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L × T Analysis in F_5 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.

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ABSTRACT

The combining ability studies assist in choosing the desirable parents for crossing in hybrid development. Forty derived hybrids generated by crossing ten F_5 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 F_6 9 and RGR F_6 7 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 F_5 1 and RGR F_5 5 lines. RGR F_5 1 x DR-8, RGR F_5 7 x DR-8 and RGR F_5 8 x DR-8 were the top three hybrids for seed cotton yield. The sca effect was positively significant in hybrids RGR F_5 7 × DR-8 and RGR F_5 1 × DR-8 for seed cotton yield.

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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 F_1s of crosses (DSMR 10 × DSG 3-5) and (DRGR 32-100 × DRGR 24-178) were advanced to F_5 generation to develop population I RSG F_5 lines and population II RGR F_5 lines respectively.

Population II RGR F_5 lines derived from cross DRGR 32-100 × DRGR 24-178 were used in the current study with the name Population I RGR F_5 lines. Randomly selected ten F_5 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 (T_1) and DSG 3-5 (T_2) (opposite testers). The F_5 lines were also crossed with one additional tester DH 7225 (T_3) and one diverse tester DR 8 (T_4). Totally four testers *viz*., DSMR 10 (T_1), DSG 3-5 (T_2), DH 7225 (T_3) and DR 8 (T_4) were used to hybridize with ten F_5 lines which resulted forty derived hybrids.

2.2 Season and Field Layout

Forty F_5 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 F_5 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 F_5 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 F_6 lines ranged from 13.75 (RGR F_6 6) to 23.88 (RGR F_6 9) with an overall mean of 17.51 whereas mean for testers it ranged from 15.25 DH 7225 to 20 DSG3-5 (Table 3). Mean for weight of boll ranged from 2.95 (RGR F_6 3) to 5.40 (RGR F_6 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 F_6 2) to 2332.23 kg/ha (RGR F_6 9) with overall mean of 1712.50 kg/ha in F_6 lines while among testers mean fluctuated from 1267.05 kg/ha (DH 7225) to2115.77 kg/ha (DR 8). Top two lines with highest recorded seed cotton yield were RGR F_6 9 (2332.23 kg/ha) and RGR F_6 7 (1899.55 kg/ha). Lint yield in F_6 lines varied from 487.54 kg/ha (RGR F_6 2) to 908.46 kg/ha (RGR F_6 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 F_5 derived hybrids of population I RGR F_5 lines were varied from 13.13 (RGR F_5 8 × DSMR 10) to 31.63 (RGR F_5 1 × DR 8) with an overall mean of 19.93 (Table 4). The weight of boll among F_5 derived hybrids varied from 2.95 to 6.15 with an overall mean of 4.51. Among the F_5 derived hybrids seed cotton yield varied from 1258.79 kg/ha (RGR F_5 8 × DSMR10) to 2577.55 kg/ha (RGR F_5 1 × DR 8). Three hybrids displaying maximum mean yield were RGR F_5 1 × DR8 (2577.55 kg/ha), RGR F_5 7 × DR8 (2391.20 kg/ha) and RGR F_5 8 × DR8 (2259.25 kg/ha). The variation in F_5 derived hybrids for lint yield varied from 461.90 kg/ha (RGR F_5 8 × DSMR 10) to 993.47 kg/ha (RGR F_5 1 × DR 8) with a mean value 698.57 kg/ha.

3.5 gca and sca Effects

RGR F_5 1 (3.98) and RGR F_5 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 F_5 7 × DR8 (8.23), RGR F_5 10 × DH 7225 (3.85) and RGR F_5 1 × DR8 (3.64). The gca effects for weight of boll in seven lines were found significant among them RGR F_5 1, RGR F_5 3, RGR F_5 5 and RGR F_5 6 lines showed positive significant gca effects. The sca effect was positively significant for nine hybrids and RGR F_5 10 × DR8 (1.41) and RGR F_5 3 × DSMR10 (1.38) were highly significant for sca effect. RGR F_5 1 (157.67) and RGR F_5 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 F_5 7 × DR8 (323.09) and RGR F_5 1 × DR8 (267.94). Two lines RGR F_5 5 (117.27) and RGR F_5 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 F_5 7 × DR8 (144.04) and RGR F_5 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 F_5 lines)

Source of variation	Df	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)
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 F_5 lines (F_5 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. Mono podia/ 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)
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	3257.146	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
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	2.55	-0.05	0.20	0.06

Table 3. *Per se* performance of F_6 lines of (Population I RGR F_5 lines) for yield in evaluation of combining ability in segregating generations from heterotic box

Sl. no.	F_6 Line	Plant height (cm)	No. of Mono podia/ 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 F_6 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 F_6 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 F_6 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 F_6 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 F_6 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 F_6 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 F_6 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 F_6 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 F_6 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 F_6 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**
	Mininmum	**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	T_1	96.75	2.25	16.25	15.38	4.35	31.38	4.75	6.82	11.63	1267.05	488.27	38.51	11.80	7.40
12	T_2	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	T_3	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	T_4	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**
	Mininmum	**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 4. *Per se* performance of derived hybrids for fourteen traits of population I RGR F_5 lines in evaluation of combining ability in segregating generations from heterotic box

Sl. no.	(Derived F_1) (F_5 line x tester)	Plant height (cm)	No. of Mono podia per plant	No. of Sympodia per plant	Sympodial length at 50% height	No. 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)
1	RGR F_5 1 x T_1	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 F_5 1 x T_2	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 F_5 1 x T_3	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 F_5 1 x T_4	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 F_5 2 x T_1	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 F_5 2 x T_2	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 F_5 2 x T_3	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 F_5 2 x T_4	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 F_5 3 x T_1	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 F_5 3 x T_2	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 F_5 3 x T_3	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 F_5 3 x T_4	107.15	1.88	17.30	40.65	19.38	3.95	5.95	6.80	9.05	1896.99	736.13	38.75	10.50	6.60
13	RGR F_5 4 x T_1	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 F_5 4 x T_2	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 F_5 4 x T_3	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 F_5 4 x T_4	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 F_5 5 x T_1	131.15	2.38	18.25	32.90	21.75	4	7.75	4.30	10.05	1969.9	783.65	39.80	11.85	7.85
18	RGR F_5 5 x T_2	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 F_5 5 x T_3	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 F_5 5 x T_4	140.00	3.13	17.15	32.00	22.75	4.75	3.90	8.25	6.95	2185.6	871.8	39.90	9.75	7.00
21	RGR F_5 6 x T_1	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 F_5 6 x T_2	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

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Sl. no.	(Derived F_1) (F_5 line x tester)	Plant height (cm)	No. of Mono podia per plant	No. of Sympodia per plant	Sympodial length 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 F_5 6 x T_3	110.55	3.75	16.15	40.15	22.00	5.80	5.15	7.85	14.65	2025.23	745.49	36.80	12.25	6.30
24	RGR F_5 6 x T_4	113.25	2.13	15.75	47.55	28.38	4.25	4.40	10.95	8.55	2078.47	811.28	39.05	13.25	7.80
25	RGR F_5 7 x T_1	124.05	1.50	16.00	34.40	14.63	3.60	4.30	8.10	10.30	1372.68	519.33	37.90	12.60	7.00
26	RGR F_5 7 x T_2	117.75	2.50	15.90	20.65	16.13	5.75	6.15	3.40	8.05	1616.43	578.96	35.85	13.15	6.65
27	RGR F_5 7 x T_3	108.75	3.50	15.40	33.75	14.13	4.60	4.45	7.75	8.15	1546.29	591.19	38.20	11.50	7.80
28	RGR F_5 7 x T_4	111.80	1.50	16.90	32.05	31.38	4.85	6.40	5.00	9.90	2391.20	939.37	39.30	11.90	8.55
29	RGR F_5 8 x T_1	108.90	1.13	16.80	31.50	13.13	4.60	4.65	6.90	10.55	1258.79	461.90	36.70	9.50	5.50
30	RGR F_5 8 x T_2	88.00	2.38	16.55	34.05	21.25	3.05	4.00	8.50	10.00	1616.89	635.98	39.35	9.35	6.10
31	RGR F_5 8 x T_3	103.25	1.75	15.90	25.15	17.00	5.35	4.65	5.45	9.90	1869.11	744.58	39.80	11.50	7.55
32	RGR F_5 8 x T_4	130.75	1.63	22.15	30.90	22.75	3.85	4.80	6.50	8.65	2259.25	894.60	39.70	10.15	6.75
33	RGR F_5 9 x T_1	108.80	1.63	15.40	33.40	18.00	3.50	4.65	7.25	9.20	1562.50	611.98	39.15	12.70	6.40
34	RGR F_5 9 x T_2	99.25	1.38	18.15	33.15	19.00	2.95	5.15	6.50	8.85	1789.35	650.21	36.35	9.85	7.50
35	RGR F_5 9 x T_3	121.15	1.50	19.80	34.65	15.63	3.40	4.80	7.25	10.45	1923.60	744.65	38.75	11.95	8.00
36	RGR F_5 9 x T_4	105.40	1.63	18.15	35.40	25.88	4.80	5.15	7.05	8.95	2187.50	851.74	38.95	13.15	7.60
37	RGR F_5 10 x T_1	94.00	1.63	20.65	29.75	14.75	3.30	5.50	5.45	9.05	1266.20	471.43	37.25	10.90	6.50
38	RGR F_5 10 x T_2	104.30	2.50	14.85	30.50	18.50	2.95	3.75	8.20	10.55	1863.42	716.73	38.40	11.65	7.10
39	RGR F_5 10 x T_3	97.65	1.38	19.65	41.40	21.25	4.40	5.45	7.65	8.90	1899.30	720.33	37.90	11.50	5.95
40	RGR F_5 10 x T_4	113.15	2.13	16.00	46.75	18.13	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**	**2.95**	**3.75**	**3.40**	**6.95**	**1258.79**	**461.90**	**35.85**	**9.35**	**5.50**
Max		**165.90**	**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 F_5 lines (F_5 lines of DRGR-24-178 x DRGR-32 100) in evaluation of combining ability in segregating generations from heterotic box

Sl. no.	F_5 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 F_5 1	-8.06**	0.09	-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 F_5 2	-4.42	-0.44*	-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 F_5 3	-4.96	-0.29	-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 F_5 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	-0.23	-0.02
5	RGR F_5 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*	-0.59	-0.17
6	RGR F_5 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	0.56**
7	RGR F_5 7	4.66	0.36*	-0.90	-0.86	0.19	-5.20**	0.17	-1.05*	-0.36	-83.83	-41.36*	-0.61	1.07**	0.50*
8	RGR F_5 8	-3.20	-0.16	0.90	-1.39*	-0.29	-5.02**	-0.63	-0.28	0.31	-64.46	-14.31	0.46	-1.09**	-0.52**
9	RGR F_5 9	-2.27	-0.35	0.92	-0.3	-0.84***	-1.27	-0.22	-0.11	-0.10	50.26	16.07	-0.12	0.69*	0.38
10	RGR F_5 10	-8.64**	0.03	0.84	-1.77**	-0.48**	1.68	0.25	0.41	-0.10	-76.88	-42.17*	-0.72*	-0.27	-0.37
	SE (g_i)	**2.90**	**0.18**	**0.54**	**0.62**	**0.15**	**1.30**	**0.32**	**0.47**	**0.23**	**49.78**	**20.18**	**0.34**	**0.33**	**0.19**
	CD (g_i) 5%	**5.86**	**0.36**	**1.09**	**1.25**	**0.30**	**2.62**	**0.65**	**0.94**	**0.47**	**100.69**	**40.81**	**0.68**	**0.67**	**0.38**
	CD (g_i) 1%	**7.85**	**0.48**	**1.45**	**1.68**	**0.40**	**3.51**	**0.87**	**1.26**	**0.63**	**134.80**	**54.64**	**0.91**	**0.91**	**0.52**
	SEd (gi-gj)	**4.10**	**0.25**	**0.76**	**0.88**	**0.21**	**1.84**	**0.45**	**0.66**	**0.33**	**70.40**	**28.54**	**0.48**	**0.47**	**0.27**
1	T_1	-2.28	-0.40**	-0.18	-3.76**	-0.08	-2.72**	0.17	-0.76*	0.08	-350.36**	-137.37**	-0.18	-0.13	-0.2
2	T_2	0.86	0.26*	-0.54	0.45	-0.11	-0.69	-0.05	-0.07	-0.30*	-66.50*	-31.29*	-0.31	-0.01	-0.03
3	T_3	-5.11**	0.03	0.02	-0.76	0.18	-0.48	-0.25	0.09	0.76**	80.40*	30.56*	0.03	0.30	-0.12
4	T_4	6.54**	0.11	0.69*	4.07**	0.01	3.88**	0.12	0.75*	-0.54**	336.46**	138.11**	0.45*	-0.17	0.35**
	SE (g_i)	**1.83**	**0.11**	**0.39**	**0.39**	**0.09**	**0.82**	**0.21**	**0.29**	**0.15**	**31.48**	**12.76**	**0.21**	**0.21**	**0.12**
	CD (g_i) 5%	**3.71**	**0.23**	**0.69**	**0.79**	**0.19**	**1.66**	**0.41**	**0.60**	**0.30**	**63.68**	**25.81**	**0.43**	**0.43**	**0.24**
	CD (g_i) 1%	**4.69**	**0.30**	**0.92**	**1.06**	**0.25**	**2.22**	**0.55**	**0.80**	**0.39**	**85.25**	**34.56**	**0.58**	**0.57**	**0.33**
	SEd (gi-gj)	**2.56**	**0.16**	**0.48**	**0.55**	**0.13**	**1.16**	**0.29**	**0.42**	**0.21**	**44.52**	**18.05**	**0.30**	**0.29**	**0.17**

Table 6. Estimates of specific combining ability effects of population I RGR F_5 lines (F_5 lines of DRGR-24-178 x DRGR-32-100) in evaluation of combining ability in segregating generations from heterotic box

Sl. no.	(Derived F_1) (F_5 line x tester)	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 F_5 1 x T_1	-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 F_5 1 x T_2	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 F_5 1 x T_3	-3.74	-0.50	-1.06	-1.02	0.04	-4.12	0.20	-0.94	-1.11*	-70.92	4.77	1.78*	0.45	-0.34
4	RGR F_5 1 x T_4	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 F_5 2 x T_1	-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 F_5 2 x T_2	-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 F_5 2 x T_3	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 F_5 2 x T_4	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 F_5 3 x T_1	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 F_5 3 x T_2	-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 F_5 3 x T_3	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 F_5 3 x T_4	-5.35	0.18	0.21	-3.88**	-0.91**	0.45	0.17	-0.43	0.37	-100.74	-34.66	0.30	-0.45	-0.54
13	RGR F_5 4 x T_1	-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 F_5 4 x T_2	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 F_5 4 x T_3	-6.28	-0.31	-1.31	-0.14	-0.56	-2.31	-0.19	0.23	-2.05**	-82.67	-34.04	-0.26	-0.09	0.00
16	RGR F_5 4 x T_4	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 F_5 5 x T_1	-0.83	0.38	1.34	3.17*	-0.92**	2.52	2.15**	-1.49	-0.16	237.70*	105.18*	0.81	1.35*	1.23**
18	RGR F_5 5 x T_2	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 F_5 5 x T_3	-29.14**	-0.44	0.64	1.29	-0.03	5.13	0.72	-0.20	3.91**	33.33	-4.12	-0.86	-0.28	-0.35
20	RGR F_5 5 x T_4	-0.80	0.61	-0.63	-3.67**	-0.26	-4.98	-1.64*	0.94	-2.63**	-233.42*	-82.16*	0.28	-0.70	-0.17
21	RGR F_5 6 x T_1	-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 F_5 6 x T_2	-0.47	-0.24	1.20	-1.58	-0.25	-1.70	-0.39	0.16	-1.83**	156.26	95.97*	1.73*	-0.91	1.51**
23	RGR F_5 6 x T_3	7.06	1.37**	-0.11	1.89	0.56	3.59	0.56	-0.15	3.69**	120.46	2.80	-2.41**	0.23	-1.14**

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Sl. no.	(Derived F_1) (F_5 line x tester)	Plant height (cm)	No. of Monopodia 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)
24	RGR F_5 6 x T_4	-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_5 7 x T_1	10.75	-0.34	0.13	-0.68	-1.02**	6.90*	-1.20	2.80**	1.12	-8.61	-0.50	0.27	0.44	-0.30
26	RGR F_5 7 x T_2	1.30	-0.02	0.39	-3.38**	1.16**	-8.87**	0.87	-2.58**	-0.74	-48.72	-46.96	-1.65*	0.87	-0.82*
27	RGR F_5 7 x T_3	-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_5 7 x T_4	-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_5 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_5 8 x T_2	-20.58**	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_5 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	0.88	1.07	1.19**
32	RGR F_5 8 x T_4	16.48**	-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_5 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_5 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_5 9 x T_3	17.61**	-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_5 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_5 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_5 10 x T_2	1.16	0.33	-2.40*	-0.11	-0.96*	-5.91*	-1.60*	0.75	1.49**	191.33	91.62*	1.01	0.71	0.50
39	RGR F_5 10 x T_3	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_5 10 x T_4	4.33	0.11	-2.48*	-4.11**	1.41**	5.76*	1.37*	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**	**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 F_5 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 F_5 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 F_5 7 × DR 8, RGR F_5 10 × DH 7225, RGR F_5 6 × DR 8, RGR F_5 5 × DSMR 10 and RGR F_5 1 × DR 8 hybrids showed positively significant sca effect for number of bolls per plant. RGR F_5 10 × DR 8, RGR F_5 3 × DSMR 10 and RGR F_5 5 × DSG 3-5 hybrids are the top three hybrids having positively significant sca effect for weight of boll. Hybrids RGR F_5 7 × DR 8, RGR F_5 1 × DR 8 and RGR F_5 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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