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Genetic studies of yield and quality traits in Indian mustard (*Brassica juncea* L.)

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Abstract

To study the heterosis, combining ability and components of genetic variance for seed yield and 11 quantitative, and qualitative characters in 40 F_1s of Indian mustard resulting from 10 lines and 4 testers along with standard check GM 3 were sown in a Randomized Block Design with three replications at Main Castor–Mustard Research Station, Sardarkrushinagar during *Rabi* 2012-13. Analysis of variance revealed the significant differences among genotypes for all the traits. The gca and sca variances were significant for all the traits. The $ó^2$ gca and $ó^2$ sca ratio indicated that non-additive gene action was predominant in the inheritance of all the traits except, plant height and number of siliquae per plant. The parents SKM 0518, SKM 0907 and SKM 0445 were good combiners for seed yield per plant. Besides among these parents SKM 0518 was also good general combiner for days to flowering, days to maturity, number of siliquae per plant, oleic acid, erucic acid and glucosinolate content. The estimates of sca effects indicated that the cross combinations SKM 0820 x GDM 4 (15.5) followed by SKM 0715 x SKM 0445 (13.5) and SKM 0907 x SKM 0445 (12.5) were significant for seed yield per plant. The cross SKM 0820 x GDM 4 registered high *per se* performance, standard heterosis and sca effects for seed yield per plant. Considering mean performance, heterosis and combining ability effects, parents SKM 0518, SKM 1013, SKM 0445 and SKM 0904 and hybrids SKM 0820 x GDM 4, SKM 0907 x SKM 0445 and SKM 0715 x SKM 0445 were found promising for the development of high yielding genotypes. The results revealed that breeding approaches like biparental mating followed by recurrent selection, diallel and line x tester selective mating design etc., are suggested to identify desirable transgressive segregants for further improvement of these traits.

Keywords: *Brassica juncea*, GCA, *heterosis*, SCA

Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is an important *Rabi* oilseeds crop. India is one of the major mustard growing countries of the world. In India, mustard was cultivated in 5.89 million hectares of area with total production of 6.60 million tonnes and productivity of 1121 kg/ha (Anonymous, 2012). In Gujarat, it occupies about 2.10 lakh hectares with the production of 3.30 lakh tonnes and productivity is 1571 kg/ha (DOA 2011-12).

Genetic variability for seed yield and yield attributing traits are studied but for quality traits the information is limited. For any crop improvement programme, analysis of genetic diversity is the first and foremost step. The Indian mustard varieties contain very high Erucic acid (> 50%) in oil and Glucosinolate (> 20 µmoles/g) in oil meal. The excessive intake of high erucic acid is health hazardous to human being. Thus, there is urgent need to make concerted effort for breeding varieties with level of total saturated fatty acid with less than four per cent and erucic acid less than two per cent. Recently, more emphasis is being given on heterosis breeding (Shull 1908). Exploitation of hybrid vigour has been recognized as an important tool for genetic improvement of yield and may serve as a major fruitful technique to break existing yield barriers.

Materials and Methods

The experimental material comprised of ten females viz. SKM 0904, SKM 0907, SKM 0518, SKM 0715, SKM 0815, SKM 0812, SKM 0817, SKM 0820, SKM 1013 and SKM 1024 and four male parents *viz*. GM 3, Kranti, GDM 4 and SKM 0445 were crossed (*Rabi* 2011-12) and thus resultant 40 hybrids used for line x tester were analysed. A set of 54 genotypes including GM 3 used as a check were sown in a Randomized Block Design with three replications during *Rabi* 2012-13 at Main Castor–Mustard Research Station, S.D. Agricultural University, Sardarkrushinagar, Dantiwada, Banaskantha, Gujarat, India. The soil of the experiment site was neutral in reaction, low in organic carbon, high in available Phosphorus and high in available potassium. Each genotype was sown in one row of 5 m length with inter and intra row distance were 45 cm and 15 cm, respectively. All the recommended agronomic practices and plant protection measures were adopted for raising a good crop.

The observations viz. plant height (cm), number of branches per plant, number of siliquae per plant, seed yield per plant (g), 1000 seed weight (g), oil content (%) and fatty acids composition % (Oleic acid, Lenoleic acid, Erucic acid); and glucosinolate content (µmole/g seed meal), were recorded on randomly selected five plants of each genotype in each replication except days to flowering and days to maturity, which were recorded on plot basis. Fatty acids composition of each sample was estimated in percentage by using Fourier Transferable Near Infrared (FT-NIR) Technique (Tiwari *et al.,* 1974). The replication wise mean values of each genotype for various traits were subjected to statistical analysis as per the procedure of Randomized Block Design as suggested by Panse and Sukhatme (1978). Analysis for heterosis and line x tester analysis were followed as under combining ability effects.

Results and Discussion

Results of ANOVA for experimental design revealed highly significant values for genotypes, parents, hybrids, and parents vs. hybrids indicating sufficient genetic variability in the material for all the characters under study. Comparison of mean squares due to parents vs. hybrids were found highly significant for all the characters under study except number of siliquae per plant, 1000-seed weight and number of branches per plant, indicating that mean of hybrids were significantly differ from that of the parents as a group for these traits by suggesting the presence of mean heterosis for all these characters (table 1).

The analysis of variance for combining ability revealed that the mean squares due to females were significant for days to flowering, days to maturity, 1000-seed weight, plant height and number of siliquae per plant. This indicated significant contribution of females towards gca variance component for these traits (table 2). Similar result was reported by Nassimi *et al.* (2006), Sagwal and Rana (2010), found that early maturity and flowering are desirable characters for short winter season. The mean square due to male were greater than those due to female for number of branches per plant, seed yield per plant, protein content, linoleic acid and erucic acid which is indicating large diversity among the male than in female for this characters. The line x tester interaction was significant for all the characters except plant height and 1000-seed weight. Indicating non additive genetic effects have important role for controlling these traits. The variance due to sca was higher than that of due to gca for all the characters except plant height and number of siliquae per plant. This indicated the role of non-additive gene action in the inheritance of these traits. Similar, results were concluded by Makwana and Patel (2010).

The ratio of $ó^2$ gca / $ó^2$ sca being less than unity for all the traits, except number of siliquae per plant and plant height, this suggested greater role of non-additive genetic variance in the inheritance of these traits. Whereas, number of siliquae per plant and plant height were found greater than unity which indicates role of additive component of variance in the inheritance of these traits. Similar results were recorded by Solanki *et al.* (2009).

The mean values showed that the parent SKM 0812 recorded the maximum number of siliquae per plant with, early flowering, early maturity, 1000-seed

Table 1: Analysis of variance for parents and hybrids for seed yield and its component 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)
Replication		2	29.21	3.83	2.48	2.20	50.49	5.96*
Parents		13	31.27*	33.12**	108.74	81.19**	2731.86**	81.61**
1	Female	9	38.85**	38.48**	104.01	62.57**	3234.55**	66.95**
2	Male	3	4.09	5.67	31.43	141.75**	1581.17*	95.89**
3	Female Vs. male	1	44.69	67.20**	383.20*	67.12**	1659.66	170.68**
4	Parents Vs. hybrid	1	873.13**	780.37**	644.30**	0.47	31.54	355.18**
5	Hybrids	39	58.75**	52.46**	154.23**	82.37**	3910.47**	198.58**
Error		106	14.37	7.65	77.07	4.10	532.55	1.58

* P d" 0.05, ** P d" 0.01

Source of variation		d.f	1000 -seed weight (g)	Oil content (%)	Lenoleic acid (%)	Oleic acid (%)	Gluco- sinolate (µm/g)	Erucic acid (%)
Replication	2	0.003	0.19	0.28	0.053	5.03	3.67	
Parents	13	0.39	4.29**	3.43**	27.55**	135.50**	38.94**	
1	Female	0.44	0.44	4.37**	3.88**	30.15**	184.77**	42.94**
2	Male	0.17	0.17	5.35**	2.07**	20.36**	10.14**	28.56**
3	Female Vs. male	1	0.67	0.30	3.60**	25.78**	68.27**	34.17**
4	Parents Vs. hybrid	1	0.14	16.60**	36.49**	2.98*	605.92**	27.85**
5	Hybrids	39	0.73**	9.94**	3.43**	12.88**	173.51**	22.19**
Error	106	0.36	0.36	0.23	0.47	1.84	1.49	

* P= 0.05, ** P= 0.01

Table 2: Analysis of variance for combining ability, estimates of components of variance and their ratio for various characters in Indian mustard

Source of variance	D. f.	Days to flowering	Days to maturity	Plant Height	No. of branches per Plant	No. of siliquae per plant	Seed yield per plant (g)
Replication	2	20.47	8.56	7.27	4.78	235.14	1.49
Crosses	39	58.75**	52.46**	154.23**	82.38**	3910.47**	198.58**
Females (line)	9	151.78**	128.88**	389.98**	44.28	13100.82**	161.12
Males (tester)	3	40.72	51.19	22.46	99.20	2165.76	258.21
Females × Males	27	29.75**	27.13**	90.30	93.20**	1040.87*	204.45**
Error	78	14.93	8.12	66.08	4.11	542.69	1.71
COMPONENTS OF VARIANCES							
$ó^2$ Females		11.45 **	10.11 **	26.08 **	3.35	1047.36***	13.30
$ó^2$Males		0.88	1.45	-1.82	3.17	54.44	8.55
$ó^2_{gca}$		3.90 **	3.92 **	6.15**	3.22	338.13**	9.91
$ó^2_{sca}$		5.13 **	6.50 **	4.41	29.70**	169.44 *	67.62**
$ó^2_{gca/}$ $ó^2_{sca}$		0.77	0.604	1.40	0.11	1.99	0.15

* P d” 0.05, ** P d” 0.01

Source of variance	D. f.	1000-Seed weight(g)	Oil content	Lenoleic acid	Oleic acid	Gluco-sinolate	Erucic acid
Replication	2	0.32	0.18	0.17	0.16	6.072*	2.86
Crosses	39	0.73**	9.94**	3.44**	12.88**	173.52**	22.19**
Females (line)	9	1.57*	13.87	3.08	15.32	297.80	12.12
Males (tester)	3	0.19	1.52	3.54	5.31	157.75	12.51
Females × Males	27	0.51	9.56**	3.54**	12.92**	133.84**	26.64**
Error	78	0.36	0.23	0.10	0.46	1.66	1.29
COMPONENTS OF VARIANCES							
$ó^2$ Females		0.11 *	1.14	0.25	1.24	24.67	0.89
$ó^2$ Males		-0.006	0.04	0.12	0.16	5.20	0.37
$ó^2_{gca}$		0.03 **	0.36	0.16	0.47	10.76 **	0.52
$ó^2_{sca}$		0.050	3.11**	1.15**	4.15 **	43.99**	8.39 **
$ó^2_{gca/}$ $ó^2_{sca}$		0.998	0.11	0.13	0.11		0.06

* P d” 0.05, ** P d” 0.01

weight, plant height and highest glucosinolate content, while the parent SKM 0815 had the highest seed yield per plant, linoleic acid content, oil and protein content. SKM 0445 recorded the highest erucic acid and oleic acid content. The mean values of cross combinations SKM 0907 x SKM 0445; SKM 1013 x SKM 0445 and SKM 715 x SKM 0445 registered the highest seed yield per plant.

An overall appraisal of general combining ability effects of parents revealed that none of the parents was found to be a good general combiner for all the characters (table 3). However, the parents SKM 0907, SKM 1013, SKM 0445, GM 3 and SKM 518 were good combiners for seed yield per plant. Among these parents SKM 518 was also good general combiners for one or more of its component traits *i.e.*, days to flowering, days to maturity, number of siliquae per plant, oleic acid, erucic acid and glucosinolate. Another parent SKM 0445, having good gene for number of siliquae per plant, number of branches per plant, and increasing protein, and linoleic content. Parent SKM 0907 was found good for number of siliquae per plant and 1000-seed weight. Thus these three parental lines were found promising for their exploitation in practical plant breeding.

A perusal of data revealed that none of the hybrids had high ranking sca effects for all the characters. Fifteen crosses expressed significant and positive sca effects for seed yield per plant. The crosses had significant positive sca effects for seed yield have also been reported by Patel *et al.* (2014). Out of 15 crosses the cross SKM 0820 x GDM 4 recorded highest sca effects for seed yield per plant followed by SKM 0715 x SKM 0445 and SKM 0907 x SKM 0445. The hybrid SKM 0907 x SKM 0445 also expressed significant sca effects for days to maturity, 1000-seed weight, erucic acid and protein content. Another hybrid, SKM 0820 x GDM 4 showed significant positive sca effects for days to flowering and days to maturity. Thus, these two hybrids SKM 0820 x GDM 4 and SKM 0907 x SKM 0445 can be exploited in practical plant breeding for selection of better transgressive segregant for earliness.

The cross SKM 1013 X GM 3 registered significant sca effects for yield component, *i.e.*, siliquae per plant and the cross SKM 0817 x Kranti recorded significant and desired sca effects for 1000-seed weight. Thus, it could be concluded that hybrids showing high sca effects for seed yield also manifested high sca effects for one or more yield attributing characters reported by Bhateria *et al.* (1995).

The cross SKM 0815 x GDM 4, SKM 0820 x Kranti and SKM 0518 x Kranti, SKM 0812 x SKM 0445 registered significant and negative sca effects for erucic acid and glucosinolate respectively. While cross combination SKM 1013 x GDM 4 manifested significant and positive sca effects for oleic acid and cross SKM 0904 x SKM 0445 showed significant and positive sca effects for lenoleic acid. (table 3).The similar findings high oleic acid and low erucic acid in some segregants were also reported in Indian mustard by Bhatt *et al.* (2008). Thus, these six crosses can be advanced in further improvement through selection and selfing generation after generation for quality traits.

An examination of data in table 3 revealed that the hybrids possessed high sca effects were irrespective of gca effects of the parents involved. A combination of good general combiners was not necessarily for best cross combinations or poor x poor hybrids always poor combinations. This indicated that involvements of non-additive gene effects along with interallelic interaction in sca effect. Better performance of hybrids having poor x poor or average x poor general combiners indicated dominance x dominance, epistasis type of gene action. This suggested that intra-allelic interactions were also important for controlling these traits. The crosses showing high sca effects involving one good general combiner, indicated additive x dominance type intra-allelic interaction, which could produce desirable transgressive segregants in subsequent generations. Thus, the ideal crosses would be the one which have good *per se* performance, high heterobeltiosis and standard heterosis, having at least one good general combiner parent along with high degree of sca effects for better performance of a hybrid in mustard crop. The crosses exhibited high sca effect for yield per plant

Table 3.Top three ranking parent 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 standard check (GM-3) in Indian mustard

Characters	Best performing parent (*per se* per-forming)	Best combiners	Best performing hybrids (*per se* performing)	Status of parents	Hybrids with high sca effects	GCA of the parents	Sca effects	Heterosis (%) over Better parent	Heterosis (%) over Standard check
Days to	SKM 0907	SKM 0904	SKM 0518 x KRANTI	G x A	SKM 0820 x GDM 4	P x A	-4.90**	18.8*	9.6
flowering	SKM 0812	SKM 0518	SKM 1024 x GM 3	G x A	SKM 1024 x GM 3	G x A	-2.70	3.0	-15.0**
	SKM 1024	SKM 1024	SKM 1013 x GDM 4	A×A	SKM 1013 x GDM 4	A x A	-3.48	-3.6	-5.2**
Days to	SKM 0518	SKM 0904	SKM 1013 x KRANTI	GxG	SKM 0907 x SKM 0445	A x A	-3.54**	2.1	-6.1**
maturity	SKM 0812	SKM 1013	SKM 1024 x KRANTI	GxG	SKM 0817 x GDM 4	A x P	-5.39**	-0.6	-6.1**
	SKM 1024	SKM 1024	SKM 1024 x GM 3	G x A	SKM 0820 x GDM 4	P x P	-5.89**	5.0*	-1.1
Plant	SKM 0518	SKM 1013	SKM 0820 x SKM 0445	AxG	SKM 0715 x KRANTI	A x A	-9.02	-4.1	-8.9**
height (cm)	SKM 0812	SKM 0820	SKM1024 x GM 3	G x A	SKM 0820 x SKM 0445	A x A	-7.19	-10.7**	-10.7**
	SKM 1024	SKM 1024	SKM 1024 x GDM 4	G x A	SKM 0907 x GM 3	A x A	-7.92	-3.3	-8.6**
No. of	SKM 0904	SKM 0907	SKM 1024 x GM 3	A×G	SKM 1024 x GM 3	A x G	9.85**	84.6**	25.6**
branches	KRANTI	SKM 0715	SKM 0812 x SKM 0445	A×G	SKM 0715 x KRANTI	G x A	7.74**	10.9	25.2**
per plant	GDM 4	*SKM 0445*	SKM 0907 x GDM 4	G x P	SKM 0904 x SKM 0445	P x G	8.37**	14.5	16.0**
No. of	SKM 0904	SKM 0518	SKM 0715 x SKM 0445	GxG	SKM 1013 x GM 3	G x P	41.33**	17.4**	15.3**
siliquae	SKM 0815	SKM 0820	SKM 0518 x GDM 4	G×P	SKM 1024 x KRANTI	A x P	28.10**	-10.2	-15.1
per plant	SKM 0812	SKM 1013	SKM 1013 x SKM 0445	GxG	SKM 1013 x SKM 0445	GxG	25.29	16.0**	13.9**
1000 seed	SKM 0812	SKM 0904	SKM 0904 x GM 3	A x G	SKM 0817 x KRANTI	A x P	0.70*	12.7	0.6
weight	SKM 0820	SKM 0907	SKM 0907 x SKM 0445	GxG	SKM 0907 x SKM 0445	GxG	0.61	13.3	6.2
	GM 3	SKM 0815	SKM 0715 x KRANTI	P x P	SKM 0715 x KRANTI	P x P	0.49	10.3	-3.4
Seed yield	SKM 0815	SKM 0907	SKM 0907 x SKM 0445	GxG	SKM 0820 x GDM 4	G x A	15.49**	29.3**	29.8**
per plant (g)	KRANTI	SKM 0518	SKM 1013 x SKM 0445	GxG	SKM 0715 x SKM 0445	P x G	13.53**	74.5**	32.4**
	GM 3	SKM 0445	SKM 0715 x SKM 0445	P x G	SKM 0907 x SKM 0445	GxG	12.45**	84.4**	63.6**
Lenoleic	SKM 0904	SKM 0815	SKM 0907 x GM 3	P x G	SKM 1013 x SKM 0445	P x G	1.62**	12.3**	35.7**
acid	SKM 0815	SKM 0817	SKM 0518 x GM 3	P x G	SKM 1024 x GDM 4	A x P	1.50**	22.1**	30.8**
	SKM 1013	SKM 0820	SKM 0817 x GM 3	GxG	SKM 1013 x GM 3	P x G	1.36**	8.4**	31.0**
Oleic acid	SKM 0817	SKM 0715	SKM 1013 x GDM4	A x P	SKM 1013 x GDM 4	A x P	4.44**	17.6**	19.0**
	SKM 0445	SKM 0518	SKM 0518 x KRANTI	GxG	SKM 0817 x SKM 0445	G x A	2.40**	-16.8**	13.0**
	KRANTI	KRANTI	SKM 0715 x SKM 0445	G x A	SKM 0812 x GM 3	G x P	2.31**	-9.5**	10.8**
Oil (%)	SKM 0907	SKM 0812	SKM 0817 x KRANTI	G x A	SKM 1013 x SKM 0445	P x A	3.51**	3.6**	7.4**
	SKM 0715	SKM 0815	SKM 0817 x GM 3	GxG	SKM 1024 x GDM 4	P x P	2.48**	0.4	7.4**
	GDM 4	SKM 0817	SKM 0815 x SKM 0445	G x A	SKM 0812 x GDM 4	G x P	2.33**	6.0**	13.4**
Erucic	SKM 0907	*SKM 0904*	SKM 0820 x KRANTI	G ×A	SKM 0815 x GDM 4	A × P	-6.52**	-9.2**	-12.2**
acid	SKM 0045	*SKM 0518*	SKM 0815 x GDM 4	A × P	SKM 0820 x KRANTI	G × A	-5.14**	-14.0**	-12.5**
	GM 3	*SKM 0820*	SKM 0904 x SKM 0445	G×G	SKM 0907 x SKM 0445	A × A	-3.89**	8.0**	-9.3**
Glucosino	SKM 0815	*SKM 0904*	SKM 0904 x GDM 4	G×G	SKM 0904 x GDM 4	G×G	-5.66**	-6.2**	-5.9**
Late	SKM 0812	*SKM 0715*	SKM 0518 x KRANTI	G × P	SKM 0518 x KRANTI	P × P	-11.40**	-5.0**	-1.9
	SKM 1024	*SKM 0817*	SKM 0817 x SKM 0445	G×G	SKM 0907 x KRANTI	P×G	-9.44**	8.0**	11.5**

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

also exhibited high or average sca effect for yield contributing characters. Considering these aspects, out of 40 crosses SKM 0907 x SKM 0445, SKM 0715 x SKM 0445 and SKM 0820 x GDM 4 were identified as promising for obtaining higher seed yield per plant.

The data for seed yield per plant revealed that twenty one and twelve hybrids manifested significant positive relative heterosis and heterobeltiosis, respectively, while, eleven hybrids showed significant positive heterosis over standard check. For this trait, high relative heterosis and heterobeltiosis expressed by the hybrids SKM 0907 x SKM 0445 and SKM 0715 x SKM 0445, respectively. These hybrids are useful for exploitation of heterosis in development of high yielding with super inbred lines (R lines) of mustard. They also possessed high heterosis for many yield attributing characters in desirable direction. The expression of heterosis for seed yield arises from the combinations of favorable yield components. *Per se* performance, heterosis and combining ability effects, the parents SKM 0518, SKM 1013, SKM 0445 and SKM 0904 and the hybrids SKM 0820 x GDM 4, SKM 0907 x SKM 0445 and SKM 0715 x SKM 0445 were found to be promising for the development of high yielding genotypes.

Conclusion

For most of quantitative and qualitative traits non-additive type of gene action was observed. The predominance of non-additive gene action can be exploited in hybrid development in mustard if stable restorer is available. On the basis of overall findings, hybrid, SKM 0907 x SKM 0445 has been identified as promising. This hybrid registered first in *per se* performance with third position in positive sca effects for seed yield. It can be further suggested that, the initial selection of parents can be done on the basis of *per se* performance and gca effects and then, biparental mating with reciprocal recurrent selection should be employed, so that non-additive gene action could be exploited for further improvement of the traits in Indian mustard.

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