore, 641003
⁴Department of Agricultural Entomology, TNAU, Coimbatore, 641003
*E-Mail: muthalvanshanmugam2012@gmail.com

**Abstract**

Six cotton lines and five testers were crossed in a line x tester mating design in 2019. Thereby hybrids along with 11 parents and a standard check were evaluated for combining ability and standard heterosis. Observations on sympodial branches per plant, the number of bolls per plant, boll weight, Ginning Out Turn, staple length and seed cotton yield per plant were recorded. Among the parents, GJHV 534, TVH 002, NDLH 32, TCH 1894 and RAHC 1040 displayed higher positive gca effects for the number of bolls/plant, sympodial branches/plant, span length, seed cotton yield and ginning outturn percentage. Such results suggested that all these five parents were good general combiners covering the yield contributing traits studied and may be preferred for hybridization and selection programmes. The crosses viz., TVH 002 x RAHC 1040, GJHV 534 x RAHC 1040 and TCH 1894 x NDLH 32 with higher estimates of sca effects for almost all the traits and also were observed with higher heterotic effects. Thus these hybrids could be potential hybrids for the exploitation of heterosis in cotton.

**Key words**: Combining ability, heterosis, cotton, lint quality

**INTRODUCTION**

Upland cotton is an important cash crop primarily grown for lint in more than 65 countries of the world. It is also called ‘White Gold’ or ‘King of Apparel Fiber’. Most of the plant breeding programmes in cotton are focused on increasing yield and improving lint quality to meet the needs of the textile industry. Sprague and Tatum (1942) used the terms general combining ability (GCA) to designate the average performance of a line in hybrid combinations and specific combining ability (SCA) as the deviation in performance of a cross combination from that predicted on the basis of the general combining abilities of the parents involved in the cross. The line x tester analysis method can be used to estimate general and specific combining abilities in both selves and cross-pollinated plants (Kempthorne, 1957). It plays as an early testing tool in identifying parents with the good combining ability and unravelling the gene action for each biometrical trait. The destiny of any crop is resolved by deducing the magnitude of additive and non-additive components in recombination breeding. Combining ability along with useful heterosis estimates paves way for identifying potential hybrids for heterosis breeding. Many advantages were offered by hybrid cotton over conventional seed variety such as increased productivity, resistance to biotic stresses and sensitivity to inputs (Ali, 2011).
MATERIALS AND METHODS
The experimental research was conducted at the Department of Cotton, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University during the 2019 and 2020 cotton growing seasons. Six cotton lines (high yield and compact plant types) and five testers (good lint quality and jassid resistance donor) (Table 1) were crossed in a line x tester mating design in 2019.

Table 1. List of lines, testers and checks used in the present study

| S. No | LINES   | S. No | TESTERS   |
|-------|---------|-------|-----------|
| 1.    | CO 17   | 1.    | RAHC 1039 |
| 2.    | TVH 002 | 2.    | RAHC 1040 |
| 3.    | TCH 1894| 3.    | KC 2      |
| 4.    | GJHV 534| 4.    | KC 3      |
| 5.    | SHC 374 | 5.    | NDLH 32   |
| 6.    | RH-1354 |       |           |

Check (Mallika) Non Bt

The intraspecific crosses of the upland cotton genotypes were made using hand emasculation and pollination methods (Doak,1934). A hybridization programme was carried out during the peak flowering stage to get an adequate quantity of crossed bolls. Crossed bolls were collected separately and ginned to obtain F1 seeds. Simultaneously, parental seeds were multiplied by selfing selected plants by the clay smear method (Ramanatha Iyer, 1936). The F1 seeds of 30 hybrids along with 11 parents and a standard check non bt hybrid (Mallika) were raised during 2020. Thirty crosses were raised in two replications in a randomized block design (RBD) with each cross in two rows of 6 m length and a spacing of 90 cm between rows and 60 cm between plants so as to maintain 10 plants in each row. The parents were also raised in the adjacent block with four rows for each entry with a spacing of 90 x 45 cm, along with a standard check hybrid for evaluating their combining ability. Recommended agronomic practices and need based plant protection measures were carried out under irrigated conditions to obtain a good crop stand.

Five plants from each genotype were selected from each replication randomly for examining the biometrical observations viz., the number of sympodial branches per plant, number of bolls per plant, boll weight (g), ginning outturn (%) and seed cotton yield per plant (g). Samples were ginned and their lint was used for the analysis of fibre quality trait span length in each replication with a minimum 10 g of lint sample by using High Volume Instrument (HVI) 900 classic. The mean data collected from entire parents, crosses and standard checks were subjected to estimate the heterosis and combining ability using TNAUSTAT statistical analysis software. The total variance was partitioned into replication and treatment for all those seven characters. The mean data were tabulated for yield contributing traits and analysis of variance (ANOVA), estimation of critical difference and standard error were reported in tables for discussion. Standard heterosis (check hybrid) values were calculated. The observed mean data were statistically calculated by TNAUSTAT software.

RESULTS AND DISCUSSION
According to the analysis of variance, hybrids and their parental lines were highly significant for all the traits. Also, mean squares due to general combining ability (GCA) and specific combining ability (SCA) were significant for all the traits and allowed arbitration of the genetic components of variance due to GCA and SCA (Tables 2, 3 and 4). The results of this study reported below were in accordance with the results of Mert et al. (2003), Baloch et al. (2012) and Monicashree et al. (2017).

Table 2. Mean squares from analysis of variance for various characters of cotton

| Source of variation | Df | NSP | NB     | BW     | GOT   | SL     | SCY   |
|---------------------|----|-----|--------|--------|-------|--------|-------|
| Replication         | 1  | 0.53| 1.05   | 0.02   | 1.59  | 0.64   | 59.85 |
| Genotypes           | 40 | 42.76**| 64.65**| 0.65**| 12.36**| 4.11**| 1244.93**|
| Parents             | 10 | 8.13**| 8.84**| 0.66**| 5.41* | 4.50**| 407.04**|
| Lines               | 5  | 37.40**| 214.76**| 0.49**| 13.44**| 2.08**| 2661.99**|
| Testers             | 4  | 38.84**| 37.50**| 1.20**| 18.39**| 16.57**| 2838.26**|
| Lines vs Testers    | 1  | 33.32**| 13.55* | 0.81**| 2.91**| 1.05**| 1413.31**|
| Crosses             | 29 | 32.52**| 78.27**| 0.67**| 14.74**| 3.91**| 1476.91**|
| Crosses vs Parents  | 1  | 686.06**| 227.78**| 0.10 NS| 12.90*| 6.18**| 2896.51**|
| Error               | 40 | 1.58| 2.18   | 0.05   | 2.42  | 0.22   | 62.31 |

* = Significant at 5% level, ** = Significant at 1% level, Df = Degrees of Freedom
NSP - Number of sympodial branches per plant
NB - Number of bolls/ plant
SL - Span length
BW - Boll weight
GOT - Ginning outturn
SCY - Seed cotton yield per plant
### Table 3. Analysis of variance for combining ability for six yield and fibre quality traits

| Source of variation | df | NSP  | NB    | BW   | GOT  | SL   | SCY  |
|---------------------|----|------|-------|------|------|------|------|
| Replication         | 1  | 1.15 | 3.31  | 0.04 | 1.57 | 0.56 | 1.84 |
| Crosses             | 29 | 32.52** | 78.27** | 0.67** | 14.74** | 3.91** | 1476.91** |
| Lines               | 5  | 37.40** | 214.76** | 0.49** | 13.44** | 2.08** | 2661.99** |
| Testers             | 4  | 38.84** | 37.50** | 1.20** | 18.39** | 16.57** | 2838.26** |
| Line × Tester       | 20 | 30.04** | 52.30** | 0.61** | 14.33** | 1.83** | 908.36** |
| Error               | 29 | 1.51  | 2.11  | 0.03  | 2.34  | 0.23  | 65.23 |

* = Significant at 5% level, ** = Significant at 1% level, DF = Degrees of Freedom

### Table 4. Genetic components for six biometrical traits

| Variance | df | NSP  | NB    | BW   | GOT  | SL   | SCY  |
|----------|----|------|-------|------|------|------|------|
| $\sigma^2_A$ | 0.5853 | 0.0817 | 0.8539 | 0.0020 | 0.0133 | 0.0682 | 18.6936 |
| $\sigma^2_D$ | 14.7821 | 14.2626 | 25.0932 | 0.2897 | 5.9969 | 0.8006 | 421.5641 |
| $\sigma^2_A/\sigma^2_D$ | 0.0395 | 0.0057 | 0.0340 | 0.0069 | 0.0022 | 0.0851 | 0.0443 |

### Table 5. Mean performance of parents for different yield attributing major traits and span length

| S.No. | Parents | NSP  | NB    | BW (g) | GOT (%) | SL (mm) | SCY (g) |
|-------|---------|------|-------|--------|---------|----------|---------|
| Lines |         |      |       |        |         |          |         |
| 1     | CO 17   | 21.20 | 24.10 | 4.66   | 36.73   | 28.00    | 112.17  |
| 2     | TVH 002 | 20.05 | 25.50 | 4.71   | 32.88   | 30.00**  | 120.10* |
| 3     | TCH 1894| 23.90* | 21.20 | 4.83*  | 34.62   | 28.30    | 102.33  |
| 4     | GJHV 534| 20.10 | 25.20 | 3.88   | 35.59   | 26.10    | 97.71   |
| 5     | SHC 374 | 19.90 | 23.80 | 3.64   | 33.46   | 26.60    | 86.34   |
| 6     | RHC-H 1438| 20.80 | 21.30 | 4.00   | 36.28   | 28.10    | 84.97   |
| Mean (Lines) | 20.99 | 23.51 | 4.28 | 36.35 | 27.85 | 100.60 |
| SED (Lines) | 0.38 | 0.65 | 0.08 | 0.28 | 0.15 | 3.61 |
| CD of lines (0.05) | 1.12 | 1.33 | 0.16 | 0.81 | 0.44 | 7.40 |
| Testers | | | | | | | |
| 1     | RAHC 1039| 19.10 | 19.60 | 3.91   | 36.35   | 30.35**  | 76.70   |
| 2     | RAHC 1040| 18.50 | 20.10 | 5.00** | 31.71   | 29.75**  | 100.40* |
| 3     | KC 2    | 20.00 | 22.60 | 3.64   | 35.62   | 27.50    | 81.67   |
| 4     | KC 3    | 15.50 | 22.20 | 3.57   | 33.31   | 27.85    | 78.74   |
| 5     | NDLH 32 | 19.50 | 25.20* | 3.37 | 33.99 | 26.00 | 84.98 |
| Mean (Testers) | 18.52 | 21.94 | 3.89 | 28.53 | 28.29 | 84.50 |
| SED (Testers) | 0.35 | 1.21 | 0.07 | 0.25 | 0.14 | 3.29 |
| CD of testers (0.05) | 1.03 | 1.21 | 0.15 | 0.74 | 0.40 | 6.75 |
| Grand Mean | 24.64 | 25.55 | 4.05 | 28.39 | 28.50 | 103.10 |

NSP - Number of sympodial branches per plant  
NB - Number of bolls/ plant  
BW - Boll weight  
GOT - Ginning outturn  
SL - Span length  
SCY - Seed cotton yield per plant

* = Significant at 5% level, ** = Significant at 1% level
The *per se* performance of parents and hybrids for yield, yield contributing characters and fibre quality traits are presented in Table 5 and Table 6, respectively. The biometrical traits viz., the number of sympodial branches per plant, the number of bolls per plant, boll weight, ginning outturn, span length, and seed cotton yield per plant were regarded as positive traits; therefore, higher mean values were preferred. The significance of lines, testers and hybrids were ascertained based on their corresponding Mean and CD values (baseline). The detailed outcome emphasizing *per se* performance of each biometrical trait is discussed as under.

### Table 6. Mean performance of hybrids for yield attributing major traits and span length

| S.No. | Hybrids                  | NSP   | NB  | BW (g) | GOT (%) | SL (mm) | SCY (g) |
|-------|--------------------------|-------|-----|--------|---------|---------|---------|
| 1     | CO 17 X RAHC 1039       | 21.43 | 28.20| 3.80   | 33.85   | 30.05** | 107.17  |
| 2     | CO 17 X RAHC 1040       | 25.20 | 27.70| 4.99** | 38.40** | 38.05   | 138.38**|
| 3     | CO 17 X KC 2            | 26.00 | 29.00| 3.52   | 36.28   | 27.75   | 102.14  |
| 4     | CO 17 X KC 3            | 29.00*| 32.50**| 4.39 | 33.56   | 26.15   | 113.39  |
| 5     | TVH 002 X RAHC 1039     | 30.00**| 31.30**| 4.62* | 30.36   | 30.05* | 144.49**|
| 6     | TVH 002 X RAHC 1040     | 28.00 | 29.60| 2.88   | 34.49   | 30.75** | 110.29  |
| 7     | TVH 002 X KC 2          | 28.30 | 31.20**| 3.86 | 35.70   | 27.55   | 120.29  |
| 8     | TVH 002 X KC 3          | 27.40 | 28.20| 3.90   | 29.13   | 29.25   | 109.98  |
| 9     | TVH 002 X NDLH 32       | 28.60 | 34.90**| 2.88 | 34.49   | 30.75** | 110.29  |
| 10    | TVH 002 X NDLH 32       | 29.80**| 32.60**| 4.86**| 35.30   | 30.65** | 158.40**|
| 11    | TCH 1894 X RAHC 1039    | 30.00**| 23.30| 4.39   | 33.24   | 29.05   | 101.83  |
| 12    | TCH 1894 X RAHC 1040    | 27.50 | 37.10**| 4.18 | 36.12   | 29.70* | 155.09**|
| 13    | TCH 1894 X KC 2         | 24.80 | 33.90**| 3.43 | 36.19   | 28.75   | 115.75  |
| 14    | TCH 1894 X KC 3         | 29.40*| 29.20| 3.80   | 32.02   | 27.35   | 111.02  |
| 15    | TCH 1894 X NDLH 32      | 30.10**| 18.60| 3.74   | 27.74   | 26.85   | 69.49   |
| 16    | GJHV 534X RAHC 1039     | 30.20**| 15.70| 2.75   | 26.27   | 30.05** | 43.07   |
| 17    | GJHV 534X RAHC 1040     | 19.10 | 27.60| 3.75   | 39.10** | 31.90** | 103.55  |
| 18    | GJHV 534X KC 2          | 21.70 | 29.10| 4.16   | 28.41   | 28.15   | 121.14  |
| 19    | GJHV 534X KC 3          | 16.36 | 21.20| 3.76   | 34.29   | 25.80   | 65.41   |
| 20    | GJHV 534X NDLH 32       | 26.60 | 17.50| 4.47   | 32.00   | 27.80   | 78.26   |
| 21    | SHC 374 X RAHC 1039     | 28.70 | 19.40| 3.97   | 27.81   | 29.30   | 77.01   |
| 22    | SHC 374 X RAHC 1040     | 32.00**| 23.80| 4.60**| 34.16   | 29.90* | 109.4   |
| 23    | SHC 374 X KC 2          | 28.20 | 19.50| 4.92**| 32.75   | 29.05   | 96.00   |
| 24    | SHC 374 X KC 3          | 16.36 | 21.20| 4.11   | 26.32   | 27.80   | 87.08   |
| 25    | SHC 374 X NDLH 32       | 28.80 | 30.95**| 4.25 | 37.20* | 29.90* | 131.35**|
| 26    | RHC-H 1438 X RAHC 1039  | 26.20 | 20.20| 4.18   | 31.71   | 29.90* | 84.53   |
| 27    | RHC-H 1438 X RAHC 1040  | 18.30 | 24.80| 4.80**| 25.47   | 29.65* | 119.26  |
| 28    | RHC-H 1438 X KC 2       | 24.90 | 23.50| 3.60   | 34.46   | 28.00   | 84.36   |
| 29    | RHC-H 1438 X KC 3       | 25.60 | 26.80| 4.89**| 34.73   | 27.85   | 131.19**|
| 30    | RHC-H 1438 X NDLH 32    | 30.00**| 22.10| 3.41   | 33.2    | 27.15   | 75.80   |

| Mean  | 26.40 | 26.56 | 4.03 | 28.86 | 28.67 | 106.70 |

| SE d   | 1.23  | 1.45  | 0.18 | 0.88  | 0.48  | 8.07   |
| CD (0.05) | 2.52  | 2.98  | 0.37 | 1.82  | 0.99  | 16.55  |

* = Significant at 5% level, ** = Significant at 1% level

- **NSP** - Number of sympodial branches per plant
- **NB** - Number of bolls per plant
- **BW** - Boll weight
- **GOT** - Ginning outturn
- **SL** - Span length
- **SCY** - Seed cotton yield per plant

https://doi.org/10.37992/2021.1204.153
With respect to the number of sympodial branches per plant, the hybrids viz., SHC 374 x RAHC 1040 (32.00), GJHV 534 x RAHC 1039 (30.20) and TCH 1894 x NDLH 32 (30.10) showed more, while, the parent SHC 374 (19.90) showed a less number of sympodial branches per plant. The maximum number of bolls per plant was recorded in TVH 002 (25.50), GJHV 534 (25.20) and NDLH 32 (25.20). Among the hybrids, TVH 002 x RAHC 1040 recorded a maximum of 39.60 bolls per plant. In the crosses, CO 17 x RAHC 1040 (4.99 g) and SHC 374 x KC 2 (4.92) higher weight of the boll was recorded and it was least in NDLH 32 (3.37). The hybrid GJHV 534 x RAHC 1040 (39.10) showed a higher value of ginning outturn, while the parent TVH 002 (32.88) recorded a lower value. Long span length was observed in the cross GJHV 534 x RAHC 1040 (31.90 mm) and the average span length was noted in GJHV 534 x KC 3 (27.30). For seed cotton yield, hybrids viz., TVH 002 x RAHC 1040 (158.40) and TCH 1894 x RAHC 1040 (155.09) recorded higher value, while among parents TVH 002 (120.10) exhibited the maximum performance for seed cotton yield per plant, while RHC H 1438 (84.97) recorded lower seed cotton yield per plant.

The general combining ability (gca) effects of parents and specific combining ability (sca) effects of hybrids for all the six characters were presented in Tables 7 and 8.

Line TVH 002 and two testers RAHC 1039 and NDLH 32 expressed a positive significant gca effect for the trait number of sympodial branches per plant. Among the crosses, SHC 374 x RAHC 1039, GJHV 534 x RAHC 1039 and CO 17 x KC 3 expressed positive sca effects for the trait number of sympodial branches per plant. It is suggested that there is a possibility of isolating potential segregating progenies in these hybrids. These results are in agreement with the outputs of Soomro et al. (2012) and Jatoi et al. (2011). In TVH 002, CO17, RAHC 1040 and TCH 1894 significant positive gca effects were noticed for the trait number of bolls per plant. The sca effects in hybrids SCH 374 x NDLH 32, GJHV 534 x KC 2 and TVH 002 x RAHC 1039 were positive and significant, while the cross TVH 002 x KC 3 recorded a negative significant sca effect for the trait number of bolls per plant. Similar results were reported by Natera et al. (2012), Thiyagu et al. (2019) and Gnanasekaran et al. (2019). The parents SHC 374 (female parent), RAHC 1039 and KC 2 (pollen parents) expressed positive additive gene action for the boll weight. However, the hybrids RHC – H 1438 x KC 3, GJHV 534 x NDLH 32, TCH 1894 x RAHC 1039 and TVH 002 x RAHC 1040 displayed positive sca effects for the weight of the boll. These results are supported by Natera et al. (2012), Huangjun and Myers (2011) and Jatoi et al. (2011).

Line TCH 1894 and tester RAHC 1040 showed positive gca effects for the trait ginning outturn. The hybrids viz., SHC 374 x NDLH 32, RHC H 1438 x KC 3 and GJHV 534 x RAHC 1040 showed positive sca effects for ginning outturn.

### Table 7. General combining ability effects of parents for yield attributing major traits and span length

| S.No | Parents | NSP | NB   | BW   | GOT  | SL   | SCY  |
|------|---------|-----|------|------|------|------|------|
|      | Lines   |     |      |      |      |      |      |
| 1    | CO 17   | -0.07 | 3.18** | 0.06 | 0.79 | -0.50** | 14.42** |
| 2    | TVH 002 | 2.02** | 6.74** | -0.17** | -0.35 | 0.80** | 20.25** |
| 3    | TCH 1894 | 1.96** | 1.86** | -0.12* | 1.68** | -0.33* | 3.94 |
| 4    | GJHV 534 | -2.94** | -5.10** | -0.25** | 0.32 | 0.07 | -24.41** |
| 5    | SHC 374 | 0.42 | -3.59** | 0.34** | -1.07* | 0.12 | -6.53* |
| 6    | RHC-H 1438 | -1.40 | -3.08** | 0.15* | -1.38** | -0.16 | -7.67** |
| SE (g) ± | 0.38 | 0.46 | 0.05 | 0.48 | 0.15 | 2.55 |
| Testers |         |     |      |      |      |      |      |
| 1    | RAHC 1039 | 1.03** | -2.16** | -0.37** | -1.20* | 1.18** | -18.85** |
| 2    | RAHC 1040 | -1.08** | 2.37** | 0.50** | 1.81** | 1.31** | 23.98** |
| 3    | KC 2    | -0.75** | 1.14* | -0.12* | 0.18 | -0.46** | -0.08 |
| 4    | KC 3    | -1.82** | -0.68 | -0.04 | -1.12* | -1.30** | -3.68 |
| 5    | NDLH 32 | 2.62** | -0.67 | 0.02 | -0.33 | -0.72** | -1.36 |
| SE (g) ± | 0.35 | 0.42 | 0.05 | 0.44 | 0.14 | 2.33 |

* = Significant at 5% level, ** = Significant at 1% level

| NSP | Number of sympodial branches per plant |
| NB  | Number of bolls/ plant                 |
| SL  | Span length                             |
| BW  | Boll weight                             |
| GOT | Ginning outturn                        |
| SCY | Seed cotton yield per plant            |
Table 8. Specific combining ability effects of hybrids for yield contributing major traits and span length

| S.No. | Cross combinations      | NSP   | NB    | BW    | GOT   | SL    | SCY   |
|-------|-------------------------|-------|-------|-------|-------|-------|-------|
| 1     | CO 17 X RAHC 1039       | -5.92**| 0.62  | 0.08  | 0.56  | 0.70  | 4.90  |
| 2     | CO 17 X RAHC 1040       | -0.05  | -4.41**| 0.41**| 2.1   | -1.42**| -6.72 |
| 3     | CO 17 X KC 2            | 0.42   | -1.88 | -0.45**| 1.60  | 0.04  | -18.89|
| 4     | CO 17 X KC 3            | 4.49**| 3.44**| -0.56**| 0.20  | -0.72*| -4.04 |
| 5     | CO 17 X NDLH 32         | 1.05   | 2.23* | 0.51**| -4.46**| 1.40**| 24.74 |
| 6     | TVH 002 X RAHC 1039     | -1.45  | 8.46**| -0.61**| 2.34* | 0.10  | 5.36  |
| 7     | TVH 002 X RAHC 1040     | 2.46**| -3.07**| 0.50**| 0.13  | -0.12 | 7.47  |
| 8     | TVH 002 X KC 2          | 0.63   | -3.24**| 0.11  | 2.16  | -1.46**| -6.58 |
| 9     | TVH 002 X KC 3          | 0.8    | -4.42**| 0.08  | -3.10**| 1.08**| -13.29|
| 10    | TVH 002 X NDLH 32       | -2.44**| 2.27* | -0.07 | -1.53 | 0.40  | 7.03  |
| 11    | TCH 1894 X RAHC 1039    | 0.61   | -2.96**| 0.85**| -0.94 | -0.47 | 10.05 |
| 12    | TCH 1894 X RAHC 1040    | 0.22   | 6.31**| -0.45**| 1.60  | 0.04  | -18.89|
| 13    | TCH 1894 X KC 2         | -2.81**| 4.34**| -0.37**| 0.63  | 0.87* | 5.20  |
| 14    | TCH 1894 X KC 3         | 2.46**| -3.07**| 0.50**| 0.13  | -0.12 | 7.47  |
| 15    | TCH 1894 X NDLH 32      | 0.52   | -3.29**| 0.67**| -2.34**| -0.22 | -2.67 |
| 16    | GJHV 534X RAHC 1039     | 5.71**| -3.60**| -0.67**| 0.17  | 0.13  | -20.36|
| 17    | GJHV 534X RAHC 1040     | -3.28**| 3.77**| -0.53**| 3.27**| 1.85**| -2.72 |
| 18    | GJHV 534X KC 2          | -1.01  | 6.50**| 0.50** | -2.50*| -0.13 | 38.94*|
| 19    | GJHV 534X KC 3          | -1.94*| -3.38**| 0.02  | 1.40  | -1.64**| -13.19|
| 20    | GJHV 534X NDLH 32       | 0.52   | -3.29**| 0.67**| -2.34**| -0.22 | -2.67 |
| 21    | SHC 374 X RAHC 1039     | 0.86   | -1.41 | -0.03 | -2.72**| -0.67 | -4.30 |
| 22    | SHC 374 X RAHC 1040     | 6.27**| -1.54 | -0.27*| -0.29 | -0.19 | -14.75*|
| 23    | SHC 374 X KC 2          | 2.13* | -4.61**| 0.67**| -0.07 | 0.72* | -4.09 |
| 24    | SHC 374 X KC 3          | -8.63*| -1.09 | -0.23 | -1.17 | 0.31  | -9.41 |
| 25    | SHC 374 X NDLH 32       | -0.63  | 8.65**| -0.14 | 4.24**| -0.17 | 32.55**|
| 26    | RHC-H 1438 X RAHC1039   | 0.17   | -1.12 | 0.37**| 0.59  | 0.21  | 4.35  |
| 27    | RHC-H 1438 X RAHC1040   | -5.62**| -1.05 | 0.12  | -4.14**| -0.17 | -3.75 |
| 28    | RHC-H 1438 X KC 2       | 0.65   | -1.12 | -0.47**| 1.83  | -0.05 | -14.58*|
| 29    | RHC-H 1438 X KC 3       | 2.42**| 4.00**| 0.75** | 3.29**| 0.64  | 35.85**|
| 30    | RHC-H 1438 X NDLH 32    | 2.38* | -0.71 | -0.79**| 2.09  | -0.64 | -21.87**|
| **SE**| 0.87                   | 1.02  | 0.13  | 1.08  | 0.34  | 0.34  | 5.71  |

* = Significant at 5% level, ** = Significant at 1% level

outturn. Present results are supported by the report of Kumar et al. (2013). Three parents viz., TVH 002, RAHC 1039 and RAHC 1040 showed positive gca effects for staple length indicating that the trait was conditioned by additive genes in these parents, suggesting the amenability of these genotypes to be used in obtaining varieties with long staple length. There were only five crosses viz., CO 17 x NDLH 32, TVH 002 x KC 3, TCH 1894 x KC 2, GJHV 534 x RAHC 1040 and SHC 374 x KC 2 which displayed positive sca effects for the trait staple length. It is suggested that there is a probability of isolating potential segregating progeny from these five hybrids. Similar results were reported by Baloch et al. (2012) and Natera et al. (2012). In case of gca, CO 17, TVH 002 and RAHC 1040 expressed the positive additive type of gene action for seed cotton yield per plant. However, hybrids viz., TCH 1894 x RAHC 1040, GJHV 534 x KC 2, SHC 374 x NDLH 32 and RHC H 1438 x KC 3 showed positive sca effects for seed cotton yield per plant. In later generations, the selection is suggested to isolate promising genotypes for the development of cultivars/hybrids to boost seed cotton yield/unit area. similar results were also reported by Kumar et al. (2013), Abro et al. (2009), Natera et al. (2012), Soomro et al. (2012), Huangjun and Myers (2011) and Jatoi et al. (2011).
The percentage of standard heterosis for six characters expressed by 30 hybrids was estimated and presented in Table 9. The hybrid Mallika was considered a standard check for all the characters. The range standard heterosis was presented for all the six yield components and fibre quality traits.

Standard heterosis ranged from -16.93 (SHC 374 x KC 3) to 62.44 (SHC 374 x RAHC 1040). Twenty four hybrids recorded significantly positive standard heterosis. While, the crosses of SHC 374 x RAHC 1040, GJHV 534 x RAHC 1039 and TCH 1894 x NDLH 32 had greater positive value for standard heterosis for the trait sympodial branches per plant. These results agree with those observed by Khan and Qasim (2012). Standard heterosis varied from -46.23 (GJHV 534 x RAHC 1039) to 35.62 (TVH 002 x RAHC 1039) for the trait number of bolls per plant. Six hybrids showed significant positive standard heterosis for the number of bolls per plant. The cross TVH 002 x RAHC 1039 had high positive standard heterosis for the number of bolls per plant. These results are in agreement with the results of Soomro et al. (2012). Standard heterosis ranged from -30.86 (GJHV 534 x RAHC 1039) to 25.82 (CO 17 x RAHC 1040) for the trait boll weight. Nine hybrids recorded significantly positive standard heterosis for boll weight. The cross TVH 002 x RAHC 1040 had a higher value for standard heterosis. These findings are supported by Nassar (2013).

### Table 9. Estimates of standard heterosis for yield contributing major traits and span length (Per cent)

| S.No. | Cross combinations | NSP  | NB   | BW   | GOT  | SL  | SCY  |
|-------|--------------------|------|------|------|------|-----|------|
| 1     | CO 17 x RAHC 1039 | 8.78 | -3.42| -4.28| -5.68| 9.67**| -7.58|
| 2     | CO 17 x RAHC 1040 | 27.92**| -5.14 | 25.82**| 7.01 | 2.37 | 19.34**|
| 3     | CO 17 x KC 2      | 31.98**| -0.68 | -11.34*| 1.09 | 1.28 | -11.91|
| 4     | CO 17 x KC 3      | 47.21**| 11.30* | -12.09*| -6.48 | -4.56*| -2.21|
| 5     | CO 17 x NDLH 32   | 52.28**| 7.19  | 16.25**| -15.39**| 5.29**| 24.61**|
| 6     | TVH 002 x RAHC 1039 | 42.13**| 35.62**| -27.58**| -3.90 | 12.23**| -2.15|
| 7     | TVH 002 x RAHC 1040 | 51.27**| 11.64* | 22.29**| -1.64 | 11.86**| 36.61**|
| 8     | TVH 002 x KC 2    | 43.65**| 6.85  | -2.90 | -0.53 | 0.55  | 3.74  |
| 9     | TVH 002 x KC 3    | 39.09**| -3.42 | -1.76 | -18.84**| 6.75**| -5.15 |
| 10    | TVH 002 x NDLH 32 | 45.18**| 19.52**| -4.28 | -10.41*| 6.39**| 14.38*|
| 11    | TCH 1894 x RAHC 1039 | 52.28**| -20.21**| 10.58* | -7.37 | 6.02**| -12.18|
| 12    | TCH 1894 x RAHC 1040 | 39.59**| 27.05**| 5.29  | 0.64  | 8.39**| 33.75**|
| 13    | TCH 1894 x KC 2   | 25.89**| 16.10**| -13.73**| 0.85  | 4.93**| -0.18 |
| 14    | TCH 1894 x KC 3   | 49.24**| 0.00  | -4.28 | -6.26  | -0.18 | -4.26 |
| 15    | TCH 1894 x NDLH 32 | 52.79**| -36.30**| -5.92 | 5.07  | -2.01 | -40.08**|
| 16    | GJHV 534 x RAHC 1039 | 53.30**| -46.23**| -30.86**| -8.09 | 9.67**| -62.86**|
| 17    | GJHV 534 x RAHC 1040 | -3.05 | -5.48 | -5.54 | 8.94* | 16.42**| -10.70|
| 18    | GJHV 534 x KC 2   | 10.15  | -0.34 | 4.79  | -11.66**| 2.74  | 4.47  |
| 19    | GJHV 534 x KC 3   | 0.00 | -40.41**| -5.16 | -4.44 | -5.84**| -43.59**|
| 20    | GJHV 534 x NDLH 32 | 35.03**| -40.07**| 12.59**| -10.82*| 1.46  | -32.51**|
| 21    | SHC 374 x RAHC 1039 | 45.69**| -33.56**| 0.00  | -19.99**| 6.93  | -33.58**|
| 22    | SHC 374 x RAHC 1040 | 62.44**| -18.49**| 15.87**| -4.82 | 9.12**| -5.65 |
| 23    | SHC 374 x KC 2    | 43.15**| -33.22**| 24.06**| -8.75*| 6.02**| -17.21**|
| 24    | SHC 374 x NDLH 32 | -16.93*| -27.40**| 3.40  | -15.48**| 1.46  | -24.90**|
| 25    | SHC 374 x KC 3    | 46.19**| 5.99  | 6.93  | 3.66  | 1.82  | 13.28 |
| 26    | RHC-H 1438 x RAHC 1039 | 32.99**| -30.82**| 5.42  | -11.63**| 9.12**| -27.11**|
| 27    | RHC-H 1438 x RAHC 1040 | -7.11 | -15.07**| 21.03**| -16.43**| 8.21**| 2.85  |
| 28    | RHC-H 1438 x KC 2  | 26.40**| -19.52**| -9.45 | -14.54**| 2.19  | -27.25**|
| 29    | RHC-H 1438 x KC 3  | 29.95**| -8.22 | 23.30**| -3.9  | 1.64  | 13.14 |
| 30    | RHC-H 1438 x NDLH 32 | 52.28**| -24.32**| -14.11| -3.22 | -0.91 | -34.63**|

SE 1.25 1.43 0.18 1.51 0.48 8.00

* = Significant at 5% level, ** = Significant at 1% level
standard heterosis. These results are in accordance with El-Hashash (2013) and Gnanasekaran et al. (2019).

Cotton textile industries demand better yield and high lint quality cotton and for this reason development of varieties with good yield potential and better fibre quality is one of the important targets of all cotton breeders. The parents GJHV 534, TVH 002, NDLH 32, TCH 1894 and RAHC were found to have higher positive gca effects. Such results suggested that all the five parents were good general combiners for the yield attributing major traits. The crosses like TVH 002 x RAHC 1040, GJHV 534 x RAHC 1040, CO 17 x RAHC 1039, SHC 374 x RAHC 1040 and TCH 1894 x RAHC 1040 were identified as the best hybrids for exploitation through heterosis breeding with regard to per se, sca effect and standard heterosis.

REFERENCES

Abro, S., Kandhro, M.M., Laghari, S., Arain, M.A. and Deho, Z.A. 2009. Combining ability and heterosis for yield contributing traits in upland cotton (Gossypium hirsutum L.). Pak. J. Bot., 41(4): 1769-1774.

Ali, G.M. 2011. Cotton hybrid seed production at PARC. Technical Report, 2(4): 1.

Baloch, A. W., Ejaz, M., Baloch, G.A., Yasir, T.A., Hayat, S., Shah, N.M., Baloch, M.J., Ahmad, I., Rahman, S., Wasila, H. and Khan, M.A. 2012. Development of superior F1 hybrids design-ii analysis for estimating combining ability of fibre and earliness in upland cotton. Global J. Biodiversity Sci. and Management, 2(1): 38-42.

Doak, C.C. 1934. A new technique in hybridizing suggested changes in existing methods of emasculation and bagging cotton flowers. J. Hered., 25: 201–204. [Cross Ref]

El-Hashash, E.F. 2013. Heterosis and gene action among single and double-cross hybrids performances in cotton. American-Eurasian J. Agric. & Environ. Sci., 13 (4): 505-516.

Geddam, Sekhar Babu and Khadi, B.M. 2013. Heterosis in GMS based diplod cotton hybrids for fibre quality traits. Asian J. Bio. Sci., 8(1): 79-81.

Gnanasekaran, M., Thiagu, K. and Gunasekaran, M. 2019. Combining ability and heterosis studies on yield and quality traits in hirsutum cotton. Electronic Journal of Plant Breeding, 10(4): 1519-1531. [Cross Ref]

Huangjun Lu. and Myers, G.O. 2011. Combining abilities and inheritance of yield components in influential upland cotton varieties. Aus. J. Crop Sci., 5(4): 384-390.

Jatoi, W.A., Baloch, M.J., Veesar, N.F. and Panhwar, S.A. 2011. Combining ability estimates from line x tester analysis for yield and yield components in upland cotton genotypes. J. Agric. Res., 49(2): 165-172.

Kempthorne, O. 1957. An introduction to genetic statistics. John Wiley and Sons, Inc. New York.

Khan, T.M. and Qasim, M. U. 2012. Genetic studies of yield traits in cotton Gossypium hirsutum L. J. Agric. Res., 50 (1): 21-28.

Kumar, M., Nirania, K.S., Sangwan, R.S. and Yadav, N.K. 2013. Combining ability studies for yield and quality traits in upland cotton Gossypium hirsutum L. J. Cotton Res. Dev., 27 (2): 171-174.

Mert, M., Gencer, O., Akiscan, Y. and Boyaci, K. 2003. Determination of superiority parents and hybrid combinations in respect to lint yield and yield components in cotton (G. hirsutum L.). Turkish J. Agric. Fore., 27: 337–43.

Monicashree, C., Amala Balu, P. and Gunasekaran, M. 2017. Combining ability and heterosis studies on yield and fibre quality traits in upland cotton (Gossypium hirsutum L.). Int.J.Curr.Microbiol.App.Sci., 6(8): 912-927. [Cross Ref]

Nassar, M.A.A. 2013. Some genetic parameters and heterosis in two crosses of Egyptian cotton. J. Appl. Sci. Res., 9(1): 548-553.

Natera, J.R., Mendez., A. Rondón., Hernández, J. and Fernando Merazo Pinto, J. 2012. Genetic studies in upland cotton Gossypium hirsutum L. general and specific combining ability. J. Agr. Sci. Tech., 14: 617-627.

https://doi.org/10.37992/2021.1204.153
Ramanatha Iyer. 1936. An inexpensive method of selfing cotton flowers. Emp. Cott. Grow. Rev., 13: 28–30.

Sprague, G. F and Tatum, L. A. 1942. General versus specific combining ability in single crosses of corn. J. Amer. Soc.Agron., 34:923-952. [Cross Ref]

Soomro, M. H., Markhand, G.S. and Mirbahar, A.A. 2012. Estimation of combining ability in F2 Population of upland cotton under drought and non- drought regimes. Pak. J. Bot., 44(6): 1951-1958.

Thiyagu, K., Gnanasekaran, M. and Gunasekaran, M. 2019. Components and fibre quality traits in upland cotton (Gossypium hirsutum L.). Electronic Journal of Plant Breeding, 10(4): 1501-1511. [Cross Ref]

Yuksel Bolek, Cokkizgin, H. and Bardak, A. 2010. Combining ability and heterosis for fiber quality traits in cotton. Plant Breeding and Seed Science, 62: 3–16. [Cross Ref]