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Research Article

Diallel analysis in Indian mustard (*Brassica juncea* L. Czern & Coss.)

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Abstract

Diallel analysis excluding reciprocals, comprised of ten parents and their hybrids was carried out to identify high heterotic crosses and their relationship in terms of general and specific combining ability (GCA and SCA) in Indian mustard in year 2013-14. Analysis of variance for GCA and SCA signify differences for all the traits. Ratio of GCA and SCA variances was below unity for all the characters except days to flowering, plant height and harvest index, which suggested superior role of non-additive genetic variance in the inheritance of these traits. Out of 45 specific crosses, the highest economic heterosis was observed in case of five crosses *viz.*, SKM 815 x RGN-303 (30.26 %), GDM 4 x RH-0555 (27.72 %), GDM 4 x RGN-303 (26.67 %), GDM 4 x RGN-282 (25.06 %) and GDM 4 x SKM 518 (18.63 %). The parents GM 3, GDM 4, RH-0555 and RSK-29 were good combiners for seed yield and its component characters. Parents RGN-303 and RSK-29 were good general combiners for oil content. Similarly, GM 3 and RGN-282 for oleic acid.

Key words

Diallel analysis, combining ability, gene action and *Brassica juncea*

Introduction

Indian mustard (*Brassica juncea*) is a naturally autogamous species, yet in this crop frequent out-crossing occurs which varies from 5 to 30% depending upon the environmental conditions and frequency of pollinating insects. Cytologically Indian mustard is an amphidiploid (2n=36), derived from interspecific cross of *Brassica rapa* (2n=20) and *Brassica nigra* (2n=16) followed by natural chromosome doubling. The improved mustard seeds contain 39-44 per cent oil. For International acceptance, erucic acid content should be <2%. Seed quality, seed yield and other yield related parameters of *Brassica* oil seed crop has been tried to improve by several researchers (Monpara, 2007). Many authors applied different strategies for improving seed yield and quality attributed of *Brassica* (Singh *et al*., 2003 and 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 material studies. Combining ability studies highlighted the predominance effect of gca for 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.

Diallel mating design has been extensively used in both self and cross pollinated species to understand the nature of gene action involved in the expression of quantitative traits. It yields reliable information on the components of variance and on gca and sca variances and their effects. Thus it helps in the selection of suitable parents for hybridization as well as in the choice of appropriate breeding procedures (Hayman, 1954 and Griffing, 1956). 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 crossed in Indian mustard.

Materials and methods

The experimental material consisted of morphological diverse genotypes/varieties *viz.*, GM 3, GDM 4, SKM 815, SKM 518, SKM 904, RH-0555, RGN-282, RGN-303, RW-1-02, RSK-29 and their 45 direct crosses *i.e*., the F_1 populations. All the 55 treatments (10 parents and 45 F_1s) were grown in Randomized Block Design with three replications at S. D. Agricultural University, Sardarkrushinagar during *Rabi* 2013-2014. These genotypes/varieties were taken on the basis of their differences *viz*., plant height, number of branches per plant, number of siliquae per plant, days to flowering, days to maturity, seed yield per plant, harvest index, 1000-seed weight, oil content and fatty acid composition. 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 mean data of each plot was used for statistical analysis, the data were subjected to analysis of variance as per the procedure suggested by Sukhatme and Amble (1989). The combining ability analysis was done by the procedure suggested by Griffing's (1956). The hybrid performance (%) tested in comparison with mean value of two parents (Relative heterosis/RH), better parent (heterobeltiosis/BPH) and standard

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check (Standard heterosis/SH) as per the formula RH = 100 x [(F_1-MP) / MP] suggested by Briggle (1963), BPH = 100 x [(F_1-BP) / BP] suggested by Fonseca and Patterson (1968) and SPH = 100 x [(F_1-SP) / SP] suggested by Meredith and Bridge (1972) respectively. Where F_1= mean hybrid performance, BP= mean performance of better parents and SP= mean performance of standard parent/check (GDM 4).

Results and discussion

The analysis of variance carried out for thirteen characters showed the significant differences amongst all the parents, F_1s and parents *vs* F_1s for all the characters except plant height, number of branches per plant and harvest index revealed significant differences,. The results were in accordance with Patel *et al*. (2013) and Arifullah (2013). Highly significant differences were recorded among the treatments for all the characters namely, days to flowering, days to maturity, plant height, number of siliquae per plant, number of branches per plant, seed yield per plant, test weight, harvest index, oil content, oleic acid, linoleic acid, linolenic acid and erucic acid (Table 1).

Heterosis over mid parent and heterobeltiosis over better parent is of no consequence for any hybrid to be acceptable commercially; it must express significant level of superiority over the standard check. Such superiority is referred to as standard heterosis. The heterosis was estimated for all cross combinations over the standard parent, GDM 4. The maximum significant heterosis for desirable direction was observed for various traits by the hybrids *viz*., GM 3 x RH-0555 for days to maturity and harvest index; SKM 904 x RW-1-02 for plant height and linolenic acid and GM 3 x RGN-282 for erucic acid, oleic acid and linoleic acid; SKM 815 x RH-0555 for number of branches per plant; SKM 904 x RGN-282 for number of siliquae per plant; GDM 4 x SKM 518 for seed yield per plant and SKM 518 x RGN-303 for oil content. Earlier desirable type of heterosis for various traits in mustard also reported by Vaghela *et al*. (2011) and Gami and Chauhan (2013).

The analysis of variance for combing ability indicated that variances due to GCA and SCA were highly significant for all the characters. The variance due to SCA was higher than the GCA for the characters *viz.* linoleic acid and erucic acid, which indicated predominated role of non-additive gene action for inheritance of these traits. On the other hand, the estimates of GCA were higher than SCA for days to flowering, days to maturity, plant height, number of branches per plant, number of siliquae per plant, seed yield per plant, test weight, harvest index, oil content, oleic acid and linolenic acid (Table 2).

The gca and sca ratio was less than unity for all the traits except days to flowering, plant height and harvest index. This indicated that non-additive component played more roles in inheritance of these characters. The non-additive type of gene action was also found in mustard by Gami and Chauhan (2013) and Ankit *et al*. (2015).

The promising combiners based on *per se* performances and signficant gca effects (Table 3) were RH-0555 and RSK-29 for number of siliquae per plant and seed yield per plant; GDM 4 and SKM 815 for days to flowering; GM 3 and SKM 518 for days to maturity and harvest index; GM 3 and GDM 4 for dwarf type plant; number of branches per plant and oleic acid; GDM 4 and SKM 815 for test weight; RGN-303 and RSK-29 for oil content; SKM 518 and SKM 904 for linoleic acid; SKM 904 and RH-0555 for linolenic acid; GM 3 and RGN-282 for erucic acid were found more desirable combiners. An overall perusal the data parents GM 3, GDM 4, RH-0555 and RSK-29 appeared to be good general combiners for most of the characters. The parents mentioned above had high general combining ability and fixable component of gene action additive could be successfully exploited by developing homozygous line have used for improved character for which improvement was desired. These parental lines might be utilized for producing the intermatting population in order to get desirable recombinants in Indian mustard. In mustard Singh *et al*. (2005), Patel *et al*. (2013) and Gami and Chauhan (2013) also reported result in this fashion with different parent.

The specific combining ability effects obtained from the analysis are presented in Table 3. The results revealed that the crosses, SKM 518 x RGN-303 for early flowering; GDM 4 x RW-1-01 for early maturity; GM 3 x RGN-303 for dwarfness; SKM 518 x RGN-303 for number of branches per plant; GM 3 x RSK-29 for number of siliquae per plant and seed yield per plant; GM 3 x RGN-303 for 1000-seed weight; GM 3 x RH-0555 for harvest index; SKM 518 x RGN-303 for oil content; GM 3 x RGN-282 for oleic acid, linoleic acid and erucic acid; SKM 518 x RW-1-01 for linolenic acid were superior/best specific combiners. These findings also reported by different workers *viz.,* Vaghela *et al.* (2011), Maurya *et al.* (2012) and Gami and Chauhan (2014). These hybrids could be further evaluated to exploit the heterosis after identifying suitable hybrid seed production technology and in future breeding programme by utilizing biparental mating or recurrent selection breeding approaches to obtain desirable segregants for development of further superior genotypes for seed yield and its component traits.

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Table 1. Analysis of variance for various characters in Indian mustard

Source of variation	d.f.	Days to flowering	Days to maturity	Plant height (cm)	No. of branches per plant	No. of siliquae per plant	Seed yield per plant (g)	1000-seed weight (g)	Harvest Index (%)	Oil content (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Erucic acid (%)
Replications	2	1.66	3.13	335.60	0.40	579.59	0.02	0.10	0.39	0.03	0.01	0.01	0.08	0.01
Genotypes G)	54	108.73 **	45.07 **	630.60 **	32.73 **	12771.78 **	67.22 **	1.12 **	158.86 **	14.35 **	4.09 **	15.36 **	4.59 **	65.44 **
Parents (P)	9	187.13 **	63.35 **	968.18 **	21.27 **	11142.05 **	21.40 **	2.12 **	210.17 **	18.06 **	0.42 **	6.70 **	4.45 **	2.53 **
Hybrids (H)	44	95.00 **	40.96 **	575.62 **	35.78 **	13286.80 **	77.69 **	0.92 **	151.98 **	13.60 **	4.71 **	17.12 **	4.71 **	78.80 **
Parents *vs.* Hybrids	1	7.18 *	61.39 **	11.75	1.98	4778.63 **	18.56 *	0.91 **	0.00	13.65 **	9.61 **	13.39 **	0.86 **	43.92 **
Error	108	1.78	2.86	120.18	2.92	410.74	4.59	0.12	7.50	0.19	0.03	0.04	0.05	0.08
S. Em. ±		0.79	0.97	6.31	1.00	11.63	1.23	0.20	1.58	0.25	0.10	0.11	0.13	0.16

*, ** Significant at 5 and 1 per cent level, respectively

Table 2. Analysis of variance 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 (cm)	No. of branches per plant	No. of siliquae per plant	Seed yield per plant (g)	1000 seed weight (g)	Harvest Index (%)	Oil content (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Erucic acid (%)
GCA	9	161.37 **	60.35 **	767.35 **	14.53 **	11477.89 **	37.16 **	1.23 **	192.53 **	8.02 **	1.95 **	4.49**	2.65**	19.73**
SCA	45	11.22 **	5.96 **	98.77**	10.19**	2813.14 **	19.45 **	0.20 **	25.04 **	4.13 **	1.24 **	5.24**	1.31**	22.23**
Error	108	0.59	0.95	40.06	0.97	136.91	1.53	0.04	2.50	0.06	0.01	0.01	0.02	0.03
σ^2gca		13.40	4.95	60.61	1.13	945.08	2.97	0.10	13.40	15.84	0.66	0.16	0.37	0.37
σ^2sca		10.62	5.00	58.71	9.21	2676.22	17.93	0.16	10.62	22.54	4.07	1.23	5.23	5.23
σ^2gca/σ^2sca		1.26	0.99	1.03	0.12	0.35	0.17	0.62	1.26	0.70	0.16	0.13	0.07	0.07

*, ** Significant at 5 and 1 per cent level, respectively

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Table 3. The three top ranking parents with respect to *per se* performance and gca effects and hybrids with respect to *per se* performance and sca effects and heterosis over better parent and check variety GDM 4

Characters	Best performing parents	Best general combiners	Best performing hybrids		Hybrids with high sca effects		*sca* effects	Heterosis over	
								Better Parent	SC-GDM 4
Days to flowering	GDM 4	GDM 4	GDM 4 x SKM 815	G x G	SKM 518 x RGN-303	G x P	-6.56**	-3.70	-
	GM 3	SKM 815	GDM 4 x RW-1-02	G x G	GM 3 xRGN-282	G x P	-5.12**	-	-
	SKM 815	SKM 518	GM 3 x RSK-29	G x G	GM 3 x RSK-29	G x G	-4.65**	-3.23	-
Days to maturity	GM 3	GM 3	GM 3 x RH-0555	G x P	GDM 4 x RW-1-02	G x A	-5.61**	-4.87 **	-4.87 **
	SKM 518	SKM 518	GM 3 x RGN-303	G x P	SKM 815 x RW-1-02	A x A	-5.08**	-	-4.01**
	RSK-29	GDM 4	GM 3 x RGN-282	G x P	GM 3 x RGN-282	G x P	-4.30**	-	-4.87**
Plant height (cm)	GM 3	GM 3	SKM 904 x RW-1-02	P x A	GM 3 xRGN-303	G x P	-20.93**	-	-11.63 *
	RSK-29	GDM 4	SKM 518 x RGN-303	P x P	GDM 4 xRH-0555	G x P	-20.23**	-6.37	-6.37
	GDM 4	RSK-29	SKM 815 x RGN-282	A x P	SKM 815 x RW-1-02	A x A	-18.37**	-4.39	-3.84
No. of branches per plant	RSK-29	GDM 4	GM 3 x SKM 815	G x A	SKM 518 x RGN-303	G x P	5.24**	16.51 *	12.38
	RW-1-02	GM 3	SKM 815 x RH-0555	G x A	GM 3 x SKM 815	G x A	5.04**	32.48 **	17.52 *
	GDM 4	SKM 518	GM 3 x GDM 4	G x G	SKM 815 x RH-0555	A x A	4.86**	28.91 **	14.36 *
No. of siliquae per plant	RH-0555	RH-0555	GDM 4 x RH-0555	A x G	GM 3 x RSK-29	P x G	108.43**	4.83	31.69 **
	RSK-29	RSK-29	SKM 904 x RGN-282	G x G	GDM 4 x RH-0555	A x G	103.49**	17.14 **	52.06 **
	RW-1-02	SKM 904	SKM 904 x RGN-303	G x A	GDM 4 x SKM 518	A x P	92.59**	27.12 **	36.48 **
Seed yield per plant (g)	RH-0555	RH-0555	SKM 904 x RGN-303	G x A	GM 3 x RSK-29	P xG	9.10**	10.7	20.10 **
	RSK-29	RSK-29	GDM 4 x RGN-282	G x A	GM 3 xRW-1-02	P x P	8.17**	6.86	9.21
	SKM 904	GDM 4	GDM 4 x SKM 518	G x A	GDM 4 x RH-0555	G x G	7.55**	24.05 **	31.62 **

*, ** Significant at 5 and 1 per cent level, respectively; G = Good, A = Average, P = Poor combining parent

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Table 3. Contd.,

Characters	Best performing parents	Best general combiners	Best performing hybrids		Hybrids with high sca effects		*sca* effects	Heterosis over	
								Better Parent	SC-GDM 4
1000 seed weight (g)	GDM 4	SKM 815	GDM 4 x SKM 518	G x A	GM 3 x RGN-303	P x P	0.87**	15.08 *	-
	SKM 815	GDM 4	GDM 4 x SKM 815	G x G	GM 3 x SKM 904	P x G	0.85**	21.73 **	-
	SKM 904	SKM 904	GDM 4 x SKM 904	G x G	SKM 518 x RGN-303	A x P	0.82**	0.39	-
Harvest Index (%)	GM 3	GM 3	GM 3 x RSK-29	G x A	GM 3 x RH-0555	G x P	8.42**	4.76	35.08 **
	RSK-29	GDM 4	GM 3 x GDM 4	G x G	GDM 4 x SKM 815	G x A	8.09**	28.95 **	28.95 **
	SKM 518	SKM 518	GM 3 x RH-0555	G x P	GM 3 x RSK-29	G x A	7.23**	8.84	40.34 **
Oil content (%)	RGN-303	RGN-303	SKM 518 x RGN-303	A x G	SKM 518 x RGN-303	A x G	4.23**	5.19 **	21.16 **
	RSK-29	RSK-29	GDM 4 x RGN-303	P x G	SKM 815 x RW-1-02	A x P	2.97**	7.19 **	12.52 **
	SKM 815	SKM 518	SKM 815 x RGN-303	A x G	GM 3 x GDM 4	P x P	2.52**	3.07 **	7.60 **
Oleic acid (%)	GDM 4	GM 3	GM 3 x RGN-282	G x G	GM 3 x RGN-282	G x G	5.50**	54.63 **	50.47 **
	GM 3	RGN-282	GM 3 x RSK-29	G x P	GDM 4 x SKM 904	G x P	1.79**	13.18 **	13.15 **
	SKM 815	GDM 4	GDM 4 x SKM 904	G x P	GM 3 x RSK-29	G x P	1.66**	20.58 **	17.32 **
Linoleic acid (%)	SKM 518	SKM 518	GM 3 x RGN-282	G x G	GM 3 x RGN-282	G x G	7.44**	59.00 **	56.58 **
	RH-0555	SKM 904	SKM 518 x RH-0555	G x P	SKM 518 x RH-0555	G x P	5.85**	21.88**	53.70 **
	SKM 904	RGN-282	RW-1-02 x RSK-29	G x P	RW-1-02 x RSK-29	G x P	5.47**	47.62 **	40.08**
Linolenic acid (%)	RH-0555	SKM904	SKM 518 x RW-1-02	G x G	SKM 518 x RW-1-02	G x G	-1.78**	-16.50 **	-20.50 **
	SKM 904	RH-0555	SKM 518 x RH-0555	G x G	SKM 815 x RW-1-02	P x G	-1.36**	-17.28**	-11.46**
	RGN-282	SKM 518	RH-0555 x RSK-29	G x G	GDM 4 x SKM 815	P x P	-1.35**	-6.94**	-6.94**
Erucic acid (%)	RW-1-02	GM 3	GM 3 x RGN-282	G x G	GM 3 x RGN-282	G x G	-27.39**	-65.16 **	-65.88 **
	RGN-303	RGN-282	GM 3 x RSK-29	G x A	RW-1-02 x RSK-29	P x A	-3.92**	-6.51 **	-8.87 **
	RSK-29	RSK-29	RW-1-02 x RSK-29	P x A	SKM 518 x RH-0555	P x P	-3.85**	-6.00 **	-7.66 **

*, ** Significant at 5 and 1 per cent level, respectively; G = Good, A = Average, P = Poor combining parent