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Estimation of heterosis and the ability to combine yield attributes and seed yield in Indian mustard (*Brassica juncea*)

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ABSTRACT

The study was carried out during winter (*rabi*) season of 2021–22 and 2022–23 at ICAR-Indian Institute of Soybean Research, Indore, Madhya Pradesh to analyse Line × Tester to estimate the general combining ability (GCA) and specific combining ability (SCA) of 11 advanced inbred lines used as female parents and 5 as testers analysis. The study also aimed to assess parental heterosis among 55 F_1 crosses in Indian mustard [*Brassica juncea* (L.) Czern & coss]. Both gene actions like non-additive and additive were having an impact, with non-additive gene actions predominating. Due to their extraordinarily substantial favorable GCA impacts on seed output and seed-related characteristics, lines RE 11, IC 597880, and CN105379 as well as testers M 37 and DRMRIJ 31, were chosen as the best general combiners. In terms of growth attributes i.e. plant height, length of main shoot alongwith yield attributes i.e. number of primary branches, test weight, oil content and other contributing traits, many hybrids also exhibited highly desirable SCA effects for different traits. The best hybrids determined by SCA effects also showed a strong correlation between heterosis and SCA effects for different traits. In addition to better parent heterosis and SCA effects, a relationship between parental combinations was observed on the basis of SCA effects. A close relationship between SCA effects and heterosis was also observed among best hybrids identified on the basis of SCA effects. Hybrid combinations EJ 22/ RC 273 (65.93%), IC 597875/RC 273 (51.80%), RNN 505/RC 273 (46.68%), Pusa Bahar/M 37 (42.36%), RNN 505/M 37 (40.76%), RE 11/M 37, Pusa Bahar/M 37, RNN 505/M 37, Pusa Bahar/RC 273, EJ 22/RC 273, CN 105379/ DRMRIJ 31, RNN 505/RC 273 and IC 597875/RC 273 exhibited highly significant and positive magnitude of SCA effects and better parent heterosis with higher per se performance for seed yield. After converting the parental lines into the proper CMS and fertility restorer lines, highly significant cross combinations may be used in the hybrid development programme.

Keywords: *Brassica juncea,* General combining ability, Heterobeltiosis, Heterosis, Hybrid, Specific combining ability

Indian mustard [*Brassica juncea* (L.) Czern & coss] is a good source crop of edible oil and India's nine main oilseed crop in India. It is a valuable species of triangle 'U' holds the prime position among *Brassica* with more than 85% shares in seed production in the country (Singh *et al.* 2022). The seed of this crop is a good source of oil as it contains 35–42% oil content. Together with soybean (36%) and groundnut (32%), Indian mustard (29%) contributed 97% part in total edible oil production in India (NAAS 2022). During last five years, rate of edible oil consumption growing doubled as compare to its production. The rapid increase in edible oil consumption in India, rising from 13.0 kg/capita/annum in 2010–11 to 19.7 kg/capita/annum in 2020–21 (GOI 2022–23) necessitates the identification and development of high-yielding varieties in Indian mustard. However, improvement in *B. juncea* is hindered by its narrow genetic base (Chauhan *et al.* 2011). Enhancing the productivity and production of *B. juncea* can be achieved by exploiting the extent of heterosis. The yield barriers in mustard can be overcome by employing heterosis breeding practices in varietal development programmes. Researchers observed various seed yields with degrees of heterosis including 115 to 239% by Singh *et al.* (2022), Meena *et al.* (2015), Gupta *et al.* (2010) and Yadava *et al.* (1974). Furthermore, Kaur *et al.* (2020), Verma *et al.* (2011), Singh *et al.* (2010), Banga and Labana (1984), Chaudhary *et al.* (1997), Hirve and Tiwari (1992) have all demonstrated positive heterosis for the yield of seeds and its contributing traits. Plant material should be evaluated for gene activity and combining ability using the Line × Tester design prior to starting a breeding programme. The gene action estimate

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can be used to assess the performance of genotypes tested for hybrid combinations (Kempthorne 1957, Gnanasekaran and Thiyagu 2021). The significance of additive gene action is demonstrated by the dominance of general combining ability (GCA) impacts for yield and its contributing qualities (Wos *et al.* 1999). On the other hand, Pandey *et al.* (1999) highlighted the significance of non-additive gene activities because of the substantial specific combining ability (SCA) impacts linked to yield and its attributing characteristics. In light of this, a study was carried out to determine the heterosis and gene activity in Indian mustard.

MATERIALS AND METHODS

Plant material and experiment design: The study was carried out during winter (*rabi*) season of 2021–22 and 2022–23 at ICAR-Indian Institute of Soybean Research, Indore, Madhya Pradesh. The study consisted of 55 cross combinations (F_1) of Indian mustard and 16 parental lines (advanced breeding lines/cultivars) out of them 11 used as female lines and remaining 5 as testers (Table 1). Crosses were attempted between parental lines in L×T mating design to generate 55 F_1 crosses during 2021–22 and evaluated during the *rabi* season of 2022–23; the parental lines along with check were grown with all F_1 hybrids with two replications in randomized block design (RBD) design. These 11 advanced inbred lines were randomly chosen on the basis of superior agronomic traits from a diversity fixed set of genotypes, received under NASF funded project, whereas testers were selected from germplasm set maintained under CRPHT project. Crop was raised in 3 m long paired rows with spacing of 45 cm between rows and 15 cm plant to plant.

Table 1 Parental genotypes (lines and testers) and their pedigree

Parental genotype	Pedigree/ Remarks
Lines	
RE 11	East European germplasm
RC 571	Indian germplasm
CN 105312	Introduced from Canada gene bank
Pusa Bahar	Cultivar
RNN 505	Variety
IC 597880	Indegenous collection
IC 597875	Indegenous collection
EJ 22	Cultivar
DJ 65	Derived *B. juncea*
IM 170	Introgressed mustard
CN 105379	Introduced from Canada gene bank
M 84	Advanced breeding line
M 37	Advanced breeding line
RC 273	Advanced breeding line
DRMR IJ 14–137	Advanced breeding line
DRMRIJ 31	Variety (Giriraj)

All the 11 lines were randomly selected from a diverse set of genotypes, evaluated under NASF funded project.

Field experimentation and data collection: All recommended agronomic practices were followed to ensure a successful crop and maintain a standard plant population. This involved irrigating three times, including pre-sowing irrigation at prescribed rates of NPK with 80-40-40 kg/ha of fertilizer. Thirteen agro-morphological characteristics were observed on five plants that were chosen randomly. These characteristics included plant height (cm), length of main shoot (cm), number of primary and secondary branches, siliqua on main shoot, seeds/siliqua, siliqua length (cm), seed yield (kg/ha), oil content (%) and test weight (g).

Data analysis: Collected data were subjected to combining ability analysis as per Kempthorne (1957). The analysis was performed using INDOSTAT Services like WINDOW STAT (version 8.6) from Hyderabad, India which calculated better parent heterosis (heterobeltiosis) as the deviation of the F_1 value from the better parent.

ANOVA for L × T analysis of each cross for each trait was done using models by some researchers (Dabholkar 1999, Singh and Chaudhary 2004):

$$\mathrm{Yijk} = \mu + \mathrm{gi} + \mathrm{gj} + \mathrm{sij} + \mathrm{rk} + \mathrm{eijk} \tag{1}$$

Where Yijk, Average value of a cross between i and j in the k^{th} replication; μ, Mean effect of population; gi, i^{th} line's GCA effect: gj, j^{th} tester's GCA effect; sij, Cross between the i^{th} line and j^{th}, tester's SCA effect; rk, Replication effect, and eijk, Environmental error related to each observation. For lines and testers, the GCA effects as well as the SCA effects for the cross i × j^{th} were computed using the methods of the aforementioned researchers:

$$\text{GCA effects (lines)}\ \ \mathrm{gi} = \frac{\mathrm{yi}}{\mathrm{tr}} - \frac{\mathrm{y}\ldots}{\mathrm{ltr}} \tag{2}$$

$$\text{GCA effects (testers)}\ \ \mathrm{gj} = \frac{\mathrm{yj}}{\mathrm{lr}} - \frac{\mathrm{y}\ldots}{\mathrm{ltr}} \tag{3}$$

$$\text{SCA effects}\ \ \mathrm{g} = \frac{\mathrm{yij}}{\mathrm{r}} - \frac{\mathrm{yj}}{\mathrm{lr}} + \frac{\mathrm{y}}{\mathrm{ltr}} \tag{4}$$

The numbers l, t and r, Lines, testers, and replications, respectively. Equations (5–7) were used to estimate the combining ability effects with standard error, and a t-test was used to determine whether the results were significant:

$$\text{S.E. (Line of GCA)} = \sqrt{\frac{\mathrm{Mse}}{\mathrm{rt}}} \tag{5}$$

$$\text{S.E. (Tester of GCA)} = \sqrt{\frac{\mathrm{Mse}}{\mathrm{rl}}} \tag{6}$$

$$\text{S.E. (SCA effects)} = \sqrt{\frac{\mathrm{Mse}}{\mathrm{r}}\mathrm{tg} = \frac{\mathrm{g\text{-}o}}{\mathrm{SEg}}} \tag{7}$$

Where Mse, Mean square of error and SE, Standard error in the ANOVA (analysis of variance).

The method of Falconer and Mackay (1996) was used to calculate better parent heterosis (BP) as per equation (8) by calculating the F1 value's departure, and F1 value deviation to estimating from the better parent using the student's t-test to test the level of heterosis:

$$\mathrm{BP} = \frac{\overline{\mathrm{F1}} - \overline{\mathrm{BP}}}{\overline{\mathrm{BP}}} \times 100\mathrm{t} = \frac{\overline{\mathrm{F1}} - \overline{\mathrm{BP}}}{\sqrt{\mathrm{var}\left(\overline{\mathrm{F1}} - \overline{\mathrm{BP}}\right)}} \tag{8}$$

Where BP, Better parent with all replication; F1, Mean of the F1 progenies.

RESULTS AND DISCUSSION

Estimation of combining ability: In the majority of the traits, the combining ability ANOVA analysis (Supplementary Table 1 and 2) revealed significant differences for testers; lines and their interaction ($p≤0.01$ and $p≤0.05$) i.e. line × testers with mean squares. The exceptions were the number of primary branches and oil content, plant height for testers, as well as the number of seeds/siliqua and secondary branches for line × testers. This implies that the plant material used in the study is genetically diverse, with considerable variability. Additionally, the study demonstrated that the manifestation of the examined characteristics was influenced by both GCA (General combining ability) and SCA (Specific combining ability). In the following areas, heterosis is clearly visible: plant height (cm), main shoot siliquae and their length (cm), test weight (g), seed yield (kg/ha) and oil content (%). These differences were significantly higher among parent and crosses. The existence of both non-additive and additive gene effects were highlighted by the calculation of SCA and GCA variation which was significantly for nearly all the characteristics. Both gene effects were present as evidenced by the ratio of variance for general and particular combining abilities which varied from 0.111 for the principal branches to 4.4914 for the test weight. A breeding approach that makes use of dominance, dominance × additive, non-fixable genetic variation through dominance × dominance, and a maximum percentage of additive × additive epistasis (genetic variation with fixable) and additive would be successful. Parental mating among individual plants selected from the F_2 generation would be helpful in accumulating favorable alleles to develop pure lines in a robust breeding programme. Additionally, creating heterotic hybrids through crossing between the utilization of non-additive components of genetic variation might be aided by these lines.

GCA effect: The GCA effect estimates in Table 2 showed that certain lines (RE 11, IC 597880 and CN 105379) and testers (M 37 and DRMRIJ 31) had positive significantly with GCA effects on various traits in Indian mustard. These indicated the interaction effects of additive × additive and the presence of additive action of gene. When GCA effects are significant, it indicates the effects of additive × additive gene control the inheritance of that specific trait (Sprague 1966). Specifically, certain parents like Pusa Bahar, IC 597880, EJ 22, CN 105379, M 37 and DRMRIJ 14–137 showed notable favourable GCA impacts for characteristics including oil content and seed yield; RC 571, IC 597880, IC 597875, CN 105379 and DRMRIJ 31 for seeds/siliquae; CN 105312, Pusa Bahar, RNN 505, IC 597875, EJ 22, IM 170, M 37 and DRMRIJ 31 for test weight; RE 11, RC 571, IM 170, M 84 and RC 273 for days to flower initiation; RE 11, RC 571, IC 597880, IC 597875, M 84 and RC 273 for days to flower senescence; RE 11, RC 571, IC 105312, IC 597880, M 84 and DRMRIJ 14–137 for days to maturity; RE 11, RC 571 and M 84 for plant height; RE 11 and M 37 for length of main shoot; Pusa Bahar and DRMRIJ 31 for number of secondary branches; RE 11, RC 571, DJ 65, CN 105379, DRMRIJ 14–137 and DRMRIJ 31 for siliqua on main shoot; similarly for siliqua length RC 571, IC 105312, Pusa Bahar, IM 170, CN 105379, M 37, DRMRIJ 14–137 and DRMRIJ 31.

Among the lines, RE 11 exhibited the maximum effects GCA for seed yield while also positively complemented days to flowering initiation and senescence and main shoot of siliqua. This was followed by CN 105379 which defined higher effects of GCA for seed yield and traits with positively complemented such as oil content, seeds/siliqua, siliqua length and siliqua on main shoot. Among the testers, M 37 displayed effects of GCA significantly positive for the seed yield and few contributions of characters including oil content, test weight, main shoot length and siliqua length. In terms of seed yield and contributing characteristics including oil content, seed and length of siliqua and siliqua on main shoot, number of secondary branches, test weight (g), and oil content, DRMRIJ 31 also shown positive substantial with GCA impacts. These findings align with the results by Verma (2000), Ghosh *et al.* (2002), Singh *et al.* (2005), Teklewold and Backer (2005), Gupta *et al.* (2010) and Yadava *et al.* (2012), Singh *et al.* (2017), Ram *et al.* (2018) and Mandal *et al*. (2023). Based on effects of GCA analysis, this utilization of parents in a programme of breeding for Indian mustard aimed at developing hybrids. The results demonstrate that certain parents have superior with combine ability of important traits and seed yield. Therefore, improving the combining ability of seed yield contributing traits, particularly GCA is a viable option. In summary, parents RE 11, IC 597880, CN 105379, M 37, and DRMRIJ 31 possess significantly higher positive effects of GCA for the seed yield, making them effective general combiners for qualities that contribute to yield, such as seed yield. According to these results, the breeding programme should be prioritized increased oil content to combine advantageous alleles into a single genetic background.

Estimates of SCA effect: The SCA effects were observed significantly higher negative for the plant height in the two crosses. IM 170/M 84 and IC 597880/DRMRIJ 14–137. However, similarly effects of SCA were also recorded for maturity days in four crosses, and two others were identified for days to flower initiation (Table 3). This suggested that shorter maturity periods and desirable traits through reduction of plant height, possibly due to heterosis with negative traits. These results were supported by previous findings from Singh *et al.* (2022), Ram *et al.* (2018), Yadava *et al.* (2012), Gupta *et al.* (2010), Meena *et al.* (2015). In total, 10 hybrids exhibited significantly highest effects of SCA for seed yield, 2 hybrids for plant height, 6 hybrids for seeds/siliqua, 5 hybrids for test weight, 3 hybrids for flowering initiation, 11 hybrids for flower senescence, 4 hybrids for days to maturity, 1 hybrid for length of main shoot, 2 hybrids and 3 hybrids for primary and secondary branches, respectively. The outcomes of the experiment

Table 2 Estimates of GCA effects of line and testers for 13 characters in Indian mustard

Parents	OC	SY	SS	TW	DFI	DFS	DM	PH	MSL	PB	SB	SM	SL
Lines													
RE 11	–1.192***	485.055***	–1.440***	–0.299***	5.164***	4.836***	2.818***	17.182***	4.473*	0.182	0.109	4.185***	–0.006
RC 571	–0.802**	37.555	0.640*	–0.759***	1.164*	3.936***	1.518***	6.782*	3.473	0.482	0.409	2.115***	0.554***
CN 105312	–1.432***	–299.846***	–0.810**	0.271***	0.664	–0.964*	1.218**	–1.918	–3.727	–0.918**	–0.991*	–3.585***	0.226***
Pusa Bahar	1.388***	–50.645	0.05	0.441***	–4.336***	–6.864***	–2.682***	–15.418***	0.073	0.482	1.309**	–5.145***	0.704***
RNN 505	0.538	–67.745	–1200***	0.501***	–0.836	–2.564***	–0.582	–4.218	–0.327	–0.018	–0.491	0.375	–0.256***
IC 597880	1.062***	113.355*	0.640*	–0.829***	–0.036	4.636**	2.318***	2.082	0.373	–0.118	–0.591	–0.115	–0.276***
IC 597875	–0.192	–139.945**	0.670**	0.231***	–0.136	2.936***	–0.782*	–2.518	3.173	0.482	0.409	–1.445**	–0.496***
EJ 22	0.608*	56.655	0.3	0.351***	–2.036***	–3.764***	–2.682***	–0.118	–1.727	–0.518	0.009	–2.055***	–0.386***
DJ 65	0.538	–129.146**	0.31	–0.189**	–0.636	–0.764	–0.682	–4.518	–3.127	–0.118	0.609	1.505**	0.024
IM 170	–0.402	–228.746***	–0.3	0.271***	1.364**	–0.864	0.018	1.182	0.673	0.282	0.209	0.385	0.174***
CN 105379	2.008***	223.455***	1.140***	0.011	–0.336	–0.564	–0.482	1.482	–3.327	–0.218	–0.991*	3.785***	0.194***
SEM ±	0.2798	48.3109	0.2483	0.0659	0.4675	0.4341	0.3773	2.8537	2.0716	0.3101	0.4531	0.4932	0.043
CD (*p*=0.05)	0.561	96.8575	0.4979	0.132	0.9373	0.8703	0.7565	5.7213	4.1532	0.6218	0.9085	0.9887	0.0867
CD (*p*=0.01)	0.7471	128.9886	0.663	0.1758	1.2482	1.1591	1.0074	7.6193	5.531	0.828	1.2099	1.3167	0.1155
Testers													
M 84	–0.443*	–18.018	–0.295	0.001	1.882***	3.118***	0.791**	6.609**	–1.045	0.027	–0.045	–1.802***	–0.140***
M 37	0.412*	164.846***	–0.055	0.442***	–3.573***	–5.336***	–2.936***	–1.164	8.727***	–0.336	0.136	–3.070***	0.122***
RC 273	–0.911***	–2.7	–0.259	–0.845***	1.836***	2.845***	1.245***	0.609	–3.045*	0.255	–0.955**	–0.668*	–0.181***
DRMR IJ 14–137	0.457*	–259.700***	0.109	0.037	0.609	0.209	1.155***	–0.618	–2.045	0.073	0.136	2.944***	0.228***
DRMRIJ 31	0.485*	115.573***	0.500**	0.365***	–0.755*	–0.836**	–0.255	–5.436**	–2.591	–0.018	0.727*	2.616***	0.215***
SEM ±	0.1887	32.5712	0.1674	0.0444	0.3152	0.2927	0.2544	1.924	1.3967	0.2091	0.3055	0.3325	0.0292
CD (*p*=0.05)	0.3782	65.3013	0.3357	0.089	0.6319	0.5868	0.51	3.8573	2.8001	0.4192	0.6125	0.6666	0.0585
CD (*p*=0.01)	0.5037	86.9641	0.447	0.1185	0.8415	0.7814	0.6792	5.1369	3.729	0.5583	0.8157	0.8877	0.0779

***, ** and *, **, Significant at 0.001, 0.01 and 0.05, respectively.

OC, Oil content (%), SY, Seed yield (kg/ha); SS, Seeds/siliqua, ; TW, Test weight (g); DFI, Days to flowering initiation; DFS, Days to flowering senescence; DM, Days to maturity; PH, Plant height (cm); MSL, Main shoot length (cm); PB, No. of primary branch; SB, No. of secondary branch; SM, Siliqua on main shoot; SL, Sliliqua length (cm).

Table 3 Highly significant (positive values except for plant height and days to maturity) SCA effects for 13 yield and yield attributing traits in F_1 crosses of Indian mustard genotypes

Character	Crosses
Oil content (%)	RC 571/DRMRIJ 14-137 (1.793), CN 105312/IJ 31 (1.895), IM 170/IJ 31 (1.865)
Seed yield (kg/ha)	RE 11/M 37 (459.355), RC 571/DRMRIJ 14-137 (435.9), Pusa Bahar/M 37 (478.555), RNN 505/M 37 (455.155) IC 597880/M 84 (501.918), IC 597875/RC 273 (386.4), EJ 22/RC 273 (492.3), CN 105312/RC 273 (351.8) IC 597880/DRMRIJ 14-137 (347.6), IC 597875/DRMRIJ 14-137 (355.9)
Seed/siliqua	RE 11/M 84 (2.235), RC 571/RC 273 (2.269), DJ 65/DRMRIJ 14-137 (2.881), CN 105379/RC 273 (1.869) IC 597880/DRMRIJ 14-137 (1.901), E J22/IJ 31 (1.200)
Test weight (g)	RNN 505/M 84 (0.549), RNN 505/M 37 (0.508), RC 571/IJ 31 (0.345), DJ 65/M 84 (0.339), IM 170/IJ 31 (0.315)
Days to flowering initiation	RE 11/M 84 (-3.482), DJ 65/DRMRIJ 14-137 (-3.409)
Days to flower senescence	RE 11/ DRMRIJ 14-137 (2.891), RC 571/ M 84 (3.382), CN 105312/ M 37 (3.736), Pusa Bahar (2.636) RNN 505/ RC 273 (1.955), Pusa Bahar/IJ 31 (2.136), IC 597880/ DRMRIJ 14-137 (2.091), IC 597880/IJ 31 (4.136) IC 597875/ RC 273 (3.155), DJ 65/ M 84 (2.082), IM 170/ M 84 (5.682)
Days to maturity	RE 11/RC 273 (-3.045), RC 571/DRMRIJ 14-137 (-3.155), RNN 505/M 84 (-2.191), EJ 22/ DRMRIJ 14-137 (-1.955)
Plant height (cm)	IM170 /M 84 (-15.409), IC 597880/ DRMRIJ 14-137 (-12.918)
Main shoot length (cm)	RC 571/M 84 (10.345)
Primary branch	RC 571/ DRMRIJ 14-137 (1.427), DJ 65/ M 37 (1.436)
Secondary branch	RC 571/ IJ 31 (2.273), CN 105312/ M 37 (2.264), Pusa Bahar/ RC 273 (2.055)
Siliqua on main shoot	RE 11/RC 273 (2.488), RC 571/RC 273 (3.058), Pusa Bahar (3.132), RNN 505/ M 84 (3.262) IC 597880/ M 37 (2.470), IC 597875/ DRMRIJ 14-137(5.136), DJ 65/M 37 (2.800)
Siliqua length (cm)	CN 105312/ RC 273 (0.231), Pusa Bahar/ M84 (0.210), RNN 505/ M 84 (0.270), RNN 505/ RC 273 (0.261), IC 597880/ RC 273 (0.331), IC 597875/ M 37 (0.342), IC597875/IJ 31 (0.355), EJ22/M37 (0.232), DJ 65/ DRMRIJ 14-137 (0.422), IM 170/ DRMRIJ 14-137 (0.272), CN 105379/ DRMRIJ 14-137 (0.302), CN 105379/ IJ 31 (0.265)

clearly indicate the good SCA effects of F_1 crosses, which remains under the influence of the different yield attributing traits. The results also reflect the absence of a direct relationship between better parent heterosis, heterobeltiosis and SCA effects.

Estimation of heterosis and heterobeltiosis: The estimation of good parent heterosis is presented for seed yield in the Supplementary Table 3. A total of 55 hybrids, 44 hybrids expressed highly positive better parent heterosis, while 29 of these hybrids showing >15% heterobeltiosis. Ten of these hybrids, including RE 11/M 37, RC 571/DRMRIJ 14–137, CN 105312/RC 273, Pusa Bahar/RC 273, RNN 505/M 37, RNN 505/RC 273, IC 597880/DRMRIJ 14–137, IC 597875/RC 273, EJ 22/RC 273, and CN 105379/RC 273, exhibited maximum better parent heterosis with significantly higher effects of SCA and their performance. Similarly outcomes were reported by some researchers with high heterobeltiosis of seed yield per plant and significantly higher effects of SCA. For example, Rout *et al.* (2025) Hybrid combinations such as SKJM–05 × Kranti, RW–85–59 × SKJM–05, and NPJ–194 × SKJM–05 exhibited notable GCA effects of parents, *per se* performance and SCA effects of hybrids for seed yield plant. Mandal *et al.* (2023) stated on the basis of high heterosis over mid parent as well as better parent and significant, SCA effects for seed yield per plant and its component traits, hybrids namely, JD-6 × Pusa Bold, PM 30 × Seeta, PM 25 × Pusa Bold, PM 24 × Kranti and PM 22 × Sarama were found to be very promising for further exploitation in breeding programme. Ghosh *et al.* (2002) observed 73.75% better parent heterosis in the cross–combination YSRL-10/Pusa Bold followed by 63.64% in AD–2041/Pusa Bold. Heterobeltiosis was shown to be 44.8% in the cross RSK 28/RH (OE) 0103 by Vaghela *et al.* (2011) and 54.38% in the hybrid PM 25/RGN by Yadava *et al.* (2012). Singh *et al.* (2022) found 115% heterosis in the cross combination NRCDR 02/Rohini whereas Meena *et al.* (2015) found 129.22% better parent heterosis in the cross DRMR 2613/Ashirwad. In a study of 15 crosses, Verma *et al.* (2011) similarly found moderate level heterosis for characteristics that contribute to yield and 24.36–80.97% heterosis for seed yield.

The identified hybrid combinations in this investigation were found to be superior on various parameter analyses. The results indicate that the presence of non-additivite and additive actions of gene is responsible for seed yield and their contribution character traits in various cross combinations. The analysis of combining ability between testers and lines has opened new opportunities to develop high yielding cultivars/hybrids. The higher yields cross/hybrids combinations are identify to utilize for commercial purpose in CMS for conversion of parental lines and their respective restore lines.

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