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Research Article

Genetic study for seed yield and seed quality traits in indian mustard [*Brassica juncea* L.Czern&coss.]

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Abstract
Combining ability, gene action and heterosis was studied in a set of seven lines, five testers and 35 hybrids of Indian mustard following L x T mating design. The ratio $\sigma^2_{gca} / \sigma^2_{sca}$ was less than one, for the traits, *viz*., days to flowering, plant height, number of branch per plant, number of siliquae per plant, seed yield per plant, 1000-seed weight, oil content, lenoleic acid content and lenolenic acid content, which suggested greater role of non-additive genetic variance in the inheritance of these traits. The cross CJ 3761 x GM 3 recorded the highest heterosis (22.70%) over check variety GDM 4, followed by ZEM 2 x Kranti (12.06%), while hybrid CJ 3761 x GM 3 exhibited highest heterobeltiosis (75.35%). Parents CJ 3761, DRMR-659-49, ZEM 1, ZEM 2, GM 1 and GM 3 were good combiners for seed yield per plant. ZEM 1 was found to be good combiner for number of branches per plant, number of siliquae per plant, oil content and linolenic acid. Considering mean performance, heterosis and combining ability effects, the parents CJ 3761, DRMR-659-49, ZEM 1, ZEM 2, GM 1 and GM 3 and the hybrids CJ 3761 x GM 3, ZEM 2 x Kranti and DRMR-659-49 x GM 2 were found to be promising for the development of high yielding genotypes.

Key words: Combining ability, GCA, SCA, Gene action and Heterobeltiosis

Introduction

Indian mustard belongs to family *Brassicacae* and genus Brassica. Indian mustard or brown mustard [*Brassica juncea* (Linn.)Czern&Coss] is a natural amphidiploids (2n = 36) of *Brassica rapa* (2n = 20) and *Brassica nigra* (2n = 16). The phenomenon of heterosis, combining ability and gene action has been proved to be the most important genetic tools in enhancing the yield of self as well as cross pollinated species. For developing high yielding varieties through hybridization, selection of suitable parents and breeding methodology are a matter of concern to the plant breeders. Heterosis study provides information about probable gene combinations and help in sorting out desirable gene combinations. The combining ability help in partitioning the total genetic variation into general combining ability of parents and specific combining ability of crosses, which is useful to assess the nature of gene action controlling different characters.

Many authors applied different strategies for improving seed yield and quality attributes of Brassica (Singh *et al*, 2003; Gami *et al*, 2012). Gami and Chauhan (2013) and Patel *et al*., (2013) have also reported difference types of gene action and combining abilities in different sets of genotypes. The ample analysis of the combining ability involved in the inheritance of quantitative characters and in the incident of heterosis is necessary for the evaluation of various possible breeding procedures (Allard, 1960). Combining ability studies highlighted the predominant effect of GCA on yield and most of the yield components indicating the importance of additive gene action (Wos *et al*., 1999). While Pandey *et al*. (1999) observed the presence of significant SCA effect for yield and yield components indicating importance of non-additive gene action. The various mating designs have been used for assessing the breeding value of the parents through the estimation of variance and combining ability effects. The Line x Tester mating design has been widely used in crop plants for testing the performance of genotypes in hybrid combinations and also for estimating the magnitude and nature of gene action (Kempthorne, 1957). Keeping these in view, the present investigation was undertaken to make an assessment of combining ability, gene action and heterosis of parents and their specific crosses in Indian mustard.

Materials and methods

The experimental material consisted of seven lines ((LES-44, CJ 3761, SKM-B-817, RH-30, DRMR-659-49, ZEM 1 and ZEM 2) and five testers (GM 1, GM 2, GM 3, GDM 4 and Kranti) crossed in a Line x Tester mating design. The resultant 35 hybrids along with their twelve parents were evaluated in Randomized Block Design with three replications at Main Castor-Mustard Research Station, S. D. Agricultural University, Sardarkrushinagar during *rabi* (2013-2014). Five representative plants were taken from each plot for recording data on different characters *viz*., days to flowering, days to maturity, plant height (cm), number of branches per plant, number of silique per plant, seed yield per plant (g), 1000-seed weight (g), oil content (%), oleic acid (%), linolenic acid (%), erucic acid (%) and linoleic acid (%). Oil content of each sample was estimated in percentage by using Nuclear Magnetic Resonance Technique (Tiwari *et al*., 1974), while fatty acids composition of each sample was estimated in percentage by using Fourier Transferable Near-Infrared (FT-NIR) Technique. The data were subjected to analysis of variance as per the procedure suggested by Sukhatme and Amble (1989). The combining ability analysis was performed for a Line x Tester matting design as per the method suggested by Kempthorne (1957). The hybrid performance (%) was assessed based on heterobeltiosis (Fonseca and Patterson, 1968) and standard heterosis (Meredith and Bridge, 1972), with GDM 4, as standard parent. Significance of heterosis value was tested using 't' test.

Results and discussion

The analysis of variance revealed significant differences among the parents for majority of the characters except for number of branches per plant indicating considerable amount of variability among the parents. Mean squares due to hybrids were significant for all the characters. This revealed existence of considerable variability in the parental materials used. Comparison of mean squares due to parent *vs*. hybrids was found highly significant for almost all the characters except plant height, number of branch per plant and linolenic acid, which indicated that mean values of hybrids were significantly different from that of the parents as a group for these traits thereby, suggesting the presence of heterosis for most of these characters (Table 1).

The analysis of variance for combining ability revealed that the mean squares due to females (lines) were significant for days to flowering, days to maturity, 1000- seed weight, oil content, oleic acid, linolenic acid, linoleic acid, and erucic acid. This indicated significant contribution of females towards general combining ability variance component for these traits. The variances due to males (testers) were non-significant for all the characters. The line x tester interaction was significant for all the characters except for days to maturity and plant height (Table 2). This signified the contribution of hybrids for specific combining ability variance components. The magnitude of variance component due to females was higher than that of males for all the characters under study which indicated greater contribution of females towards $\sigma^2_{gca.}$

The ratio of σ^2_{gca} / σ^2_{sca} being less than unity was found for the traits *viz*., days to flowering, plant height, number of branch per plant, number of silique per plant, seed yield per plant, 1000-seed weight, oil content, lenoleic acid and lenolenic acid, which suggested greater role of non-additive genetic variance in the inheritance of these traits (Table 2). The presence of predominantly large amount of non-additive gene action would be required for the maintenance of heterozygosity in the population. Breeding methods such as biparental mating followed by reciprocal recurrent selection may increase frequency of genetic recombination and fasten the rate of genetic improvement (Hanson *et al*, 1960). The above results are in accordance with the findings of Katiyar *et al*.(2005), Mohan Lal *et al*.(2011), Patel *et al*.(2013) and Gami and Chauhan (2014). However, the ratio of σ^2_{gca} / σ^2_{sca} being more than unity was found for the traits *viz*., days to maturity, 1000 –seed weight, oleic acid and erucic acid, which suggested greater role of additive genetic variance in the inheritance of these traits. The above results are in accordance with the findings of Shamima Nashrin *et al*.(2011), Turi *et al*.(2011), Patel *et al*.(2013) and Pandey *et al*.(2013).

The *sca* effects varied from -8.62 (CJ 3761 x GM 2) to 10.51 (CJ 3761 x GM-3). Nine crosses expressed significant and positive *sca* effects for seed yield per plant (Table 3a). The high sca effects for seed yield per plant was recorded in CJ 3761 x GM 3 (10.51) followed by ZEM 2 x Kranti (9.89) and DRMR-659-49 x GM 2 (6.64). The crosses CJ 3761 x GM 3 and SKM-B-817 x GM 3 registered significant *sca* effects for yield component, *i.e.*,siliquae per plant. The cross DRMR-659-49 x GM 3 recorded significant and desired sca effects for 1000-seed weight. The above results are in accordance with the findings of Gami and Chauhan (2013) and Tele *et al* (2014).

The cross DRMR-659-49 x GM 3 followed by DRMR-659-49 x GM 1 and SKM-B-817 x GM 2 showed significant and positive sca effects for oil content. The cross CJ 3761 x GM 2 registered significant and negative sca effects for erucic acid and significant and positive sca effects for linoleic acid , while cross combination ZEM 2 x GM 2 manifested significant and negative sca effects for lenolenic acid. The similar sca effect was recorded previously for seed quality components by Gami and Chauhan (2014).

The degree of heterosis varied from cross to cross for all the characters. Considerably high heterosis values in certain crosses and low in other crosses revealed that nature of gene action varied with the genetic constitution of the parental material. Heterobeltiosis is important as they provide an idea about the role of dominance and over-dominance type of genetic control. In most of the characters variable numbers of crosses depicted heterosis in both positive and negative direction, indicating that genes with negative as well as positive effect were dominant.

In this study, two hybrids manifested significant positive standard heterosis for seed yield (Table 3a). The cross CJ 3761 x GM 3 recorded the highest heterosis (22.70%) over check variety GDM 4 followed by ZEM 2 x Kranti (12.06%), while hybrid CJ 3761 x GM 3 exhibited highest heterobeltiosis (75.35%). High amount of heteobeltiosis was observed under the presentstudyagree with those reported by Vaghela *et al*. (2011) and Gami *et al*. (2011). For number of branches per plant, moderate value of heterobeltiosis (29.41%) and standard heterosis (15.79%) were recorded. Similar trend was noticed by Monpara and Dobariya (2007). The high heterobeltiosis and standard heterosis was observed for number of siliquae per plant. The positive as well as negative heterotic effects observed under the present study are in accordance with reports of Gami and Chauhan (2013) and Meena *et al* (2014).

The moderate heterosis was recorded for 1000-seed weight over better parent and standard check (GDM 4). The heterosis range observed under the present study agrees with those reported Monpara and Dobariya (2007). In case of oil content the heterobeltiosis and standard heterosis were moderate. The positive desirable heterosis for oil content was earlier reported by Patel *et al.* (2010) and Gami and Chauhan (2014). Since, fatty acid composition comprised linolenic acid and erucic acid content, negative heterosis was desired for these traits, while for oleic acid and linoleic acid desirable positive heterosis was desired.

The examination of the data revealed that the crosses, which expressed high *per se* performance, high heterotic value and desirable sca effects for various characters involved either good x good, good x average, good x poor, average x good and average x average, combining parents. This suggested that intra-allelic interactions were also important for these traits as reported by Turi *et al*.(2011) and Patel *et al*.(2013).

An overall appraisal of general combining ability effect of parents revealed that none of the parents was found good general combiner simultaneously for all the characters (Table 3a & b). However, the parents CJ 3761, DRMR-659-49, ZEM 1, ZEM 2, GM 1 and GM 3 were good combiners for seed yield per plant. Among these parents, CJ 3761 was also good general combiner for one or more of its component traits *i.e.,* days to maturity, number of branches per plant and number of siliquae per plant, oleic acid, erucic acid and linoleic acid, while parent DRMR-659-49 was proved to be good donor for number of siliquae per plant and linolenic acid.

The cross CJ 3761 x GM 3 registered high *per se* performance, standard heterosis and sca effects for seed yield per plant and component traits *i.e*., number of branches per plant and number of silique per plant and the parents (CJ 3761, GM 3) were also good combiners (Table 3a). While for quality trait hybrid DRMR-659-49 x GM 3 was registered high sca effects (2.73), high heterobeltiosis (5.29 %) and standard heterosis (4.42 %) for oil content. The hybrid CJ 3761 x GM 2 was best for erucic acid content with high *sca* effect and involved both good combiners as parents (Table 3b).

References

Allard, R.W.1960. Principles of Plant Breeding. *John Wiley and Sons Inc.,* New York.

Briggle, L.W. 1963. Heterosis in wheat : *A Review. Crop Sci*., **3**: 407-412.

Fonseca, S. and Patterson, F. 1968. Hybrid vigour in a seven parent diallel cross in common winter wheat (*Triticum aestivum* L.). *Crop Sci.,* **8**: 85-88.

Gami, R.A. and Chauhan, R.M. 2013.Heterosis and combining ability analysis for seed yield and its attributes in Indian mustard [*Brassica juncea* (L.) Czern and Coss]. *Internat., J. Agric. Res*., **47**(6): 535-539.

Gami, R.A. and Chauhan, R.M. 2014.Genetic analysis for oil content and oil quality trait in Indian mustard [*Brassica juncea* (L.) Czern and Coss]. *Internat., J. Agric. Sci*., **10**(1): 146-150.

Gami, R.A., Thakkar, D.A., Patel, M.P., Parmar, H.D. and Patel, P.S. 2011. Heterosis for seed yield and its components in Indian mustard [*Brassica juncea* (L.) Czern&Coss]. *J. Oilseeds Res.,* **28** (1): 60-62.

Gami, R.A., Thakkar, D.A.,Patel, M.P., Prajapati, K.P. and Patel, P.S. 2012. Combining ability analysis for yield and its contributing traits in Indian mustard [*Brassica juncea* (L.) Czern&Coss]. *J. Oilseeds Res*., **29** (2): 137-138.

Hanson, J.B.; Hageman, R.H. and Fisher, M.E. 1960. The association of carbohydrates with mitochondria of corn scutellum. *Agron. J.,* **52:** 49-52.

Katiyar, R.K., Chamola, R., Banerjee, P.K. and Singh, H.B. 2005. Assessment of heterosis and combining ability for seed yield in Indian mustard [*Brassica juncea* (L.) Czern&Coss]. *Brassica*, 7 (1&2): 33-37.

Kempthorne, O. 1957. An Introduction to Genetic Statistics. John Willey and Sons Inc., New York.

Meena, H.S, Bhagirath Ram, Arun Kumar, Singh B.K, Meena P.D., Singh V.V and Dhiraj Singh 2014. Heterobeltiosis and standard heterosis for seed yield and important traits in *Brassica juncea. J. Oilseed Brassica,* **5** (2): 134-140.

Meredith, W.R. and Bridge, R.R. 1972. Heterosis and gene action in cotton *Gossypiumhirsutum.,Crop Sci.,***12**:304-310

Mohan Lal; Singh, D.P. and Bagadi, D.L. 2011. Combining ability analysis for seed yield and its components in Indian mustard [*Brassica juncea* (L.) Czern&Coss]. *Agric. Sci. Digest*, **31** (1): 35 – 37.

Monpara, B.A. and Dobariya, K.L. 2007. Heterosis and combining ability in Indian mustard [*Brassica juncea* (L.) Czern&Coss]. J. Oilseeds Res., *24* (2): 306-308.

Pandey S., Kabdal M. and Tripathi M.K. 2013 Study of Inheritance of erucic acid in Indian mustard [*Brassica juncea* (L.) Czern&Coss]. *Octa. J.Biosci.***1** (1):77-84.

Pandey, L.D., Singh, B. and Sachan, J.N.1999 Brassica hybrid research in India: Status and Prospect. Paper 263. *In Proc. 10th Int. RapseedConfr. Caneberra, Australia,* pp: 26-29.

Patel, A.M., Arha, M.D. and Khule, A.A. 2013. Combining ability analysis for seed yield and its attributes in Indian mustard (*Brassica juncea* (L.) Czern and Coss). *Asian J. Bio.Sic*., **8** (1): 11-12.

Patel, C.G.; Parmar, M.B.; Patel, K.R. and Patel, K.M. 2010. Exploitation of heterosis breeding in Indian mustard, [*Brassica juncea* (L.) Czern&Coss]. *J. Oilseeds Res.*,**27** (1): 47-48.

ShamimaNasrin; FatehaNur; KhursidaNasreen; Shahidur, R.B.; Shahnaj Sarkar and Mahbub Islam. 2011. Heterosis and combining ability analysis in Indian mustard [*Brassica juncea* (L.) Czern&Coss]. *Bangladesh Res. Pub. J.*, **6** (1): 65-71.

Singh, K.H., Gupta, M.C., Shrivastava, K.K. and Kumar, P.R. 2003. Combining ability and heterosis in Indian mustard. *J. Oilseeds Res*., **20** (1): 35-39.

Sukhatme P V and Amble V N. 1989. *Statistical Methods for Agricultural Workers*, ICAR, New Delhi.

Tele R.B., Patil S.R Lole, M.D., Khillari A.V., Solanke P.D. and BansodS.C. 2014. Genetic analysis in Indian mustard (*Brassica juncea*) through diallel mating. *J. Oilseed Brassica*, **5** (1): 55-60.

Tiwari, P.N., Gambier, P.N. and Rajan, T.S. 1974. Rapid and non-destructive determination of seed oil by Pulsed Nuclear Magnetic Resonance Technique. *J. Amer. Chem. Soc*., **51**: 104-109.

Turi, N.A; Raziuddin; Farhtullah; Khan, N.U; Iqbalmunir, Shah, A.H. and Khan, S. Ghulam, H.; Jehan, B.; Sajid, K. and Mohammad, S. (2011). Combining ability for yield related traits in [*Brassica juncea*. (L.) Czern&Coss]. *Pak. J. Bot.*, **43** (2): 1241-1248.

Vaghela, P.O.; Thakkar, D.A.; Bhadauria, H.S.; Sutariya, D.A.; Parmar, S.K. and Prajapati, D.V. 2011. Heterosis and combining ability for yield and its component traits in Indian mustard [*Brassica juncea* (L.) Czern&Coss]. *J. Oilseed Brassica*, **2** (1): 39-43.

Wos, H., BartkowiakBroda, I. Budizianowski,G. and Krzymanski J.1999. Breeding of winter and spring oilseed rape hybrid at malyszyn. Paper 544. *In Proc. 10th Int. RapseedConfr. Caneberra, Australia,* pp: 26-29.

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Table 1. Analysis of variance for parents and hybrids for seed yield and quality characters in Indian mustard

Source of variation	d.f.	Days to flowering	Days to maturity	Plant height	No. of branches per plant	No. of siliquae per plant	Seed yield per plant
Replications	2	1.93	0.90	222.17	6.21	192.11	3.30
Treatments	46	25.76**	25.52**	276.91**	11.69**	21542.2**	83.73**
Parents	11	67.30**	25.48**	668.41**	4.15	8161.11**	58.24**
Females	6	97.30**	41.41**	852.52**	3.20	6936.93**	43.64**
Males	4	24.76**	7.06	132.93	6.60	9691.10**	79.55**
Female vs. Male	1	57.42**	3.56	1705.67**	0.02	9386.28*	60.68**
Parent vs. hybrid	1	71.03**	63.88**	42.90	3.60	63343.4**	0.002
Hybrids	34	10.99**	24.40**	157.13*	14.37**	24641.9**	94.43**
Error	92	3.96	8.55	98.53	2.81	1938.44	4.33

Source of variation	d.f.	1000 - Seed weight	Oil content	Linolenic acid	Oleic acid	Erucic acid	Linoleic acid
Replications	2	0.09	0.038	0.28	0.25	0.54	0.36
Treatments	46	0.61**	14.77**	8.09**	127.23**	318.05**	23.23**
Parents	11	0.47**	17.72**	17.43**	318.97**	716.00**	54.77**
Females	6	0.21	19.47**	27.69**	389.71**	855.47**	66.34**
Males	4	0.12	2.76*	6.20**	1.96**	10.56**	2.64**
Female vs. Male	1	3.37**	67.06**	0.83*	1162.61**	2700.5**	193.89**
Parent vs. hybrid	1	3.33**	134.56**	0.08	51.20**	888.28**	79.20**
Hybrids	34	0.57**	10.29**	5.31**	241.85**	172.53**	11.38**
Error	92	0.13	0.13	0.14	0.34	1.68	0.30

* P ≤ 0.05, ** P ≤ 0.01.

Table 2. Analysis of variance (mean square) for combining ability, estimates of components of variance and their ratio for various characters in Indian mustard

Source of variation	d.f.	Days to flowering	Days to maturity	Plant height	No. of branches per plant	No. of siliquae per plant	Seed yield per plant
Replications	2	0.181	3.46	219.32	4.66	1108.26	1.01
Crosses	34	10.99**	24.40**	157.13	14.38**	24641.89**	94.43**
Females (Lines)	6	31.73**	96.87**	250.05	22.82	33828.48	142.24
Males (Testers)	4	5.04	3.41	122.18	8.68	19382.61	74.13
Females x Males	24	6.81*	9.78	139.74	13.22**	23221.79**	85.87**
Error	68	3.74	13.26	102.82	3.18	2367.13	4.49
COMPONENTS OF VARIANCE							
σ^2 Females		1.85**	5.89**	10.10	1.33	2126.00	9.19
σ^2 Males		0.05	0.25	1.13	0.28	830.67	3.32
σ^2_{gca}		0.80**	2.31**	4.87	0.72*	1370.39*	5.76*
σ^2_{sca}		0.95*	0.41	13.73	3.47**	7094.45**	27.17**
σ^2_{gca} / σ^2_{sca}		0.84	5.63	0.31	0.21	0.19	0.21

Source of variation	d.f.	1000 – Seed weight	Oil content	Oleic Acid	Linolenic acid	Erucic acid	Linoleic acid
Replications	2	0.164	0.428	0.295	0.311	0.473	0.782
Crosses	34	0.57**	10.29 **	51.20**	5.310 **	172.53**	11.38**
Females (Lines)	6	1.14 *	23.45 *	241.85**	11.130 *	809.80**	25.91*
Males (Testers)	4	0.536	3.17	7.306	3.163	29.167	4.63
Females x Males	24	0.44**	8.18 **	10.860 **	4.21**	37.11**	8.87**
Error	68	0.129	1.04	0.32	0.13	2.19	0.31
COMPONENTS OF VARIANCE							
σ^2 Females		0.07*	1.50*	16.10**	0.73*	58.87**	1.71*
σ^2 Males		0.02	0.11	0.33	0.14	1.31	0.21
σ^2_{gca}		0.04**	0.69*	6.90**	0.39**	23.21**	0.83*
σ^2_{sca}		0.10**	2.43**	3.50**	1.36**	11.80**	2.86**
σ^2_{gca} / σ^2_{sca}		0.40	0.28	1.97	0.29	1.97	0.29

* $P \leq 0.05$, ** $P \leq 0.01$.

Table 3a. Three top ranking parents with respect to *per se* performance and gca effects and three top ranking hybrids with respect to *per se* performance, sca effects and heterosis over better parent and standard check (GDM 4) for yield and its components

Character	Best performing parent (*per se* performance)	Best general combiners	Best performing hybrids *per se* performance	Hybrids with high sca effects	GCA of the parents	SCA Effects	Heterosis (%) over Better parent	Heterosis (%) over Standard check (GDM 4)
Days to flowering	GDM 4	LES-44	SKM-B-817x GM 1	SKM-B-817x GM 1	A x P	-2.78	-3.27	-5.73
	SKM-B-817	SKM-B-817	CJ 3761 x Kranti	ZEM 1 x GM 2	P x A	-1.93	-11.56	-2.54
	DRMR-659-49	Kranti	LES-44 x Kranti	DRMR-659-49x GM 2	A x A	-1.40	-1.29	-2.54
Days to Maturity	RH 30	CJ 3761	CJ 3761 x GM 2	DRMR-659-49x GM 1	P x A	-2.89	-1.24	-0.93
	DRMR-659-49	SKM-B-817	SKM-B-817 x Kranti	RH-30 x GM 2	G x A	-2.41	-1.25	-1.25
	KRANTI	ZEM 1	CJ 3761 x GDM 4	DRMR-659-49 x GDM 4	P x P	-2.51	-0.31	-
Plant Height	GM 1	RH- 30	LES-44 x GM 1	LES-44 x GM 1	A x A	-11.15	-	-2.80
	GM 2	GM 2	RH-30 x GM 2	ZEM 2 x GM 3	P x P	-8.10	-	-
	RH- 30	SKM-B-817	SKM-B-817 x Kranti	CJ 3761x GDM 4	P x P	-7.94	-	-
Number of branches per plant	SKM-B-817	ZEM 1	CJ 3761x GM 3	CJ 3761x GM 3	G x G	2.60	29.41	15.79
	GDM 4	GM 3	ZEM 1 x GDM 4	SKM-B-817 x GM 3	P x G	2.60	-	-
	ZEM 1	CJ 3761	CJ 3761xGM 1	ZEM-2 x Kranti	P x P	2.41	9.8	-
Number of siliquae per plant	GDM 4	DRMR-659-49	CJ 3761 x GM 3	CJ 3761 x GM 3	G x G	159.03	101.32	50.29
	RH-30	GM 3	ZEM-2 x Kranti	SKM-B-817 x GM 3	P x G	141.03	17.65	15.23
	SKM-B-817	CJ 3761	CJ 3761 x GM 1	ZEM-2 x Kranti	A x A	124.32	64.08	28.97
Seed yield per plant	GDM 4	DRMR-659-49	CJ 3761 x GM 3	CJ 3761 x GM 3	G x G	10.51	75.35	22.70
	RH-30	ZEM 1	ZEM-2 x Kranti	ZEM-2 x Kranti	G x A	9.89	39.28	12.06
	SKM-B-817	CJ 3761	CJ 3761 x GM 1	DRMR-659-49 x GM 2	G x P	6.64	23.89	6.34
1000-seed weight	Kranti	RH-30	DRMR-659-49 x GM 3	DRMR-659-49 x GM 3	P x G	0.75	19.94	14.56
	GDM 4	SKM-B-817	SKM-B-817 x GM 2	DRMR-659-49 x GM 1	P x A	0.46	11.88	4.62
	DRMR-659-49	GM 3	RH-30 x GDM 4	RH-30 x GDM 4	G x P	0.41	9.66	9.73

G = Good combiner; A = Average combiner and P = Poor combining parent.

Table 3b. Three top ranking parents with respect to *per se* performance and gca effects and three top ranking hybrids with respect to *per se* performance, sca effects and heterosis over better parent and standard check (GDM 4) for oil and its quality characters

Character	Best performing parent (*per se* performance)	Best general combiners	Best performing hybrids *per se* performance	Hybrids with high sca effects	GCA of the parents	SCA Effects	Heterosis (%) over	
							Better parent	Standard check (GDM 4)
Oil content	GDM 4	RH-30	RH-30 x Kranti	DRMR-659-49 x GM 3	P x P	2.73	5.29	4.42
	Kranti	ZEM 1	SKM-B-817 x GM 2	DRMR-659-49 x GM 1	P x A	2.04	4.97	4.10
	DRMR-659-49	SKM-B-817	RH-30 x GM 2	SKM-B-817 x GM 2	G x A	1.39	5.73	4.82
Oleic acid	RH-30	LES-44	LES-44 x GM 3	RH-30 x GDM 4	P x P	3.60	-	8.18
	LES-44	CJ 3761	LES-44 x GM 1	CJ 3761 x GM 2	G x A	3.21	16.73	40.47
	ZEM 1	GM 3	LES-44 x Kranti	SKM-B-817 x GM 3	P x G	3.95	53.49	35.18
Linolenic acid	ZEM 1	RH-30	RH-30 x GDM 4	ZEM 2 x GM 1	G x P	-2.16	-	-21.77
	RH 30	SKM-B-817	SKM-B-817 x GM 3	SKM-B-817 x GM 3	G x G	-1.61	-18.74	-25.46
	GM 1	DRMR-659-49	SKM-B-817 x GDM 4	DRMR-659-49 x Kranti	G x A	-1.58	-11.92	-23.76
Erucic acid	LES-44	LES-44	LES 44 x GM 3	CJ 3761 x GM 2	G x G	-7.64	-25.31	-32.11
	RH 30	CJ 3761	LES 44 x GM 2	CJ 3761 x GM 1	G x G	-5.69	-20.31	-27.25
	ZEM 1	GM 2	LES 44 x Kranti	RH-30 x GDM 4	P x P	-3.57	-	-
Linoleic acid	RH-30	CJ 3761	CJ 3761 x GM 2	CJ 3761 x GM 2	G x G	2.75	21.58	36.25
	LES-44	LES-44	LES-44 x GM 2	SKM-B-817 x GM 3	A x A	2.53	25.52	20.00
	ZEM 2	GM 2	CJ 3761 x GM 1	LES-44 x GM 2	G x G	2.46	-8.22	-

G = Good combiner; A = Average combiner and P = Poor combining parent.