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Consistency of combining ability in segregating generations of a heterotic box subjected to reciprocal selection in cotton

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ABSTRACT : Consistency of combining ability over F_4 and F_5 generations derived hybrids, locations, seasons and testers was estimated in current study. Heterotic box was created by crossing DSMR 10 line (stay-green group) with DSG 3-5 line (robust group) and DRGR 32-100 line with DRGR 24-178 line (RGR group) to generate two highly diverse base populations. The resulted F_1s were advanced to F_4 generation for evaluating the recombinational variability which were generated. Selected F_4 lines of (DSMR10 x DSG 3-5) cross were crossed with DRGR 32-100 (T_1) and DRGR 24-178 (T_2), DH 7225 (T_3) and DRGR 4 (T_4). Lines of (DRGR 32-100 x DRGR 24-178) cross were crossed with DSMR 10 (T_5) and DSG 3-5 (T_6), DH 7225 (T_7) and DR 8 (T_8). Heritability of combining ability was 26 per cent for lines of (DSMR10 × DSG 3-5) cross and 45.50 per cent for lines of (DRGR 24-178 × DRGR 32-100) cross. Correlation for F_1s of RSG group and RGR group was (r=0.59**) and (r=0.80**), respectively, which was highly significant for both groups. The F_4 derived hybrids of RSG group and RGR group evaluated at two locations showed the correlation value (r=-0.077) and (r=0.237), respectively. DH 7225 (T_3) have shown gca effect (309.99**) in population I RSG F_4 lines and (372.38**) in population I RSG F_5 lines. In population II RGR F_4 lines and population II RGR F_5 lines, DR 8 (T_8) have shown gca effect (285.36**) and (336.46**). DH 7225 (T_3) in RSG population and DR 8 (T_8) in RGR population have shown the consistency of combining ability over tester.

Key Words : Combining ability, cotton, heterotic box, reciprocal selection

Cotton is an important often cross pollinated crop where heterosis is successfully exploited through release of both inter and intra specific hybrids. The ease of manual emasculation and crossing has been the reason for enabling manual hybrid seed production and this also enables intermating simulating random mating where by the procedures of population improvement schemes defined for cross pollinated crops can also be applied to improve hybrid performance. Though heterotic groups are formed and exploited in maize there are limited attempts made to develop heterotic groups based on performance of hybrids and exploit them through population improvement schemes in self pollinated crops. Earlier studies were conducted at University of Agricultural Sciences at Dharwad such as Pranesh (2014) and Kenchareddi (2014) on heterotic groups in cotton. Patil *et al.,* (2011), Pranesh (2014) and Kencharaddi (2014) demonstrated the possibility of identifying a heterotic box and improving combining ability through modified (suiting the mating system of cotton) reciprocal selection for combining ability in F_4 generation.

Many quantitative traits are measured in the F_1, seed cotton yield of the F_1 can be adjudged as the best yardstick to measure

combining ability (ability to combine with the tester) of the parental line. Based on performance (seed cotton yield) of hybrids, and the groups of parents which were diverse leading to high heterosis and productivity, the hybrids have been identified and constituents of each heterotic group were identified and revised over years based on consistency of observations. The lines of robust/stay green in general gave productive hybrids (heterotic) when crossed with the RGR group. Some of the diverse heterotic groups developed over years include robust *v/s* compact types, robust/stay green *v/s* compact types, robust/stay green *v/s* high relative growth rate (RGR) groups (Patil, 2010).

Exploitation of heterotic groups was taken up through selection in segregating generations of opposite groups Pranesh (2014) and Kencharaddi (2014). The material used for present study was derived from the diverse pairs of two parents (heterotic box) involving robust/ stay green (RSG) versus high relative growth rate (RGR) heterotic groups. This heterotic box was chosen based on predicted performance of double cross hybrid (Kencharaddi *et al.,* 2015) for initiating reciprocal selection for combining ability.

MATERIALS AND METHODS

Material used : Initially the material was created for exploiting opposite heterotic groups by identification of heterotic box involving elite combiner lines of opposite heterotic groups. Because of this reason elite combiners DSMR10 line (of stay green group), DSG 3-5 line (of robust group) and two DRGR 32-100 and DRGR 24-178 lines (of RGR group) were chosen to develop a heterotic box.

These four elite lines were crossed in below given pattern to generate two highly diverse base populations.

(DSMR 10 × DSG 3-5)	(DRGR 32-100 × DRGR 24-178)
↓	↓
F_1	F_1

Then the F_1s of within group crosses were advanced to F_4 generation and recombinational variability was evaluated in the same. The F_4 lines are selected for evaluation of combining ability because in many studies it is seen that F_4 lines have greater uniformity as compared to the corresponding F_3 lines.

In the current study, to check consistency of combining ability over generation ten randomly selected F_4 lines from both the populations were evaluated for combining ability. The same lines of both the populations were advanced to the F_5 generation and again evaluated for the consistency of combining ability. In the heterotic box utilized in present study F_4 lines of both populations were evaluated for combining ability by Kencharaddi, 2014 at another location (Belavatgi in Karnataka) during 2013. Since study on the combining ability of the same ten lines was repeated during 2014-2015 in Dharwad (Karnataka) it was possible to understand how far assessment of combining ability reveals consistency of combining ability across seasons and locations.

Testers : These selected F_4 lines were crossed with the parents of the opposite group population *i.e.* lines of (DSMR 10 × DSG 3-5) cross

were crossed with DRGR 32-100 and DRGR 24-178 (opposite testers) and lines of (DRGR 32-100 × DRGR 24-178) cross were crossed with DSMR 10 and DSG 3-5 (opposite testers). The selected lines were also crossed with one additional tester DH 7225 which was common for both populations and one diverse tester. F_4 lines of (DSMR 10 × DSG 3-5) population were crossed to additional diverse tester DRGR 4 and DR 8 was used as additional diverse tester for F_4 lines of (DRGR 32-100 × DRGR 24-178) population. Hence, it was possible to assess consistency of combining ability over testers. This scheme of assessing combining ability was repeated in F_5 generation by advancing selected F_4 lines to F_5 generation. Performance of derived F_1s was utilized as the index of combining ability. Three approaches were used for checking consistency of combining ability over generations.

I. Regression Approach : The seed cotton yield values of derived F_1s involving lines in two successive generations (based on F_4 and F_5 lines) were utilized for determining regression values *i.e.*, b_{F5F4}. Heritability of combining ability was calculated based on regression approach.

$$h^2 = (b / 2r_{XY})$$

where;

h^2 = Narrow sense heritability

b = Regression coefficient

r_{XY} = Coefficient of parentage

II. Correlation of derived F_1s performance: Simple correlation of F_4 derived hybrids with F_5 derived hybrids was also calculated to know the consistency of combining ability.

III. Grouping performance of derived F_1s: The F_4 and F_5 derived hybrids were ranked based on performance (seed cotton yield) and compared for consistency of combining ability over generations.

RESULTS AND DISCUSSION

Two opposite segregating F_4 populations representing a heterotic box of cotton were utilized for assessing combining ability by using four testers. Ten lines of each F_4 population were evaluated again in F_5 generation to check consistency of combining ability.

Consistency of combining ability was calculated over F_4 and F_5 generations, locations, seasons and testers based on the performance of derived hybrids. The performance of derived hybrids was taken as the measure of combining ability because of the fact that line with higher combining ability will combine well with taster and it will be revealed in the form of superior performance. The results are described under following headings:-

Consistency of combining ability over generations

1. Heritability of combining ability : Combining ability is an important aspect in development of hybrids, so it is necessary to know about the combining ability of parents and hybrids. For the same objective the F_4 lines are crossed with the four selected testers and their derived F_1s were generated. The same selected F_4 lines were advanced to F_5 generation and again crossed with the previously used testers and derived F_1s are generated. These derived F_1s of both the generation (F_4 and F_5 derived hybrids) are evaluated for calculating the

Table 1. Estimation of heritability of combining ability based on performance of derived hybrids (F_1s) of RSG group (DSMR 10 x DSG 3-5) cross

Sl. No.	Derived F_1s (F_4 line × tester)	Seed cotton yield (kg/ha)	Rank	Derived F_1s (F_5 line × tester)	Seed cotton yield (kg/ha)	Rank	Overall Mean of derived F_1s	Rank
Top eight								
1	RSG F_4 9 x T_3	2866.71	1	RSG F_5 9 x T_3	2750.23	1	2808.47	1
2	RSG F_4 7 x T_3	2785.87	2	RSG F_5 7 x T_3	2318.52	6	2552.20	2
3	RSG F_4 10 x T_3	2570.36	4	RSG F_5 10 x T_3	2500.00	2	2535.18	3
4	RSG F_4 5 x T_3	2578.70	3	RSG F_5 5 x T_3	2406.02	3	2492.36	4
5	RSG F_4 4 x T_3	2425.92	10	RSG F_5 4 x T_3	2299.77	7	2362.84	5
6	RSG F_4 2 x T_3	2362.49	11	RSG F_5 2 x T_3	2354.86	4	2358.68	6
7	RSG F_4 10 x T_4	2432.41	9	RSG F_5 10 x T_4	2203.70	8	2318.05	7
8	RSG F_4 9 x T_4	2437.05	8	RSG F_5 9 x T_4	2150.71	9	2293.88	8
Above medium eight								
9	RSG F_4 3 x T_3	2239.81	14	RSG F_5 3 x T_3	2327.55	5	2283.68	9
10	RSG F_4 7 x T_4	2551.43	5	RSG F_5 7 x T_4	1831.02	24	2191.23	10
11	RSG F_4 10 x T_1	2477.31	7	RSG F_5 10 x T_1	1891.20	22	2184.26	11
12	RSG F_4 4 x T_1	2154.59	16	RSG F_5 4 x T_1	2093.75	10	2124.17	12
13	RSG F_4 8 x T_3	2113.88	17	RSG F_5 8 x T_3	2070.60	13	2092.24	13
14	RSG F_4 4 x T_4	2062.95	20	RSG F_5 4 x T_4	2022.64	16	2042.80	14
15	RSG F_4 7 x T_2	2065.27	19	RSG F_5 7 x T_2	1995.83	18	2030.55	15
16	RSG F_4 8 x T_4	2025.68	22	RSG F_5 8 x T_4	2027.82	15	2026.75	16
Medium eight								
17	RSG F_4 9 x T_1	2549.76	6	RSG F_5 9 x T_1	1489.35	37	2019.56	17
18	RSG F_4 2 x T_1	2259.48	12	RSG F_5 2 x T_1	1752.31	30	2005.90	18
19	RSG F_4 6 x T_3	1966.43	23	RSG F_5 6 x T_3	2015.74	17	1991.08	19
20	RSG F_4 3 x T_4	2243.01	13	RSG F_5 3 x T_4	1731.94	32	1987.47	20
21	RSG F_4 7 x T_1	2201.80	15	RSG F_5 7 x T_1	1740.51	31	1971.15	21
22	RSG F_4 1 x T_3	1870.13	26	RSG F_5 1 x T_3	2071.30	12	1970.72	22
23	RSG F_4 10 x T_2	1812.96	29	RSG F_5 10 x T_2	2068.72	14	1940.84	23
24	RSG F_4 4 x T_2	1784.02	31	RSG F_5 4 x T_2	2074.07	11	1929.04	24
Below medium eight								
25	RSG F_4 5 x T_4	2043.05	21	RSG F_5 5 x T_4	1790.27	27	1916.66	25
26	RSG F_4 1 x T_4	1829.85	27	RSG F_5 1 x T_4	1922.45	19	1876.15	26
27	RSG F_4 2 x T_4	1826.61	28	RSG F_5 2 x T_4	1904.84	20	1865.73	27
28	RSG F_4 6 x T_4	1904.16	24	RSG F_5 6 x T_4	1800.00	26	1852.08	28
29	RSG F_4 5 x T_1	1895.83	25	RSG F_5 5 x T_1	1785.88	28	1840.85	29
30	RSG F_4 8 x T_1	1792.62	30	RSG F_5 8 x T_1	1776.62	29	1784.62	30
31	RSG F_4 3 x T_1	2102.77	18	RSG F_5 3 x T_1	1453.70	38	1778.24	31
32	RSG F_4 8 x T_2	1676.38	35	RSG F_5 8 x T_2	1877.77	23	1777.08	32
Bottom eight								
33	RSG F_4 5 x T_2	1768.51	32	RSG F_5 5 x T_2	1675.23	35	1721.87	33
34	RSG F_4 3 x T_2	1524.07	38	RSG F_5 3 x T_2	1893.32	21	1708.70	34
35	RSG F_4 2 x T_2	1677.77	34	RSG F_5 2 x T_2	1704.63	33	1691.20	35
36	RSG F_4 6 x T_2	1458.33	39	RSG F_5 6 x T_2	1815.28	25	1636.80	36
37	RSG F_4 9 x T_2	1595.36	37	RSG F_5 9 x T_2	1602.55	36	1598.96	37
38	RSG F_4 1 x T_2	1432.86	40	RSG F_5 1 x T_2	1685.34	34	1559.10	38
39	RSG F_4 1 x T_1	1734.95	33	RSG F_5 1 x T_1	1364.81	39	1549.88	39
40	RSG F_4 6 x T_1	1620.36	36	RSG F_5 6 x T_1	1322.22	40	1471.29	40

Regression of performance of derived F_1 (combining ability) involving lines in F_5 and F_4 generations ($bF_{5\ on}\ F_4$) = 0.49
Heritability (h^2_{NS}) for Combining Ability = 26 per cent
Correlation of F_4 and F_5 derived hybrids (r) = 0.59**

Table 2. Estimation of heritability of combining ability based on performance of derived hybrids (F_1s) of RGR group (DRGR 24-178 × DRGR 32-100) cross

Sl. No.	Derived F_1s (F_4 line × tester)	Seed cotton yield (kg/ha)	Rank	Derived F_1s (F_5 line × tester)	Seed cotton yield (kg/ha)	Rank	Overall Mean of derived F_1s	Rank
Top eight								
1	RGR F_4 1 x T_8	2724.07	1	RGR F_5 1 x T_8	2577.54	1	2650.81	1
2	RGR F_4 7x T_8	2228.935	6	RGR F_5 7 x T_8	2391.20	2	2310.07	2
3	RGR F_4 5 x T_7	2331.01	3	RGR F_5 5 x T_7	2196.31	4	2263.66	3
4	RGR F_4 5 x T_8	2333.325	2	RGR F_5 5 x T_8	2185.61	6	2259.47	4
5	RGR F_4 9 x T_8	2182.405	7	RGR F_5 9 x T_8	2187.50	5	2184.95	5
6	RGR $F_{4\ 6}$ x T_8	2287.955	4	RGR F_5 6 x T_8	2078.47	7	2183.21	6
7	RGR $F_{4\ 6}$ x T_7	2261.105	5	RGR F_5 6 x T_7	2025.23	8	2143.17	7
8	RGR F_4 8 x T_8	1987.26	18	RGR F_5 8 x T_8	2259.26	3	2123.26	8
Above medium eight								
9	RGR F_4 4 x T_8	2148.14	8	RGR F_5 4 x T_8	2019.45	9	2083.79	9
10	RGR F_4 2 x T_8	2117.13	9	RGR F_5 2 x T_8	1997.91	10	2057.52	10
11	RGR F_4 5 x T_6	2056.71	12	RGR F_5 5 x T_6	1978.47	12	2017.59	11
12	RGR F_4 10 x T_8	2069.44	11	RGR F_5 10 x T_8	1925.46	14	1997.45	12
13	RGR F_4 1 x T_6	2079.16	10	RGR F_5 1 x T_6	1901.85	17	1990.51	13
14	RGR $F_{4\ 6}$ x T_6	2026.615	13	RGR F_5 6 x T_6	1914.12	16	1970.37	14
15	RGR F_4 1 x T_7	1938.655	20	RGR F_5 1 x T_7	1982.64	11	1960.65	15
16	RGR F_4 3 x T_8	2012.495	14	RGR F_5 3 x T_8	1896.99	19	1954.74	16
Medium eight								
17	RGR F_4 9 x T_7	1964.345	19	RGR F_5 9 x T_7	1923.61	15	1943.98	17
18	RGR F_4 5 x T_5	1883.56	27	RGR F_5 5 x T_5	1969.91	13	1926.73	18
19	RGR F_4 2 x T_7	1999.24	16	RGR F_5 2 x T_7	1843.75	23	1921.49	19
20	RGR F_4 10 x T_7	1928.935	21	RGR F_5 10 x T_7	1899.30	18	1914.12	20
21	RGR F_4 3 x T_7	1908.56	24	RGR F_5 3 x T_7	1878.88	20	1893.72	21
22	RGR F_4 4 x T_6	1988.19	17	RGR F_5 4 x T_6	1779.40	26	1883.79	22
23	RGR F_4 8 x T_7	1859.72	28	RGR F_5 8 x T_7	1869.12	21	1864.42	23
24	RGR F_4 4 x T_7	1925.69	23	RGR F_5 4 x T_7	1793.75	24	1859.72	24
Below medium eight								
25	RGR F_4 9 x T_6	1896.29	25	RGR F_5 9 x T_6	1789.35	25	1842.82	25
26	RGR F_4 10 x T_6	1738.42	32	RGR F_5 10 x T_6	1863.42	22	1800.92	26
27	RGR F_4 7x T_7	2001.615	15	RGR F_5 7 x T_7	1546.29	32	1773.95	27
28	RGR F_4 7x T_6	1890.275	26	RGR F_5 7 x T_6	1616.43	29	1753.35	28
29	RGR F_4 2 x T_6	1798.605	30	RGR F_5 2 x T_6	1679.17	27	1738.89	29
30	RGR F_4 9 x T_5	1781.015	31	RGR F_5 9 x T_5	1562.50	31	1671.76	30
31	RGR F_4 2 x T_5	1844.91	29	RGR F_5 2 x T_5	1400.93	35	1622.92	31
32	RGR $F_{4\ 6}$ x T_5	1928.495	22	RGR F_5 6 x T_5	1279.62	38	1604.06	32
Bottom eight								
33	RGR F_4 3 x T_6	1723.375	33	RGR F_5 3 x T_6	1350.69	37	1537.03	33
34	RGR F_4 7x T_5	1679.395	34	RGR F_5 7 x T_5	1372.68	36	1526.04	34
35	RGR F_4 8 x T_6	1430.55	37	RGR F_5 8 x T_6	1616.89	28	1523.72	35
36	RGR F_4 3 x T_5	1521.985	35	RGR F_5 3 x T_5	1518.52	33	1520.25	36
37	RGR F_4 1 x T_5	1486.11	36	RGR F_5 1 x T_5	1430.56	34	1458.33	37
38	RGR F_4 4 x T_5	1217.82	40	RGR F_5 4 x T_5	1591.44	30	1404.63	38
39	RGR F_4 8 x T_5	1396.985	38	RGR F_5 8 x T_5	1258.80	40	1327.89	39
40	RGR F_4 10 x T_5	1372.68	39	RGR F_5 10 x T_5	1266.20	39	1319.44	40

Regression of performance of derived F_1 (combining ability) involving lines in F_5 and F_4 generations ($bF_{5\ on}\ F_4$) = 0.85
Heritability (h^2_{NS}) for Combining Ability = 45.50 per cent
Correlation of F_4 and F_5 derived hybrids (r) = 0.80**

heritability of combining ability.

Based on the regression of F_5 derived hybrids over the F_4 derived hybrids of the same lines of (DSMR10 × DSG 3-5) cross and (DRGR 24-178 × DRGR 32-100), the heritability of the combining ability was calculated. According to the formulae regression value was divided with the coefficient of parentage ($2r_{Xy}$ = 15/16) depending upon the generations of the lines used in the analysis. Regression value (b) for the lines of (DSMR 10 × DSG 3-5) cross was (0.49). This regression value has been divided with the coefficient of parentage ($2r_{Xy}$ = 15/16) to obtain the heritability of combining ability which was 26 per cent (Table 1) for the lines of (DSMR 10 × DSG 3-5) cross. Regression value (b) for the lines of (DRGR 24-178 × DRGR 32-100) cross was (0.85) and heritability of combining ability was 45.50 per cent (Table 2).

2. Correlation : The correlation of F_4 and F_5 derived hybrids was calculated to check the consistency of the combining ability. The mean seed cotton yield of the derived hybrids was used in correlation analysis. For the derived hybrids of RSG group the correlation obtained was (r = 0.59**) (Table 1). The correlation was found to be highly significant showing that derived hybrids were related to each other and their performance was consistent over generations. This shows that the lines of RSG group have consistency in combining ability over generations. In case of RGR group correlation obtained for the derived hybrids was (r = 0.80**) (Table 2). In RGR group also correlation of derived hybrids was found highly significant. This result shows that the lines have consistency in combining ability over generations.

3. Rankings of derived hybrids : The forty derived hybrids are divided into various groups based on their ranking of mean seed cotton yield among them. The F_4 derived hybrids were ranked among them and similarly F_5 derived hybrids were also ranked. Then overall mean of seed cotton yield of F_4 and F_5 derived hybrids were taken. Finally the overall mean rank of derived hybrids was compared with the F_4 rank and F_5 rank. The rankings were given in the table 1 and 2 for RSG and RGR groups respectively. In the derived hybrids of RSG group the hybrids coming under the top eight club were having the same ranks (difference in ranks were more or less similar) in both generations (Table 1). The hybrids coming under the bottom eight club also revealed the same pattern of ranks. Regarding the derived hybrids of RGR group similar trends were observed (Table 2). The result shows that derived hybrids of both groups had consistency in their performance over generations. Hence it can be concluded from results that RSG and RGR lines showed consistency in combining ability over generations.

Consistency of combining ability over locations and seasons : The F_4 derived hybrids were evaluated for the consistency of combining ability over locations and seasons, for which the randomly selected F_4 derived hybrids which were already evaluated were taken. These previously evaluated F_4 derived hybrids along with F_5 derived hybrids of same lines were evaluated for this study. This experiment was done in both the group *i.e.* RSG and RGR group.

1. Correlation : The correlation between

Table 3. Correlation analysis of F_4 derived hybrids of RSG group (DSMR 10 × DSG 3-5) over location and seasons

Sl. No.	Derived F_1s (F_4 line × tester)at Belabatgi (2012-2013)	Mean seed cotton yield (kg/ha)	Derived F_1s (F_4 line × tester) at Dharwad (2014-2015)	Mean seed cotton yield (kg/ha)
1	RSG F_4 1 x T_1	2092	RSG F_4 1 x T_1	1734.95
2	RSG F_4 1 x T_2	3370	RSG F_4 1 x T_2	1432.865
3	RSG F_4 1 x T_3	3710	RSG F_4 1 x T_3	1870.135
4	RSG F_4 1 x T_4	3881	RSG F_4 1 x T_4	1829.855
5	RSG F_4 2 x T_1	2703	RSG F_4 2 x T_1	2259.485
6	RSG F_4 2 x T_2	2734	RSG F_4 2 x T_2	1677.77
7	RSG F_4 2 x T_3	4290	RSG F_4 2 x T_3	2362.495
8	RSG F_4 2 x T_4	3427	RSG F_4 2 x T_4	1826.615
9	RSG F_4 3 x T_1	3343	RSG F_4 3 x T_1	2102.775
10	RSG F_4 3 x T_2	2197	RSG F_4 3 x T_2	1524.07
11	RSG F_4 3 x T_3	2679	RSG F_4 3 x T_3	2239.81
12	RSG F_4 3 x T_4	2972	RSG F_4 3 x T_4	2243.005
13	RSG F_4 4 x T_1	3176	RSG F_4 4 x T_1	2154.595
14	RSG F_4 4 x T_2	3592	RSG F_4 4 x T_2	1784.02
15	RSG F_4 4 x T_3	3092	RSG F_4 4 x T_3	2425.92
16	RSG F_4 4 x T_4	3041	RSG F_4 4 x T_4	2062.955
17	RSG F_4 5 x T_1	4342	RSG F_4 5 x T_1	1895.83
18	RSG F_4 5 x T_2	4128	RSG F_4 5 x T_2	1768.51
19	RSG F_4 5 x T_3	4169	RSG F_4 5 x T_3	2578.7
20	RSG F_4 5 x T_4	4429	RSG F_4 5 x T_4	2043.055
21	RSG F_4 6 x T_1	4121	RSG F_4 6 x T_1	1620.365
22	RSG F_4 6 x T_2	4594	RSG F_4 6 x T_2	1458.33
23	RSG F_4 6 x T_3	4601	RSG F_4 6 x T_3	1966.43
24	RSG F_4 6 x T_4	4485	RSG F_4 6 x T_4	1904.16
25	RSG F_4 7 x T_1	4173	RSG F_4 7 x T_1	2201.8
26	RSG F_4 7 x T_2	4336	RSG F_4 7 x T_2	2065.275
27	RSG F_4 7 x T_3	4346	RSG F_4 7 x T_3	2785.875
28	RSG F_4 7 x T_4	4166	RSG F_4 7 x T_4	2551.435
29	RSG F_4 8 x T_1	3422	RSG F_4 8 x T_1	1792.625
30	RSG F_4 8 x T_2	3901	RSG F_4 8 x T_2	1676.38
31	RSG F_4 8 x T_3	4257	RSG F_4 8 x T_3	2113.885
32	RSG F_4 8 x T_4	3892	RSG F_4 8 x T_4	2025.685
33	RSG F_4 9 x T_1	3880	RSG F_4 9 x T_1	2549.765
34	RSG F_4 9 x T_2	4351	RSG F_4 9 x T_2	1595.365
35	RSG F_4 9 x T_3	2920	RSG F_4 9 x T_3	2866.71
36	RSG F_4 9 x T_4	3800	RSG F_4 9 x T_4	2437.05
37	RSG F_4 10 x T_1	2686	RSG F_4 10 x T_1	2477.31
38	RSG F_4 10 x T_2	2797	RSG F_4 10 x T_2	1812.96
39	RSG F_4 10 x T_3	2260	RSG F_4 10 x T_3	2570.365
40	RSG F_4 10 x T_4	2919	RSG F_4 10 x T_4	2432.41

Correlation (r) = (-0.0766)

Table 4. Correlation analysis of F_4 derived hybrids of RGR group (DRGR 24-178 × DRGR 32-100) over locations and seasons

Sl. No.	Derived F_1s (F_4 line × tester)at Belabatgi (2012-2013)	Mean seed cotton yield (kg/ha)	Derived F_1s (F_4 line × tester) at Dharwad (2014-2015)	Mean seed cotton yield (kg/ha)
1	RGR F_4 1 x T_5	3563	RGR F_4 1 x T_5	1486.11
2	RGR F_4 1 x T_6	3691	RGR F_4 1 x T_6	2079.16
3	RGR F_4 1 x T_7	2731	RGR F_4 1 x T_7	1938.655
4	RGR F_4 1 x T_8	3503	RGR F_4 1 x T_8	2724.07
5	RGR F_4 2 x T_5	4669	RGR F_4 2 x T_5	1844.91
6	RGR F_4 2 x T_6	4263	RGR F_4 2 x T_6	1798.605
7	RGR F_4 2 x T_7	4315	RGR F_4 2 x T_7	1999.24
8	RGR F_4 2 x T_8	3820	RGR F_4 2 x T_8	2117.13
9	RGR F_4 3 x T_5	3373	RGR F_4 3 x T_5	1521.985
10	RGR F_4 3 x T_6	3377	RGR F_4 3 x T_6	1723.375
11	RGR F_4 3 x T_7	4518	RGR F_4 3 x T_7	1908.56
12	RGR F_4 3 x T_8	3492	RGR F_4 3 x T_8	2012.495
13	RGR F_4 4 x T_5	3520	RGR F_4 4 x T_5	1217.82
14	RGR F_4 4 x T_6	3019	RGR F_4 4 x T_6	1988.19
15	RGR F_4 4 x T_7	2670	RGR F_4 4 x T_7	1925.69
16	RGR F_4 4 x T_8	4557	RGR F_4 4 x T_8	2148.14
17	RGR F_4 5 x T_5	3694	RGR F_4 5 x T_5	1883.56
18	RGR F_4 5 x T_6	4032	RGR F_4 5 x T_6	2056.71
19	RGR F_4 5 x T_7	3761	RGR F_4 5 x T_7	2331.01
20	RGR F_4 5 x T_8	3796	RGR F_4 5 x T_8	2333.325
21	RGR $F_{4\,6}$ x T_5	4068	RGR $F_{4\,6}$ x T_5	1928.495
22	RGR $F_{4\,6}$ x T_6	4162	RGR $F_{4\,6}$ x T_6	2026.615
23	RGR $F_{4\,6}$ x T_7	4264	RGR $F_{4\,6}$ x T_7	2261.105
24	RGR $F_{4\,6}$ x T_8	4422	RGR $F_{4\,6}$ x T_8	2287.955
25	RGR F_4 7x T_5	3506	RGR F_4 7x T_5	1679.395
26	RGR F_4 7x T_6	3580	RGR F_4 7x T_6	1890.275
27	RGR F_4 7x T_7	3478	RGR F_4 7x T_7	2001.615
28	RGR F_4 7x T_8	3675	RGR F_4 7x T_8	2228.935
29	RGR F_4 8 x T_5	4288	RGR F_4 8 x T_5	1396.985
30	RGR F_4 8 x T_6	3301	RGR F_4 8 x T_6	1430.55
31	RGR F_4 8 x T_7	2958	RGR F_4 8 x T_7	1859.72
32	RGR F_4 8 x T_8	4166	RGR F_4 8 x T_8	1987.26
33	RGR F_4 9 x T_5	3371	RGR F_4 9 x T_5	1781.015
34	RGR F_4 9 x T_6	3777	RGR F_4 9 x T_6	1896.29
35	RGR F_4 9 x T_7	3975	RGR F_4 9 x T_7	1964.345
36	RGR F_4 9 x T_8	4580	RGR F_4 9 x T_8	2182.405
37	RGR F_4 10 x T_5	3625	RGR F_4 10 x T_5	1372.68
38	RGR F_4 10 x T_6	2676	RGR F_4 10 x T_6	1738.42
39	RGR F_4 10 x T_7	3543	RGR F_4 10 x T_7	1928.935
40	RGR F_4 10 x T_8	4197	RGR F_4 10 x T_8	2069.44

Correlation (r) = (-0.237)

the F_4 derived hybrids evaluated at the two places Belavatgi (2013) and Dharwad (2015) was calculated. The mean seed cotton yield data of F_4 derived hybrids which was evaluated in another study by Kencharaddi (2014) at the Belavatgi farm was used. This old data were correlated with the mean seed cotton yield data of same F_4 derived hybrids which were re-evaluated at ARS Dharwad, farm. The results of correlation analysis are presented below for RSG and RGR F_4 derived hybrids.

The F_4 derived hybrids of RSG group evaluated at two places has shown the correlation value (r = -0.077) (Table 3). The correlation was non-significant for the F_4 derived hybrids of RSG group showing that the hybrid performance was inconsistent over locations. Considering F_4 derived hybrids of RGR group (Table 4) the correlation value was (r = 0.237). In this case also correlation was non-significant for the F_4 derived hybrids which depicts hybrid performance was inconsistent over locations. It can be concluded from results that combining ability over locations and seasons was inconsistent for both RSG and RGR group.

Consistency of combining ability of hybrids tested in F_4 generation over locations/ seasons was low may be because in earlier experiment at Belavatagi crop was grown in intensive management situation during 2012-2013. In present experiment done at ARS, Dharwad crop was grown in rainfed situation. Further the season was harsh during 2014-2015 and rainfall was erratic. The two environments where F_4 derived hybrids were evaluated were so contrasting Hybrids performing better in intensive management situation may have done well at Belavatagi while hybrids tolerant to harsh moisture stress situation may have done well at ARS, Dharwad. This may be the main reason for lack of consistency in performance of F_4 derived hybrids.

Table 5. Consistency of combining ability over testers used for population I RSG F_4 and F_5 lines and population II RGR F_4 and F_5 lines

Sl. No.	Tester	*gca* effect	
		F_4 generation	F_5 generation
Population I RSG lines			
1.	DRGR 24-178 (T_1)	10.91	-272.04**
2.	DRGR 32-100 (T_2)	-388.48**	-99.8**
3.	DH 7225 (T_3)	309.99**	372.38**
4.	DRGR 4 (T_4)	67.58*	-0.53
Population II RGR lines			
5.	DSMR 10 (T_5)	-312.48**	-350.36**
6.	DSG 3-5 (T_6)	-60.96*	-66.50*
7.	DH 7225 (T_7)	88.11**	80.40*
8.	DR 8 (T_8)	285.36**	336.46**

3. Consistency of combining ability over testers : In the population I RSG F_4 lines the common tester DH 7225 (T_3) have the highest gca effect (309.99**) and diverse tester DRGR 4 (T_4) have second highest gca effect (67.58*). In the population I RSG F_5 lines the common tester DH 7225 (T_3) have the highest gca effect (372.38**) and diverse tester DRGR 4 (T_4) have second highest gca effect (-0.53) (Table 5). Hence, it can be concluded that the common tester DH 7225 (T_3) and diverse tester DRGR 4 (T_4) have shown the consistency of combining ability in RSG population. In the population II RGR F_4 lines diverse tester DR 8 (T_8) have the highest gca effect (285.36**) and common tester DH 7225 (T_7) have the second highest gca effect (88.11**) (Table 5). In the population II RGR F_5 lines diverse tester DR 8 (T_8) have the highest gca effect (336.46**) and common tester DH 7225 (T_7) have

the second highest gca effect (80.40**). Result shows that diverse tester DR 8 (T_8) and common tester DH 7225 (T_7) have shown the consistency of combining ability in RGR population.

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