L × T Analysis in F₅ Lines of RGR Population Derived through Exploitation of Heterotic Groups in Gossypium Species

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Authors' contributions

This work was carried out in collaboration between both authors. Author SSP designed the study and provided the guidance for the experiment. Author GT conducted the experiment, statistical analyses and wrote the draft of manuscript. Both authors read and approved the final manuscript.

ABSTRACT

The combining ability studies assist in choosing the desirable parents for crossing in hybrid development. Forty derived hybrids generated by crossing ten F₅ lines to the four testers for assessing combining ability. Hybrids along with the parents were planted in randomized block design and analysis of variance suggested that lines had significant differences for all the characters studied except number of monopodia per plant, reproductive points on sympodia and ginning outturn. Significant line effect of seed cotton yield and lint yield was revealed by ANOVA for combining ability. Variance of sca was higher than Variance of gca for all characters apart from seed cotton yield and lint yield. RGR F₅₉ and RGR F₅₇ lines were recorded to be the highest seed cotton yielding lines. The gca effects were highly significant for seed cotton yield and lint yield in RGR F₅₁ and RGR F₅₅ lines. RGR F₅₁ × DR-8, RGR F₅₇ × DR-8 and RGR F₅₈ × DR-8 were the top three hybrids for seed cotton yield. The sca effect was positively significant in hybrids RGR F₅₇ × DR-8 and RGR F₅₁ × DR-8 for seed cotton yield.
Keywords: Cotton; L × T study; gca effects and sca effects.

1. INTRODUCTION

Cotton a crop of wealth and prominence which is closely associated with human civilization and known as "King of Fibre". India occupies maximum area of cotton cultivation (with 34% of world’s area) while China stands first in cotton production before India (with 21% of world’s production). Cotton accounts for 50 per cent of all fibres used in textile industry because it is the most important natural fibre in clothing industry. It is mostly cultivated in the tropical regions as well as temperate regions of more than 50 countries. The China, India, USA, Middle East and Australia are the major cotton growing countries. Genus of cotton i.e. Gossypium comprised of four cultivated, two wild tetraploid and 44 wild diploid species. All cultivated species of cotton viz. Gossypium arboreum, G. herbaceum, G. barbadense and G. hirsutum were commercially grown only in India. Hybridization method is of supreme importance for breaking yield plateau by generating the recombinational variability. It proceeds with choosing the parents with utmost care generally done using combining ability of parents and hence studying the combining ability is important. Selection of desirable parents to exploit heterosis is assisted by combining ability effects which also evaluate the capability of parents to produce high yielding hybrids with stable performance. The genetic information regarding ability of lines in a series of crosses were provided by combining ability [1]. gca/ sca ratio of greater than one suggests the major existence of additive gene action which can be exploited by progeny selection in segregating generations. While gca/sca ratio of less than one advocates the major existence of non-additive gene action which can be utilized by heterosis breeding but if gca/sca ratio equates one it suggests that additive as well as non-additive gene action are equally important. The objective of present investigation was to estimate the combining ability of the lines which were developed from crossing between heterotic groups.

2. MATERIALS AND METHODS

2.1 Development of Genetic Material

Elite combiner lines viz. DSMR 10, DSG 3-5, DRGR 32-100 and DRGR 24-178 belonging to different heterotic groups viz. Stay green, Robust, RGR group and RGR group respectively were selected and crossed in subsequent manner [DSMR-10 × DSG 3-5], [DRGR 32-100 × DRGR 24-178] to generate two highly diverse base populations [2]. Later the F₁s of crosses (DSMR 10 × DSG 3-5) and (DRGR 32-100 × DRGR 24-178) were advanced to F₂ generation to develop population I RSG F₅ lines and population II RGR F₅ lines respectively.

Population II RGR F₅ lines derived from cross DRGR 32-100 × DRGR 24-178 were used in the current study with the name Population I RGR F₅ lines. Randomly selected ten F₅ lines were crossed with the parents of the opposite group population i.e. lines of DRGR 32-100 × DRGR 24-178 cross were crossed with DSMR 10 (T₁) and DSG 3-5 (T₂) (opposite testers). The F₆ lines were also crossed with one additional tester DH 7225 (T₃) and one diverse tester DR 8 (T₄). Totally four testers viz., DSMR 10 (T₁), DSG 3-5 (T₂), DH 7225 (T₃) and DR 8 (T₄) were used to hybridize with ten F₅ lines which resulted forty derived hybrids.

2.2 Season and Field Layout

Forty F₅ derived hybrids, fourteen parents (lines & testers) along with two commercial checks Mallika and Jadoo were sown at ARS, Dharwad Farm. The experiment was conducted using randomized block design replicating the genotypes twice during Kharif, 2014-2015. Standard agronomical package of practices for cotton were followed to raise the good crop.

2.3 Observations

Four random healthy plants representing the entry were selected for recording observations on the following traits viz: height of plant, number of monopodia per plant, number of sympodia per plant, number of bolls per plant, weight of boll (gm), length of sympodial (cm), reproductive points on sympodia, inter-boll distance (cm), interbranch distance (cm), seed cotton yield (kg/ha), lint yield (kg/ha), ginning outturn, seed index (gm) and lint index.

2.4 Statistical Analysis

Recorded mean data over replications were analyzed using Analysis of variance (ANOVA), estimation of Standard Error (SE) and Critical Difference (CD) [3]. Line × Tester analysis [4] were used for estimating the combining ability.
3. RESULTS

3.1 Analysis of Variance

Population I RGR F₅ lines revealed significant differences among the parents for all characters excluding number of monopodia per plant, reproductive points on sympodia and ginning outturn (Table 1). Significant differences were seen for all traits except number of monopodia per plant, reproductive points on sympodia and ginning outturn in lines while among testers significant differences were observed for weight of boll, length of sympodial at 50% height, inter boll distance, inter branch distance, seed cotton yield, lint yield, seed index and lint index were found significant.

Interaction between lines and testers was found to be non-significant for number of monopodia per plant, number of sympodia per plant, number of bolls per plant, reproductive points on sympodia, seed cotton yield, lint yield and ginning outturn. Variance of hybrids were found significant for most of the characters studied while interaction between hybrids and parents was found to be significant for most of the traits except height of plant, number of monopodia per plant, weight of boll, inter boll distance, ginning outturn and lint index.

3.2 ANOVA for Combining Ability

Population I RGR F₅ lines, revealed traits like seed cotton yield and lint yield were significant in line effect while for tester effect, number of bolls per plant, seed cotton yield and lint yield were found significant (Table 2). All the traits studied possessed significant L × T interactions. SCA variance was greater than gca variance for all the traits except for seed cotton yield and lint yield.

3.3 Per se Performance of Parents

Number of bolls per plant, in F₅ lines ranged from 13.75 (RGR F₅ 6) to 23.88 (RGR F₅ 9) with an overall mean of 17.51 whereas mean for testes it ranged from 15.25 DH 7225 to 20 DSG3-5 (Table 3). Mean for weight of boll ranged from 2.95 (RGR F₅ 6) to 5.40 (RGR F₅ 2) with the overall mean of 4.42 while testers mean ranged from 3.70 (DSMR 10) to 5.05 (DSG3-5). Seed cotton yield varied from 1263.68 kg/ha (RGR F₅ 2) to 2332.23 kg/ha (RGR F₅ 9) with overall mean of 1712.50 kg/ha in F₅ lines while among testers mean fluctuated from 1267.05 kg/ha (DH 7225) to 2115.77 kg/ha (DR 8). Top two lines with highest recorded seed cotton yield were RGR F₅ 9 (2332.23 kg/ha) and RGR F₅ 7 (1899.55 kg/ha). Lint yield in F₅ lines varied from 487.54 kg/ha (RGR F₅ 2) to 908.46 kg/ha (RGR F₅ 9) whereas for testers it ranged from 488.27 kg/ha (DH 7225) to 796.74 kg/ha (DR 8).

3.4 Per se Performance of Hybrids

Number of bolls per plant in F₅ derived hybrids of population I RGR F₅ lines were varied from 13.13 (RGR F₅ 8 × DSMR 10) to 31.63 (RGR F₅ 1 × DR 8) with an overall mean of 19.93 (Table 4). The weight of boll among F₅ derived hybrids varied from 2.95 to 6.15 with an overall mean of 4.51. Among the F₅ derived hybrids seed cotton yield varied from 1258.79 kg/ha (RGR F₅ 8 × DSMR10) to 2577.55 kg/ha (RGR F₅ 1 × DR 8). Three hybrids displaying maximum mean yield were RGR F₅ 1 × DR8 (2577.55 kg/ha), RGR F₅ 7 × DR8 (2391.20 kg/ha) and RGR F₅ 8 × DR8 (2259.25 kg/ha). The variation in F₅ derived hybrids for lint yield varied from 461.90 kg/ha (RGR F₅ 8 × DSMR 10) to 993.47 kg/ha (RGR F₅ 1 × DR 8) with a mean value 698.57 kg/ha.

3.5 gca and sca Effects

RGR F₅ 1 (3.98) and RGR F₅ 5 (2.42) had shown positively significant gca effect for number of bolls per plant while among testers DR 8 (4.07), had shown significantly positive gca effect (Table 5). The sca effects of hybrids were significant in twelve hybrids but only five were in positive direction for number of bolls per plant (Table 6). Hybrids showing maximum sca effect were RGR F₅ 7 × DR8 (8.23), RGR F₅ 10 × DH 7225 (3.85) and RGR F₅ 1 × DR8 (3.64). The gca effects for weight of boll in seven lines were found significant among them RGR F₅ 1, RGR F₅ 3, RGR F₅ 5 and RGR F₅ 6 lines showed positive significant gca effects. The sca effect was positively significant for nine hybrids and RGR F₅ 10 × DR8 (1.41) and RGR F₅ 3 × DSMR10 (1.38) were highly significant for sca effect. RGR F₅ 1 (157.67) and RGR F₅ 5 (267.09) lines exhibited positive significant gca effects whereas among testers DR8, was noted to be the best combiner followed by DH7225 for seed cotton yield. For seed cotton yield only four hybrids possessed significant sca effect and the top two hybrids were RGR F₅ 7 × DR8 (323.09) and RGR F₅ 1 × DR8 (267.94). Two lines RGR F₅ 5 (117.27) and RGR F₅ 1 (56.85) for lint yield showed positively significant gca effects while DR8 (138.11) and DH7225 (30.56) testers exhibited positively significant gca effect. Top two hybrids showing highly significant sca effect for lint yield were RGR F₅ 7 × DR8 (144.04) and RGR F₅ 5 × DSMR10 (105.18).
Table 1. Analysis of variance for different quantitative characters for evaluation of combining ability in segregating generations from heterotic box (Population I RGR F₄ lines)

| Source of variation | Df | Plant height (cm) | No. of Monopodia per plant | No. of Sympodia per plant | No. of bolls per plant | Boll weight (g) | Symposidal length at 50% height (cm) | Reproductive points on sympodia | Inter boll distance (cm) | Inter branch distance (cm) | Seed cotton yield (kg ha⁻¹) | Lint yield (kg ha⁻¹) | Ginning outturn (%) | Seed index (g) | Lint index (g) |
|---------------------|----|------------------|-----------------------------|---------------------------|------------------------|----------------|-------------------------------------|--------------------------------|---------------------|------------------------|---------------------------------|-----------------|----------------------|----------------|----------------|
| Replicates          | 1  | 35.59            | 0.06                        | 6.50                      | 2.44                   | 0.58           | 10.96                               | 0.05                           | 0.89                | 5.97                   | 11394.58                         | 1095.76         | 0.24                 | 2.28          | 1.08          |
| Treatments          | 53 | 500.20            | 0.71                        | 7.33                      | 33.96                  | 1.41           | 114.69                              | 1.49                           | 5.00                | 27.02                  | 196373.70                         | 32020.10        | 2.41                 | 2.56          | 1.09          |
| Parents             | 13 | 706.84            | 0.41                        | 11.08                     | 12.42                  | 1.15           | 149.01                              | 0.45                           | 7.24                | 56.52                  | 181776.80                         | 26884.75        | 1.08                 | 3.46          | 1.15          |
| Parents (Line)      | 9  | 837.05            | 0.45                        | 15.69                     | 14.15                  | 1.31           | 131.80                              | 0.57                           | 5.70                | 66.12                  | 172815                           | 26685.23        | 1.22                 | 3.64          | 1.14          |
| Parents (Testers)   | 3  | 44.69             | 0.24                        | 0.86                      | 10.05                  | 0.69           | 160.25                              | 0.09                           | 6.82                | 39.79                  | 260236.30                         | 34985.80        | 1.02                 | 2.56          | 0.95          |
| Parents (L vs T)    | 1  | 1521.49           | 0.58                        | 0.35                      | 3.88                   | 1.08           | 270.08                              | 0.46                           | 22.40               | 20.35                  | 27054.73                          | 4377.24         | 0.01                 | 4.52          | 1.79          |
| Parent vs crosses   | 1  | 7.32              | 0.85                        | 21.29                     | 145.45                 | 0.02           | 976.20                              | 14.32                          | 3.83                | 534.83                 | 311916.30                         | 44681.10        | 0.26                 | 3.00          | 1.01          |
| Crosses             | 39 | 443.96            | 0.81                        | 5.728                     | 38.29                  | 1.53           | 81.16                               | 1.50                           | 4.28                | 4.16                   | 198276.70                         | 33407.25        | 2.91                 | 2.25          | 1.08          |
| Error               | 53 | 163.59            | 0.26                        | 3.21                      | 4.16                   | 0.17           | 15.08                               | 0.69                           | 1.87                | 1.56                   | 19857.36                          | 3260.012        | 0.85                 | 0.73          | 0.25          |

Table 2. Analysis of variance for combining ability involving population I RGR F₄ lines (F₄ lines of DRGR-24-178 x DRGR-32-100) and its derived hybrids for different characters in evaluation of combining ability in segregating generations from heterotic box

| Source of variation | Df | Plant height (cm) | No. of Monopodia/ plant | No. of Sympodia per plant | No. of bolls per plant | Boll weight (g) | Symposidal length at 50% height (cm) | Reproductive points on sympodia | Inter boll distance (cm) | Inter branch distance (cm) | Seed cotton yield (kg ha⁻¹) | Lint yield (kg ha⁻¹) | Ginning outturn (%) | Seed index (g) | Lint index (g) |
|---------------------|----|------------------|-------------------------|---------------------------|------------------------|----------------|-------------------------------------|--------------------------------|---------------------|------------------------|---------------------------------|-----------------|----------------------|----------------|----------------|
| Replicates          | 1  | 1.89             | 0.15                    | 5.94                      | 1.8                    | 0.54           | 0.001                               | 0.09                           | 0.01                | 1.77                   | 57.98                            | 106.42          | 0.2                  | 2.92          | 1.37          |
| Line Effect         | 9  | 716.16           | 0.98                    | 5.26                      | 29.92                  | 1.88           | 94.77                               | 0.97                           | 4.12                | 1.63                   | 130923.20                         | 23891.76        | 2.43                 | 3.75          | 1.28          |
| Tester Effect       | 3  | 499.64           | 1.66                    | 5.33                      | 210.31                 | 0.35           | 154.57                              | 0.72                           | 7.79                | 6.51                   | 1645653                          | 265737          | 2.19                 | 0.91          | 1.18          |
| Line Tester Eff.    | 27 | 347.04           | 0.65                    | 5.92                      | 21.96                  | 1.54           | 68.46                               | 1.77                           | 3.95                | 4.75                   | 59908.34                          | 10764.66        | 3.14                 | 1.89          | 1.00          |
| Error               | 39 | 67.17            | 0.24                    | 2.31                      | 3.06                   | 0.17           | 13.41                               | 0.83                           | 1.73                | 0.42                   | 19824.1                | 3257.14         | 0.91                 | 0.88          | 0.29          |
| s²gca               | 38.62 | 0.07            | 0.21                    | 7.01                     | -0.03                  | 7.94           | 0.001                               | 0.30                           | 0.26                | 59169.96                           | 9574.97         | -0.06                | 0.10          | 0.02          |
| s²gca/s²sca         | 139.93 | 0.20           | 1.81                    | 9.45                     | 0.68                   | 27.52          | 0.47                                | 1.11                           | 2.16                | 20042.12                           | 3753.75         | 1.12                 | 0.50          | 0.36          |
| s²gca/s²sca         | 0.27 | 0.38            | 0.11                    | 0.74                     | -0.04                  | 0.28           | 0.00                                | 0.27                           | 0.12                | 2.95                                | -0.05           | 0.20                 | 0.06          | -0.06         |
| Sl. no. | F₈ Line | Plant height (cm) | No. of Mono podia/ plant | No. of Symodia per plant | No. of bolls per plant | Boll weight (g) | Sympodial length at 50% height (cm) | Reproductive points on sympodia | Inter boll distance (cm) | Inter branch distance (cm) | Seed cotton yield (kg ha⁻¹) | Lint yield (kg ha⁻¹) | Ginning outturn (%) | Seed index (g) | Lint index (g) |
|--------|---------|------------------|------------------------|------------------------|------------------------|----------------|-------------------------------------|-------------------------------|------------------------|------------------------|-----------------------------|------------------|-----------------|----------------|---------------- |
| 1      | RGR F₈ 1 | 114.25 | 1.50 | 16.88 | 16.63 | 4.05 | 39.38 | 4.88 | 8.06 | 15.44 | 1728.50 | 650.85 | 37.64 | 12.31 | 7.43 |
| 2      | RGR F₈ 2 | 133.13 | 1.63 | 18.38 | 18.13 | 5.40 | 30.63 | 4.75 | 6.45 | 7.75 | 1263.68 | 487.54 | 38.59 | 8.82 | 5.54 |
| 3      | RGR F₈ 3 | 106.75 | 1.25 | 18.75 | 16.25 | 2.95 | 16.38 | 3.13 | 5.20 | 18.94 | 1406.25 | 554.37 | 39.42 | 10.32 | 6.71 |
| 4      | RGR F₈ 4 | 101.50 | 2.13 | 16.00 | 18.25 | 3.95 | 35.88 | 4.50 | 7.97 | 20.50 | 1748.62 | 700.00 | 40.02 | 10.35 | 6.91 |
| 5      | RGR F₈ 5 | 91.25  | 1.25 | 17.25 | 17.13 | 4.75 | 33.75 | 4.00 | 8.71 | 8.13 | 1763.90 | 662.73 | 37.56 | 12.78 | 7.69 |
| 6      | RGR F₈ 6 | 113.63 | 2.00 | 19.38 | 13.75 | 3.85 | 36.50 | 4.00 | 9.25 | 16.13 | 1499.20 | 568.17 | 37.92 | 11.25 | 6.87 |
| 7      | RGR F₈ 7 | 123.00 | 1.25 | 15.13 | 18.50 | 5.35 | 39.13 | 4.38 | 8.94 | 9.44 | 1899.55 | 737.54 | 38.88 | 10.28 | 6.54 |
| 8      | RGR F₈ 8 | 107.75 | 1.38 | 14.75 | 17.25 | 4.75 | 29.88 | 3.75 | 8.03 | 16.50 | 1664.13 | 640.46 | 38.40 | 10.03 | 6.25 |
| 9      | RGR F₈ 9 | 105.88 | 1.00 | 10.25 | 23.88 | 3.85 | 19.50 | 4.13 | 4.98 | 5.63 | 2332.23 | 908.46 | 38.97 | 12.94 | 8.26 |
| 10     | RGR F₈ 10| 164.38 | 2.50 | 13.13 | 15.38 | 5.25 | 24.00 | 4.75 | 5.01 | 21.38 | 1819.01 | 690.55 | 37.98 | 11.69 | 7.15 |
| Mean   |         | 116.15 | 1.59 | 15.99 | 17.51 | 4.42 | 30.50 | 4.23 | 7.26 | 13.98 | 1712.50 | 660.07 | 38.54 | 11.07 | 6.94 |
| Minimum|         | 91.25  | 1.00 | 10.25 | 13.75 | 2.95 | 16.38 | 3.13 | 4.98 | 5.63 | 1263.68 | 487.54 | 37.56 | 8.82 | 5.54 |
| Maximum|         | 164.38 | 2.50 | 19.38 | 23.88 | 5.40 | 39.38 | 4.88 | 9.25 | 21.38 | 2332.23 | 908.46 | 40.02 | 12.94 | 8.26 |
| 11     | T₁     | 96.75  | 2.25 | 16.25 | 15.38 | 4.35 | 31.38 | 4.75 | 6.82 | 11.63 | 1267.05 | 486.27 | 38.51 | 11.80 | 7.40 |
| 12     | T₂     | 98.13  | 1.75 | 15.25 | 15.25 | 4.70 | 16.13 | 4.38 | 3.69 | 22.00 | 1493.30 | 574.88 | 38.48 | 9.46 | 5.91 |
| 13     | T₃     | 106.88 | 2.13 | 15.13 | 20.00 | 5.70 | 31.38 | 4.63 | 6.88 | 13.94 | 1698.68 | 669.67 | 39.42 | 9.31 | 6.06 |
| 14     | T₄     | 97.63  | 1.50 | 16.38 | 16.13 | 4.65 | 15.63 | 4.25 | 3.68 | 15.88 | 2115.77 | 796.74 | 37.65 | 10.21 | 6.17 |
| Mean   |         | 99.84  | 1.91 | 15.75 | 16.69 | 4.85 | 23.63 | 4.50 | 5.27 | 15.86 | 1643.70 | 632.39 | 38.52 | 10.19 | 6.38 |
| Minimum|         | 96.75  | 1.50 | 15.13 | 15.25 | 4.35 | 15.63 | 4.25 | 3.68 | 11.63 | 1267.05 | 488.27 | 37.65 | 9.31 | 5.91 |
| Maximum|         | 106.88 | 2.25 | 16.38 | 20.00 | 5.70 | 31.38 | 4.75 | 6.88 | 22.00 | 2115.77 | 796.74 | 39.42 | 11.80 | 7.40 |

Table 3. Per se performance of F₈ lines of (Population I RGR F₇ lines) for yield in evaluation of combining ability in segregating generations from heterotic box.
| Sl. no. | (Derived F₁) (F₂ line x tester) | Plant height (cm) | No. of Monopodia per plant | No. of Sympodia per plant | Sympodial length at 50% height | No. of bulbs per plant | Boll weight (g) | Reproductive points on sympodia | Inter boll distance (cm) | Inter branch distance (cm) | Seed cotton yield (kg ha⁻¹) | Lint yield (kg ha⁻¹) | Ginning out turn (%) | Seed index (g) | Lint index (g) |
|--------|---------------------------------|-------------------|-----------------------------|----------------------------|-------------------------------|-----------------------|----------------|-------------------------------|----------------------------|--------------------------|-----------------------------|-------------------------|------------------|-------------|-------------|
| 1      | RGR F₂₁ x T₁                    | 91.15             | 1.88                        | 15.30                      | 33.65                         | 19.38                 | 4.25           | 4.80                          | 7.10                       | 8.75                     | 1430.55                     | 519.7                   | 36.30           | 10.25       | 7.15        |
| 2      | RGR F₂₁ x T₂                    | 116.30            | 2.63                        | 18.15                      | 39.15                         | 22.5                  | 5.8            | 5.00                          | 7.85                       | 8.95                     | 1901.85                     | 717.79                  | 37.75           | 12.65       | 7.15        |
| 3      | RGR F₂₁ x T₃                    | 94.00             | 1.50                        | 15.15                      | 33.15                         | 22.13                 | 5.05           | 5.00                          | 6.65                       | 8.50                     | 1982.64                     | 790.76                  | 39.95           | 12.55       | 6.80        |
| 4      | RGR F₂₁ x T₄                    | 110.00            | 1.88                        | 16.15                      | 45.05                         | 31.63                 | 4.2            | 5.40                          | 8.40                       | 9.20                     | 2577.55                     | 993.47                  | 38.55           | 11.75       | 7.95        |
| 5      | RGR F₂₂ x T₁                    | 103.40            | 0.75                        | 16.75                      | 31.65                         | 14.13                 | 5.45           | 5.05                          | 6.30                       | 8.65                     | 1400.92                     | 546.92                  | 39.05           | 10.50       | 6.75        |
| 6      | RGR F₂₂ x T₂                    | 102.05            | 1.88                        | 15.65                      | 42.15                         | 22.63                 | 4.6            | 6.55                          | 6.45                       | 9.20                     | 1679.16                     | 615.96                  | 36.65           | 11.35       | 6.40        |
| 7      | RGR F₂₂ x T₃                    | 104.90            | 1.13                        | 15.80                      | 35.00                         | 20.38                 | 4.65           | 4.90                          | 7.25                       | 9.25                     | 1843.74                     | 697.38                  | 37.80           | 11.10       | 5.80        |
| 8      | RGR F₂₂ x T₄                    | 115.65            | 2.00                        | 16.65                      | 39.05                         | 22                   | 4.15           | 5.20                          | 7.50                       | 9.05                     | 1997.91                     | 783.93                  | 39.25           | 9.60        | 7.35        |
| 9      | RGR F₂₃ x T₁                    | 117.40            | 1.63                        | 14.40                      | 42.65                         | 17.13                 | 6.15           | 6.20                          | 6.90                       | 9.25                     | 1518.52                     | 552.68                  | 36.40           | 11.20       | 6.35        |
| 10     | RGR F₂₃ x T₂                    | 86.90             | 1.63                        | 16.30                      | 31.90                         | 20.88                 | 4.45           | 6.25                          | 5.15                       | 9.25                     | 1350.7                      | 519.82                  | 38.45           | 11.80       | 6.85        |
| 11     | RGR F₂₃ x T₃                    | 112.40            | 1.25                        | 17.60                      | 30.05                         | 19.38                 | 4.85           | 4.25                          | 7.05                       | 9.35                     | 1878.88                     | 722.09                  | 38.40           | 11.00       | 7.35        |
| 12     | RGR F₂₃ x T₄                    | 107.15            | 1.88                        | 17.30                      | 40.65                         | 19.38                 | 3.95           | 5.95                          | 6.80                       | 9.05                     | 1896.89                     | 736.13                  | 38.75           | 10.50       | 6.60        |
| 13     | RGR F₄₁ x T₁                    | 105.90            | 1.13                        | 18.05                      | 31.30                         | 15.38                 | 3.9            | 4.95                          | 6.35                       | 10.15                    | 1591.44                     | 629.44                  | 39.60           | 10.85       | 7.35        |
| 14     | RGR F₄₁ x T₂                    | 128.40            | 2.13                        | 16.50                      | 51.40                         | 21.13                 | 3.6            | 5.65                          | 9.15                       | 9.95                     | 1779.4                      | 694.86                  | 39.10           | 11.25       | 6.80        |
| 15     | RGR F₄₁ x T₃                    | 105.40            | 1.38                        | 16.55                      | 38.40                         | 16.88                 | 3.65           | 4.50                          | 8.75                       | 8.30                     | 1793.74                     | 692.6                   | 38.60           | 11.20       | 6.85        |
| 16     | RGR F₄₁ x T₄                    | 127.50            | 2.00                        | 20.25                      | 43.65                         | 17.75                 | 4.95           | 4.65                          | 9.45                       | 9.95                     | 2019.45                     | 767.39                  | 38.00           | 10.65       | 6.90        |
| 17     | RGR F₅₅ x T₁                    | 131.15            | 2.38                        | 18.25                      | 32.90                         | 21.75                 | 4.7            | 7.75                          | 4.30                       | 10.05                    | 1969.9                      | 783.65                  | 39.80           | 11.85       | 7.85        |
| 18     | RGR F₅₅ x T₂                    | 165.90            | 2.13                        | 15.20                      | 29.75                         | 22                   | 6.1            | 4.15                          | 7.25                       | 8.70                     | 1978.46                     | 765.65                  | 38.65           | 10.25       | 6.10        |
| 19     | RGR F₅₅ x T₃                    | 100.00            | 2.00                        | 17.75                      | 37.75                         | 22.88                 | 5.15           | 5.90                          | 6.45                       | 14.80                    | 2196.31                     | 842.3                   | 38.35           | 10.65       | 6.35        |
| 20     | RGR F₅₅ x T₄                    | 140.00            | 3.13                        | 17.15                      | 32.00                         | 22.75                 | 4.7            | 5.40                          | 8.25                       | 6.95                     | 2185.6                      | 871.8                   | 39.90           | 9.75        | 7.00        |
| 21     | RGR F₆₆ x T₁                    | 101.65            | 1.13                        | 16.15                      | 25.80                         | 13.38                 | 5.5            | 5.40                          | 4.85                       | 9.50                     | 1279.62                     | 514.94                  | 40.25           | 10.55       | 7.10        |
| 22     | RGR F₆₆ x T₂                    | 109.00            | 2.38                        | 16.90                      | 34.65                         | 19.75                 | 4.7            | 4.40                          | 8.00                       | 8.05                     | 1914.11                     | 776.81                  | 40.60           | 10.80       | 9.05        |
| Sl. no. | (Derived F1) | Plant height (cm) | No. of Monopodia per plant | No. of Sympodia at 50% height (cm) | Number of bolls per plant | Boll weight (g) | Reproductive points on sympodia | Inter boll distance (cm) | Inter branch distance (cm) | Seed cotton yield (kg ha\(^{-1}\)) | Lint yield (kg ha\(^{-1}\)) | Ginning out turn (%) | Seed index (g) | Lint index (g) |
|--------|--------------|-------------------|----------------------------|----------------------------------|---------------------------|----------------|-------------------------------|-------------------------|----------------------------|-------------------------------|-----------------|-----------------|------------|-------------|
| 23     | RGR F5 x T3  | 110.55            | 3.75                       | 16.15                            | 20.00                     | 5.80           | 5.15                          | 7.85                    | 14.65                     | 2025.23                     | 745.49          | 36.80           | 12.25      | 6.30        |
| 24     | RGR F6 x T4  | 113.25            | 2.13                       | 15.75                            | 28.38                     | 4.25           | 4.40                          | 10.95                   | 8.55                      | 2078.47                     | 811.28          | 39.05           | 13.25      | 7.80        |
| 25     | RGR F7 x T1  | 124.05            | 1.50                       | 16.00                            | 34.40                     | 3.60           | 4.30                          | 8.10                    | 10.30                     | 1372.68                     | 519.33          | 37.90           | 12.60      | 7.00        |
| 26     | RGR F6 x T2  | 117.75            | 2.50                       | 15.90                            | 20.65                     | 5.75           | 6.15                          | 3.40                    | 8.05                      | 1616.43                     | 578.96          | 35.85           | 13.15      | 6.65        |
| 27     | RGR F7 x T3  | 108.75            | 3.50                       | 15.40                            | 33.75                     | 4.60           | 4.45                          | 7.75                    | 8.15                      | 1546.29                     | 591.19          | 38.20           | 11.50      | 7.80        |
| 28     | RGR F7 x T4  | 111.80            | 1.50                       | 16.90                            | 32.05                     | 4.85           | 6.40                          | 5.00                    | 9.90                      | 2391.20                     | 939.37          | 39.30           | 11.90      | 8.55        |
| 29     | RGR F8 x T1  | 108.90            | 1.13                       | 16.80                            | 31.50                     | 4.65           | 6.90                          | 10.55                   | 1258.79                   | 461.90                      | 36.70           | 9.50            | 5.50       | 7.80        |
| 30     | RGR F8 x T2  | 88.00             | 2.38                       | 16.55                            | 34.05                     | 4.00           | 4.00                          | 8.50                    | 10.00                     | 1616.89                     | 635.98          | 39.35           | 9.35       | 6.10        |
| 31     | RGR F8 x T3  | 103.25            | 1.75                       | 15.90                            | 25.15                     | 5.35           | 4.65                          | 5.45                    | 9.90                      | 1869.11                     | 744.58          | 39.80           | 11.50      | 7.55        |
| 32     | RGR F8 x T4  | 130.75            | 1.63                       | 22.15                            | 30.90                     | 3.85           | 4.80                          | 6.50                    | 8.65                      | 2259.25                     | 894.60          | 39.70           | 10.15      | 6.75        |
| 33     | RGR F9 x T1  | 108.80            | 1.63                       | 15.40                            | 33.40                     | 3.50           | 4.65                          | 7.25                    | 9.20                      | 1562.50                     | 611.98          | 39.15           | 12.70      | 6.40        |
| 34     | RGR F9 x T2  | 99.25             | 1.38                       | 18.15                            | 33.15                     | 2.95           | 5.15                          | 6.50                    | 8.85                      | 1789.35                     | 650.21          | 36.35           | 9.85       | 7.50        |
| 35     | RGR F9 x T3  | 121.15            | 1.50                       | 19.80                            | 34.65                     | 3.40           | 4.80                          | 7.25                    | 10.45                     | 1923.60                     | 744.65          | 38.75           | 11.95      | 8.00        |
| 36     | RGR F9 x T4  | 105.40            | 1.63                       | 18.15                            | 35.40                     | 4.80           | 5.15                          | 7.05                    | 8.95                      | 2187.50                     | 851.74          | 38.95           | 13.15      | 7.60        |
| 37     | RGR F10 x T1 | 94.00             | 1.63                       | 20.65                            | 29.75                     | 3.30           | 5.50                          | 9.05                    | 1266.20                   | 471.43                      | 37.25           | 10.90           | 6.50       | 5.00        |
| 38     | RGR F10 x T2 | 104.30            | 2.50                       | 14.85                            | 30.50                     | 2.95           | 3.75                          | 8.20                    | 10.55                     | 1863.42                     | 716.73          | 38.40           | 11.65      | 7.10        |
| 39     | RGR F10 x T3 | 97.65             | 1.38                       | 19.65                            | 41.40                     | 4.40           | 5.45                          | 7.65                    | 8.90                      | 1899.30                     | 720.33          | 37.90           | 11.50      | 5.95        |
| 40     | RGR F10 x T4 | 113.15            | 2.13                       | 16.00                            | 46.75                     | 5.45           | 6.90                          | 8.80                    | 8.95                      | 1925.46                     | 717.13          | 37.25           | 9.75       | 6.95        |
| Mean   | 110.92        | 1.88               | 16.95                       | 35.42                            | 19.93                     | 4.51           | 5.15                          | 7.12                    | 9.46                      | 1815.48                     | 698.57          | 38.42           | 11.22      | 7.00        |
| Min    | 86.90         | 0.75               | 14.40                       | 20.65                            | 13.13                     | 5.60           | 3.75                          | 10.05                   | 4.40                      | 1258.79                     | 461.90          | 35.85           | 9.35       | 5.50        |
| Max    | 185.90        | 3.75               | 22.15                       | 51.40                            | 31.63                     | 6.15           | 7.75                          | 10.95                   | 14.80                     | 2577.55                     | 993.47          | 40.60           | 13.25      | 9.05        |
Table 5. Estimates of general combining ability effects of population I RGR F₂ lines (F₂ lines of DRGR-24-178 x DRGR-32 100) in evaluation of combining ability in segregating generations from heterotic box

| Sl. No. | F₂ line | Plant height (cm) | No. of Mono podia per plant | No. of Sympodia per plant | No. of bolls per plant | Boll weight (g) | Sympodial length at 50% height (cm) | Reproductive points on sympodia | Inter boll distance (cm) | Inter branch distance (cm) | Seed cotton yield (kg ha⁻¹) | Lint yield (kg ha⁻¹) | Ginning outturn (%) | Seed index (g) | Lint index (g) |
|--------|---------|-------------------|-----------------------------|---------------------------|-----------------------|----------------|--------------------------------------|-------------------------------|------------------------|------------------------|----------------------------|----------------|-----------------|---------------|----------------|----------------|
| 1      | RGR F₂ 1| -8.06             | -0.77                       | 3.98                      | 0.32                  | 2.33           | -0.10                                | 0.38                          | -0.61                  | 157.67                 | 56.85                     | -0.28               | 0.58            | 0.26          |
| 2      | RGR F₂ 2| -4.42             | -0.74                       | -0.14                     | 0.21                  | 1.54           | 0.27                                  | -0.24                         | -0.42                  | -85.04                 | -37.52                    | -0.23              | -0.58           | -0.42         |
| 3      | RGR F₂ 3| -4.96             | -0.55                       | -0.74                     | 0.34                  | 0.89           | 0.51                                  | -0.64                         | -0.24                  | -154.21                | -65.89                    | -0.42              | -0.09           | -0.21         |
| 4      | RGR F₂ 4| 5.87              | 0.23                        | 0.89                      | -2.14                  | -0.48          | 5.76                                 | -0.22                         | 1.30                   | 0.13                   | -19.47                    | -2.5             | 0.41            | -0.02         |
| 5      | RGR F₂ 5| 23.33             | 0.52                        | 0.14                      | 2.42                   | 0.49           | -2.32                                 | 0.27                          | -0.56                  | 0.66                   | 267.09                     | 117.27          | 0.75            | -0.17         |
| 6      | RGR F₂ 6| -2.31             | 0.46                        | -0.72                     | 0.95                   | 0.55          | 1.62                                 | -0.32                         | 0.79                   | 0.72                   | 8.88                      | 13.56           | 0.75            | 0.50          |
| 7      | RGR F₂ 7| 4.66              | 0.36                        | -0.90                     | -0.86                  | 0.19           | -5.20                                | -1.05                         | -0.36                  | -83.83                  | -41.36                    | -0.61             | 1.07            | 0.50          |
| 8      | RGR F₂ 8| -3.20             | -0.16                       | 0.90                      | -1.39                  | -0.29         | -5.02                                 | -0.63                         | 0.28                   | -64.46                  | -14.31                    | 0.46              | -1.09           | -0.52         |
| 9      | RGR F₂ 9| -2.27             | -0.35                       | 0.92                      | 0.3                    | 0.84          | -1.27                                 | -0.22                         | -0.11                  | -10.4                   | 50.26                      | 16.07            | -0.12           | 0.69          |
| 10     | RGR F₂ 10| -6.64             | 0.03                        | 0.84                      | -1.77                  | -0.48          | 1.68                                 | 0.25                          | 0.41                   | -76.88                  | -42.17                    | -0.72             | -0.27           | -0.37         |
|        | SE (g)  | 2.90              | 0.18                        | 0.54                      | 0.62                   | 0.15          | 1.30                                 | 0.32                          | 0.47                   | 49.78                   | 20.18                      | 0.34              | 0.33            | 0.19          |
|        | CD (g)  | 5.86              | 0.36                        | 1.09                      | 1.25                   | 0.30          | 2.62                                 | 0.65                          | 0.94                   | 100.69                  | 40.81                      | 0.68              | 0.67            | 0.38          |
|        | CD (g)  | 7.85              | 0.48                        | 1.45                      | 1.68                   | 0.40          | 3.51                                 | 0.87                          | 1.26                   | 134.80                  | 54.64                      | 0.91              | 0.91            | 0.52          |
|        | SEd (g-g) | 4.10             | 0.25                        | 0.76                      | 0.88                   | 0.21          | 1.84                                 | 0.45                          | 0.66                   | 70.40                   | 28.54                      | 0.48              | 0.47            | 0.27          |
| 1      | T₁      | -2.28             | -0.40                       | -0.18                     | -3.76                  | -0.08         | -2.72                                | -0.17                         | -0.07                  | -66.50                  | -31.29                    | -0.01             | -0.01           | -0.03         |
| 2      | T₂      | 0.86              | 0.26                        | -0.54                     | 0.45                   | -0.11         | -0.69                                | -0.05                         | -0.07                  | -350.36                 | -137.37                    | -0.18             | -0.13           | -0.2          |
| 3      | T₃      | -5.11             | 0.03                        | 0.02                      | -0.76                  | 0.18          | -0.48                                | -0.25                         | 0.09                   | -80.40                  | 30.56                      | 0.03              | 0.30            | -0.12         |
| 4      | T₄      | 6.54              | 0.11                        | 0.69                      | 4.07                   | 0.01          | 3.88                                 | 0.21                          | 0.37                   | 336.46                  | 138.11                    | 0.45              | -0.17           | 0.35          |
|        | SE (g)  | 1.83              | 0.11                        | 0.39                      | 0.39                   | 0.09          | 0.82                                 | 0.21                          | 0.29                   | 31.48                   | 12.76                      | 0.21              | 0.21            | 0.12          |
|        | CD (g)  | 3.71              | 0.23                        | 0.69                      | 0.79                   | 0.19          | 1.66                                 | 0.41                          | 0.60                   | 63.68                   | 25.81                      | 0.43              | 0.43            | 0.24          |
|        | CD (g)  | 4.66              | 0.30                        | 0.92                      | 1.06                   | 0.25          | 2.22                                 | 0.55                          | 0.80                   | 85.25                   | 34.56                      | 0.58              | 0.57            | 0.33          |
|        | SEd (g-g) | 2.56             | 0.16                        | 0.48                      | 0.55                   | 0.13          | 1.16                                 | 0.29                          | 0.42                   | 44.52                   | 18.05                      | 0.30              | 0.29            | 0.17          |
Table 6. Estimates of specific combining ability effects of population I RGR F₃ lines (F₂ lines of DRGR-24-178 x DRGR-32-100) in evaluation of combining ability in segregating generations from heterotic box

| Sl. no. | (Derived F₁) (F₂ line x tester) | Plant height (cm) | No. of Mono podia per plant | No. of Sympodia per plant | No. of boilers per plant | Boll weight (g) | Sympodial length at 50% height (cm) | Reproductive points on sympodia | Inter boll distance (cm) | Inter branch distance (cm) | Seed cotton yield (kg ha⁻¹) | Lint yield (kg ha⁻¹) | Ginning outturn (%) | Seed index (g) | Lint index (g) |
|---------|---------------------------------|-------------------|-----------------------------|----------------------------|---------------------------|----------------|------------------------------------|-------------------------------|--------------------------|--------------------------|-------------------------------|-------------------|-----------------|----------------|-------------|
| 1       | RGR F₃ x T₁                     | -9.43             | 0.31                        | -0.71                      | -0.77                      | -0.49         | -1.38                              | -0.42                         | 0.37                     | -0.18                    | -192.23                      | -98.35            | 1.65            | -1.42         | 0.09        |
| 2       | RGR F₃ x T₂                     | 12.57             | 0.39                        | 2.50                      | -1.86                      | 1.08           | 2.09                               | 0.00                          | 0.42                     | 0.41                     | -4.80                         | -6.35             | -0.08           | 0.86          | -0.09       |
| 3       | RGR F₃ x T₃                     | -3.74             | -0.50                       | -1.06                      | -1.02                      | 0.04           | -4.12                              | 0.20                          | -0.94                    | -1.11                    | -70.92                        | 4.77              | 1.78            | -0.34         | -0.34       |
| 4       | RGR F₃ x T₄                     | 0.60              | -0.20                       | -0.73                      | 3.64                      | -0.63         | 3.42                               | 0.23                          | 0.15                     | 0.89                     | 267.94                        | 99.93             | -0.04           | 0.12          | 0.34        |
| 5       | RGR F₃ x T₁                     | -0.82             | -0.28                       | 0.72                       | -1.89                      | 0.82           | -2.59                              | -0.55                         | 0.19                     | -0.47                    | 20.85                         | 23.25             | 1.04            | -0.01         | 0.38        |
| 6       | RGR F₃ x T₂                     | -5.31             | -0.17                       | -0.03                      | 2.39                       | 0.00           | 5.87                               | 1.17                          | -0.35                    | 0.47                     | 15.23                         | -13.79            | -1.23           | 0.72          | -0.15       |
| 7       | RGR F₃ x T₃                     | 3.52              | -0.34                       | -0.44                      | 1.36                       | -0.25          | -1.49                              | -0.28                         | 0.28                     | -0.55                    | 32.90                         | 5.76              | -0.42           | 0.16          | -0.65       |
| 8       | RGR F₃ x T₄                     | 2.61              | -0.46                       | -0.26                      | -1.86                      | -0.58          | -1.80                              | -0.35                         | -0.13                    | 0.55                     | -68.99                        | -15.22            | 0.61            | -0.87         | 0.43        |
| 9       | RGR F₃ x T₁                     | 13.72             | 0.44                        | -1.82                      | 1.70                       | 1.38           | 9.05                               | 0.37                          | 1.19                     | -0.06                    | 207.61                        | 57.38             | -1.42           | 0.20          | -0.24       |
| 10      | RGR F₃ x T₂                    | -19.92            | -0.24                       | 0.44                       | 1.24                       | -0.29          | -3.73                              | 0.64                          | -1.25                    | 0.33                     | -244.07                       | -81.57            | 0.76            | 0.68          | 0.09        |
| 11      | RGR F₃ x T₃                    | 11.56             | -0.38                       | 1.18                       | 0.95                       | -0.18          | -5.78                              | -1.17                         | 0.48                     | -0.64                    | 137.20                        | 58.84             | 0.37            | -0.43         | 0.68        |
| 12      | RGR F₃ x T₄                    | -5.35             | 0.18                        | 0.71                       | -3.88                      | -0.91         | 0.45                               | 0.17                          | -0.43                    | 0.37                     | -100.74                       | -34.66            | 0.30            | -0.45         | -0.54       |
| 13      | RGR F₄ x T₁                    | -8.62             | -0.13                       | 0.39                       | 1.36                       | -0.04          | -7.16                              | -0.16                         | -1.31                    | 0.48                     | 145.80                        | 70.74             | 0.96            | -0.01         | 0.58        |
| 14      | RGR F₄ x T₂                    | 10.74             | 0.20                        | -0.80                      | 2.89                       | -0.31          | 10.89                              | 0.76                          | 0.80                     | 0.67                     | 49.89                         | 30.09             | 0.58            | 0.27          | -0.15       |
| 15      | RGR F₄ x T₃                    | -6.28             | -0.31                       | -1.31                      | -0.14                      | -0.56          | -2.31                              | -0.19                         | 0.23                     | 2.05³                    | 82.67                         | -34.04            | -0.26           | -0.09         | 0.00        |
| 16      | RGR F₄ x T₄                    | 4.16              | 0.24                        | 1.72                       | 4.11                      | 0.91          | 1.42                               | 0.41                          | 0.27                     | 0.90                     | -113.02                       | -66.80            | -1.28           | -0.17         | -0.42       |
| 17      | RGR F₅ x T₁                    | -0.83             | 0.38                        | 1.34                       | 3.17                      | -0.92         | 2.52                               | 2.15³                         | -1.49                    | -0.16                    | 237.70                        | 105.18            | 0.81            | 1.35          | 1.23        |
| 18      | RGR F₅ x T₂                    | 30.77             | -0.55                       | -1.35                      | -0.79                      | 1.21          | 2.66                               | -1.23                         | 0.76                     | -1.11                    | -37.61                        | -18.90            | -0.22           | -0.37         | -0.70       |
| 19      | RGR F₅ x T₃                    | -29.14            | -0.44                       | 0.64                       | 1.29                       | -0.03          | 5.13                               | 0.72                          | -0.20                    | 3.91²                    | 33.33                         | -4.12             | -0.86           | -0.28         | -0.35       |
| 20      | RGR F₅ x T₄                    | -0.80             | 0.61                        | -3.67                      | -2.26                      | 4.98          | -1.64                              | 0.94                          | 2.63²                    | -233.42                   | -82.16            | 0.28            | -0.70         | -0.17       |
| 21      | RGR F₆ x T₁                    | -4.68             | -0.81                       | 0.09                       | -3.74                      | 0.52           | -8.51                              | 0.39                          | -2.29                    | -0.77                    | -194.37                       | -59.82            | 1.26            | -1.04         | -0.26       |
| 22      | RGR F₆ x T₂                    | -0.47             | -0.24                       | 1.20                       | -1.58                      | -0.25          | -1.70                              | -0.39                         | 0.16                     | -1.83³                   | 156.26                        | 95.97             | 1.73            | -0.91         | 1.51        |
| 23      | RGR F₆ x T₃                    | 7.06              | 1.37º                       | -0.11                      | 1.89                       | 0.56           | 3.59                               | 0.56                          | -0.15                    | 3.69³                    | 120.46                       | 2.80              | -2.41           | 0.23          | -1.14       |
| Sl. no. | (Derived $F_3$, $F_9$ x $F_1$) | Plant height (cm) | No. of Monopodia per plant | No. of Sympodia per plant | No. of boilers per plant | Boll weight (g) | Sympodial length at 50% height (cm) | Reproductive points on symodia | Inter boll distance (cm) | Inter branch distance (cm) | Seed cotton yield (kg ha$^{-1}$) | Lint yield (kg ha$^{-1}$) | Ginning outturn (%) | Seed index (g) | Lint index (g) |
|--------|--------------------------------|------------------|-----------------------------|---------------------------|-------------------------|----------------|-------------------------------------|--------------------------------|--------------------------|--------------------------|--------------------------------|-----------------|----------------|----------------|----------------|
| 24     | RGR F$_3$ 6 x T$_1$            | -1.90            | -0.33                       | -1.18                     | 3.42                    | -0.83          | 6.62                                 | -0.56                          | 2.28                     | -1.09                    | -82.35                        | -38.96          | -0.58          | 1.71           | -0.11          |
| 25     | RGR F$_3$ 7 x T$_1$            | 10.75            | -0.34                       | 0.13                      | -0.66                   | -1.02           | 6.90                                 | -1.20                          | 2.80                     | 1.12                     | -8.61                         | -0.50           | 0.27            | 0.44           | -0.30          |
| 26     | RGR F$_3$ 7 x T$_2$            | 1.30             | -0.02                       | 0.39                      | -3.38                   | 1.16            | -8.87                                 | 0.97                           | -2.58                    | -0.74                    | -48.72                        | -46.96          | 1.65           | 0.87           | -0.82          |
| 27     | RGR F$_3$ 7 x T$_{14}$         | -1.72            | 1.21                        | -0.67                     | -4.17                   | -0.28           | 4.01                                 | -0.63                          | 1.60                     | -1.71                    | -265.76                       | -96.59          | 0.35           | -1.09          | 0.42           |
| 28     | RGR F$_3$ 7 x T$_{14}$         | -10.33           | -0.85                       | 0.16                      | 8.23                    | 0.14            | -2.05                                 | 0.95                           | -1.81                    | 1.34                     | 323.09                        | 144.04          | 1.04           | -0.22          | 0.70           |
| 29     | RGR F$_3$ 8 x T$_1$            | 3.46             | -0.19                       | -0.87                     | -1.64                   | 0.47            | 3.82                                 | -0.05                          | 0.83                     | 0.69                     | -141.85                       | -84.99          | -2.01          | -0.50          | -0.77          |
| 30     | RGR F$_3$ 8 x T$_2$            | -20.58$^{-5}$    | 0.39                        | -0.76                     | 2.27                    | -1.05           | 4.34                                 | -0.48                          | 1.74                     | 0.53                     | -67.62                        | -16.99          | 0.77            | -0.77          | 0.35           |
| 31     | RGR F$_3$ 8 x T$_3$            | 0.64             | 0.00                        | -1.97                     | -0.77                   | 0.96            | -4.77                                 | 0.37                           | -1.48                    | -0.64                    | 37.70                         | 29.76           | 1.07           | 1.19           | 1.07           |
| 32     | RGR F$_3$ 8 x T$_4$            | 16.48$^{-5}$     | -0.20                       | 3.60$^{*}$                | 0.14                    | -0.38           | -3.38                                 | 0.15                           | -1.09                    | -0.58                    | 171.78                        | 72.22           | 0.36            | 0.20           | 0.07           |
| 33     | RGR F$_3$ 9 x T$_1$            | 2.43             | 0.50                        | -2.29                     | 2.14                    | -0.08           | 1.97                                 | -0.46                          | 1.01                     | -0.25                    | 47.12                         | 34.71           | 1.03           | 0.91           | -0.77          |
| 34     | RGR F$_3$ 9 x T$_2$            | -10.26           | -0.43                       | 0.81                      | -1.08                   | -0.60           | -0.31                                 | 0.26                           | -0.44                    | -0.21                    | 9.89                          | -33.14          | -1.65          | -2.05          | 0.15           |
| 35     | RGR F$_3$ 9 x T$_3$            | 17.61$^{-5}$     | -0.06                       | 1.90                      | -3.23                   | -0.45           | 0.98                                 | 0.11                           | 0.15                     | 0.32                     | -22.54                        | -0.56           | 0.42            | -0.27          | 0.75           |
| 36     | RGR F$_3$ 9 x T$_4$            | -9.79            | -0.01                       | -0.42                     | 2.18                    | 1.12            | -2.63                                 | 0.09                           | -0.71                    | 0.13                     | -14.70                        | -1.01           | 0.20           | 1.41           | -0.12          |
| 37     | RGR F$_3$ 10 x T$_1$           | -5.99            | 0.13                        | 3.04                      | 0.36                    | -0.64           | 4.63                                 | -0.07                          | -1.31                    | -0.40                    | -122.03                       | -47.59          | -0.27          | 0.08           | 0.08           |
| 38     | RGR F$_3$ 10 x T$_2$           | 1.16             | 0.33                        | -2.40$^{-5}$              | -0.11                   | -0.96           | -5.91                                 | -1.60$^{-5}$                   | 0.75                     | 1.49$^{*}$              | 191.33                        | 91.62           | 1.01           | 0.71           | 0.50           |
| 39     | RGR F$_3$ 10 x T$_{14}$        | 0.49             | -0.56                       | 1.84                      | 3.85$^{*}$              | 0.19            | 4.78                                 | 0.30                           | 0.03                     | -1.22                    | 80.30                         | 33.36           | 0.17            | 0.25           | -0.55          |
| 40     | RGR F$_3$ 10 x T$_{14}$        | 4.33             | 0.11                        | -2.48$^{-5}$              | -4.11                   | 1.41$^{*}$      | 5.76                                 | 1.37$^{-5}$                    | 0.52                     | 0.13                     | -149.60                       | -77.39          | -0.90          | -1.03          | -0.02          |
| SE (ij) | 5.80                         | 0.35            | 1.07                        | 1.24                      | 0.29                    | 2.59            | 0.64                                 | 0.93                           | 0.46                     | 0.68                     | 99.56                         | 40.36           | 0.68           | 0.67           | 0.38           |
| CD SCA, @ 5% | 11.72     | 0.71           | 2.17                        | 2.50                      | 0.60                    | 5.24            | 1.30                                 | 1.88                           | 0.94                     | 201.38                   | 81.63           | 1.37           | 1.35           | 0.77           |
| CD SCA, @ 1% | 15.70     | 0.95           | 2.91                        | 3.35                      | 0.80                    | 7.01            | 1.74                                 | 2.52                           | 1.25                     | 269.60                   | 109.28          | 1.83           | 1.81           | 1.03           |
| SEd (Sij-Skl) | 8.20     | 0.50           | 1.52                        | 1.75                      | 0.42                    | 3.66            | 0.91                                 | 1.32                           | 0.65                     | 140.80                   | 57.07            | 0.95           | 0.94           | 0.54           |
4. DISCUSSION

In the study gca/sca variance ratio were found less than one for all traits viz. height of plant, number of monopodia per plant, number of sympodia per plant, number of bolls per plant, weight of boll, length of sympodial, reproductive points on sympodia, inter-boll distance, interbranch distance, ginning outturn, seed index and lint index suggesting the preponderance of non-additive (dominant) gene action hence hybrid development using these traits will be rewarding. gca variances were found to be greater than sca variance for seed cotton yield and lint yield advising the existence of additive gene action hence selection during segregating generations would be effective. Many researchers reported additive gene action for the seed cotton yield [5-13]. Additive gene action for lint yield was revealed in some studies [8,14].

Present experiment suggests that high seed cotton yielding and lint yielding variety may be constituted as these traits possessed additive gene action while all other important traits viz. number of bolls per plant, weight of boll would be suitable for hybrid development. RGR F₅ 5 line exhibited positively significant gca effect for height of plant, number of monopodia per plant, number of bolls per plant, weight of boll, interbranch distance, seed cotton yield, lint yield and ginning outturn hence it can be utilized for further breeding works. RGR F₅ 1 line has revealed positively significant gca effect for number of bolls per plant, weight of boll, seed cotton yield and lint yield which may be useful for breeding the specific traits. DR 8 tester showed positively significant gca effect for height of plant, number of sympodia per plant, number of bolls per plant, length of sympodial, inter-boll distance, seed cotton yield, lint yield, ginning outturn and lint index. RGR F₅ 7 × DR 8, RGR F₅ 10 × DH 7225, RGR F₅ 6 × DR 8, RGR F₅ 5 × DSMR 10 and RGR F₅ 1 × DR 8 hybrids showed positively significant sca effect for number of bolls per plant. RGR F₅ 10 × DR 8, RGR F₅ 3 × DSMR 10 and RGR F₅ 5 × DSG 3-5 hybrids are the top three hybrids having positively significant sca effect for weight of boll. Hybrids RGR F₅ 7 × DR 8, RGR F₅ 1 × DR 8 and RGR F₅ 5 × DSMR 10 exhibited positively significant sca effect coupled with higher mean yield for seed cotton yield and lint yield.

5. CONCLUSION

Finally it can be concluded from the research that the parents having higher general combining ability for seed cotton yield and lint yield can be utilized in future hybrid breeding program while parents having higher gca effects for specific traits can be used for their improvement. Hybrids performing excellently good can be tested over the various environments for their stability and released later if resulted stable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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