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Analysis of Yield and Its Components Based on Heterosis and Combining Ability in Indian Mustard (*Brassica juncea* L. Czern & Coss.)

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ABSTRACT

A study of diallel analysis excluding reciprocal crossesof ten parents were carried out to identify high heterotic crosses and their relationship in terms of general (GCA) and specific combining ability (SCA) in Indian mustard. The genotypes for study have been taken on the basis of their differences in plant height, number of branches per plant, number of siliquae per plant, days to flowering, days to maturity, seed yield per plant, harvest index, test weight, oil content and fatty acid composition. ANOVA study of GCA and SCA variances for all the characters were significant. The ratio of GCA and SCA variances were below unity for all the characters, except days to flowering and plant height, which indicates that all the traits inherited with dominant effects except these two characters. The parents GM 3, GDM 4, RH 0555 and RSK 29 were good general combiners for seed yield and its component characters. For quality components, parents RGN 303 and RSK 29 were found to be good general combiners for oil content. Similarly, GM 3 and RGN 282 for oleic acid, SKM 518 and SKM 904 for linoleic acid, SKM 904 and RH 0555 for linolenic acid and GM 3 and RGN 282 for erucic acid were found good general combiners. On the basis of per se performance, heterosis and combining ability effects for seed yield per plant and its components, parents GM 3, GDM 4 and SKM 904 and the hybrids SKM 904 x RGN-303, GDM 4 x RGN-282 and GDM 4 x SKM 518 were identified superior hybrids for their large scale testing.

Key words: *Heterosis, Combining ability, Gene action and Indian mustard*

INTRODUCTION

India is one of the major mustard growing country in the world cultivating 6.36million ha Indian mustard with total production of 8.03million tones and productivity of 1262 kg/ha.In Gujarat,it occupies about 0.21 million ha with the production of 0.34 milliontones and productivity is 1619 kg/ha[1].Indian mustard (*Brassica juncea*) is a naturally autogamous species, yet in this crop frequent out-crossing occurs which varies from 5 to 18% depending upon the environmental conditions and random variation of pollinating insects.

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Cytologically Indian mustard is an amphidiploid (2n=36), derived from interspecific cross of *Brassica campestris* (2n=20) and *Brassica nigra* (2n=16) followed by natural chromosome doubling. The improved mustard seeds contain 38-46% oil. For International acceptance, erucic acid content should be below 2%.

Seed quality, seed yield and other yield related parameters of *Brassica* oil seed crop has been tried to improve by several researchers[10]. Many authors applied different strategies for improving seed yield and quality attributes of *Brassica*[5]. For the study of inheritance of quantitative characters and evaluation of various possible breeding procedures in heterosis phenomena, the comprehensive study of combining ability is immensely essential. Evaluation of breeding material for general and specific combining ability as well as the extent of heterosis for seed yield and yield components are prerequisites in any breeding programme aimed for development of hybrids. Therefore, the present investigation was carried out with an aimed to study heterosis and combining ability for yield and its components in Indian mustard.

MATERIALS AND METHODS

There are ten morphologically diverse genotypes*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 were comprised for present study. All the 55 treatments were grown in Randomized Complete Block Design with three replications at Agronomy Instructional Farm, S. D. Agricultural University, Sardarkrushinagar (Gujarat) during *Rabi* 2013-2014. The parents and F_1s were grown in single row of two-meter length with spaced between two lines 45 cm apart. The distance of 15 cm between the plants within row was maintained by thinning.Thirteen observations were recorded both as visual assessment [days to flowering and days to maturity] on plot basis and measurement [plant height (cm), number of branches per plant, number of siliquae per plant, seed yield per plant (g), 1000 seed weight (g), harvest index (%) and five quality traits *viz.*, oil content (%), oleic acid (%), linoleic acid (%), linolenic acid (%) and erucic acid (%)] on randomly selected five competitive individual plants.All the recommended agronomic practices and plant protection measures were adopted for raising the healthycrop. 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[13]. The combining ability analysis was done by the procedure suggested by Griffing's[7]. The hybrid performance (%) tested in comparison with mean value of two parents (Relative heterosis/RH), better parent (heterobeltiosis/BPH) and standard check (Standard heterosis/SH) as per the formulae suggested by Briggle[3], Fonseca and Patterson[4] and Meredith and Bridge[9], respectively.

RESULTS AND DISCUSSION

The analysis of variance for thirteen characters revealed highlysignificant differences amongst all the parents, the F_1's and parent's *vs* F_1's for all the characters except plant height, number of branches per plant and harvest index indicated sufficient variability among the material utilised under study which were in accordance with Vaghela *et al*[14]., Patel *et al*[11]., and Arifullah *et al*[2].

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 is referred to as standard heterosis. The heterosis was estimated for all the cross combinations over the economic parent GDM 4. The maximum negative and significant heterosis was observed in GM 3 x RH 0555 for days to maturity; GM 3 x RGN 303 for plant height; SKM 518 x RW 1-02 for linolenic acid and GM 3 x RGN 282 for erucic acid; while the maximum and positive heterosis was observed in GM 3 x SKM 815 for number of branches per plant; GDM 4 x RH 0555 for number of siliquae per plant and seed yield per plant; GM 3 x RSK 29 for harvest index; SKM 518 x RGN 303 for oil content; GM 3 x RGN 282 for oleic acid and linoleic acid (Table 3).

The analysis of variance for combing ability (Table 2) indicated that variance due to general combining ability (gca) and specific combining ability (sca) were highly significant for all the characters, this indicates that the importance of additive as well as non-additive gene action in the inheritance of traits studiedwhich in agreement with the results of Vaghela*et al*[14]. The variance due to sca is higher than the gca for the characters *viz.*, days to maturity, number of branches per plant, number of siliquae per plant, test weight, seed yield per plant, oil contet, oleic acid, linoleic acid and erucic acid indicated that role of non-additive gene action in inheritance of these traits. On the other hand, the estimates gca variance is higher than sca variance for days to flowering, harvest index and plant heightindicated that role of additive gene actionin the expression of these characters.

The gca and sca variance ratio was less than unity for all the characters except days to flowering, plant height and harvest index. This indicated that non-additive component played more role in inheritance of the characters. These results are akin with those of Rao and Gulati[12].

The promising combiners based on *per se* performances and significant gca effects (Table 3) were GDM 4 and SKM 815 for days to flowering; GM 3 and SKM 518 for days to maturity; GM 3 and GDM 4 for dwarf planttype,harvest index and number of branches per plant; RH 0555 and RSK 29 for number of siliquae per plant and seed yield per plant; GDM 4 and SKM 815 for test weight; RGN 303 and RSK 29 for oil content; GM 3 and RGN 282 for oleic acid; SKM 518 and SKM 904 for linoleic acid; SKM 904 and RH 0555 for linoleic acid; GM 3 and RGN282 for erucic acid were found more desirable combiners. These findings were correspondence to those of Patel *et al*[11]., and Gami *et al*[6].

The parents GM 3, GDM 4, RH 0555 and RSK 29appeared to be good general combiner for most of the characters discussed above had high general combining ability and fixable component of gene action additive and additive x additive type of epistasis, these 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 intermating population in order to get desirable recombinants in Indian mustard.

Analysis of specific combining ability is important parameter for judging the specific combinations for exploiting it through heterosis breeding programme. The good specific cross combinations are selected based on their sca effects (Table 3). A perusal of the table the data of SCAeffects revealed that the cross combinations *viz*.,, SKM 518 x RGN 303 for early flowering, for number of branches per plant, oil contentand test weight; GDM 4 x RW 1-02 for early maturity; GM 3 x RGN 303 for dwarfness and for test weight;GM 3 x RSK 29 for number of siliquae per plantand for seed yield per plant; GM 3 x RH 0555 for harvest index; GM 3 x RGN 282 for oleic acid, linoleic acid anderucic acid; SKM 518 x RW 1-02 for linolenic acid were found best specific cross combinations. Similar findings were also reported by Vaghela *et al*[14]., and Maurya *et al*[8].

From the above discussion, it can be concluded that the parents GM 3, GDM 4 and SKM 904 (donor to get high yield) may further be used for future under different breeding programmesand crosses SKM 904 x RGN303, GDM 4 x RGN 282 and GDM 4 x SKM 518 were identified as superior hybrids due to high SCA effect and high heterosis for seed yield and its related traits. Thus, large scales testing of these crosses wereneeded to develop strain/s with high and stable seed yield in Indian mustard.

Table 1: Analysis of variance for parents and hybrids 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)
Replications	2	1.66	3.13	335.60	0.40	579.59	0.02	0.10
Genotypes (G)	54	108.73 **	45.07 **	630.60 **	32.73 **	12771.78 **	67.22 **	1.12 **
Parents (P)	9	187.13 **	63.35 **	968.18 **	21.27 **	11142.05 **	21.40 **	2.12 **
Hybrids (H)	44	95.00 **	40.96 **	575.62 **	35.78 **	13286.80 **	77.69 **	0.92 **
Parent *vs.*Hybrids	1	7.18 *	61.39 **	11.75	1.98	4778.63 **	18.56 *	0.91 **
Error	108	1.78	2.86	120.18	2.92	410.74	4.59	0.12
S. Em. ±		0.79	0.97	6.31	1.00	11.63	1.23	0.20

Source of variation	d.f.	Harvest Index (%)	Oil content (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Erucic acid (%)
Replications	2	0.39	0.03	0.01	0.01	0.08	0.01
Genotypes (G)	54	158.86 **	14.35 **	4.09 **	15.36 **	4.59 **	65.44 **
Parents (P)	9	210.17 **	18.06 **	0.42 **	6.70 **	4.45 **	2.53 **
Hybrids (H)	44	151.98 **	13.60 **	4.71 **	17.12 **	4.71 **	78.80 **
Parent *vs.*Hybrids	1	0.00	13.65 **	9.61 **	13.39 **	0.86 **	43.92 **
Error	108	7.50	0.19	0.03	0.04	0.05	0.08
S. Em. ±		1.58	0.25	0.10	0.11	0.13	0.16

*** 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 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)
GCA	9	161.37 **	60.35 **	767.35 **	14.53 **	11477.89 **	37.16 **	1.23 **
SCA	45	11.22 **	5.96 **	98.77**	10.19**	2813.14 **	19.45 **	0.20 **
Error	108	0.59	0.95	40.06	0.97	136.91	1.53	0.04
σ^2gca		13.40	4.95	60.61	1.13	945.08	2.97	0.10
σ^2sca		10.62	5.00	58.71	9.21	2676.22	17.93	0.16
σ^2gca/σ^2sca		1.26	0.99	1.03	0.12	0.35	0.17	0.62

Source of variation	d.f.	Harvest Index (%)	Oil content (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Erucic acid (%)
GCA	9	192.53 **	8.02 **	1.95 **	4.49**	2.65**	19.73**
SCA	45	25.04 **	4.13 **	1.24 **	5.24**	1.31**	22.23**
Error	108	2.50	0.06	0.01	0.01	0.02	0.03
σ^2gca		13.40	15.84	0.66	0.16	0.37	0.22
σ^2sca		10.62	22.54	4.07	1.23	5.23	1.29
σ^2gca/σ^2sca		1.26	0.70	0.16	0.13	0.07	0.17

*** P ≤ 0.05, ** P ≤ 0.01.**

Table 3 : The three top ranking parents with respect to *per se* performance and gca effects; the three top ranking 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	SKM 518 x RGN-303	-6.56**	-3.70	-
	GM 3	SKM 815	GDM 4 x RW-1-02	GM 3 x RGN-282	-5.12**	-	-
	SKM 815	SKM 518	GM 3 x RSK-29	GM 3 x RSK-29	-4.65**	-3.23	-
Days to maturity	GM 3	GM 3	GM 3 x RH-0555	GDM 4 x RW-1-02	-5.61**	-4.87 **	-4.87 **
	SKM 518	SKM 518	GM 3 x RGN-303	SKM 815 x RW-1-02	-5.08**	-	-4.01**
	RSK-29	GDM 4	GM 3 x RGN-282	GM 3 x RGN-282	-4.30**	-	-4.87**
Plant height (cm)	GM 3	GM 3	SKM 904 x RW-1-02	GM 3 x RGN-303	-20.93**	-	-11.63 *
	RSK-29	GDM 4	SKM 518 x RGN-303	GDM 4 x RH-0555	-20.23**	-6.37	-6.37
	GDM 4	RSK-29	SKM 815 x RGN-282	SKM 815 x RW-1-02	-18.37**	-4.39	-3.84
No. of branches per plant	RSK-29	GDM 4	GM 3 x SKM 815	SKM 518 x RGN-303	5.24**	16.51 *	12.38
	RW-1-02	GM 3	SKM 815 x RH-0555	GM 3 x SKM 815	5.04**	32.48 **	17.52 *
	GDM 4	SKM 518	GM 3 x GDM 4	SKM 815 x RH-0555	4.86**	28.91 **	14.36 *
No. of siliquae per plant	RH-0555	RH-0555	GDM 4 x RH-0555	GM 3 x RSK-29	108.43**	4.83	31.69 **
	RSK-29	RSK-29	SKM 904 x RGN-282	GDM 4 x RH-0555	103.49**	17.14 **	52.06 **
	RW-1-02	SKM 904	SKM 904 x RGN-303	GDM 4 x SKM 518	92.59**	27.12 **	36.48 **
Seed yield per plant (g)	RH-0555	RH-0555	SKM 904 x RGN-303	GM 3 x RSK-29	9.10**	10.7	20.10 **
	RSK-29	RSK-29	GDM 4 x RGN-282	GM 3 x RW-1-02	8.17**	6.86	9.21
	SKM 904	GDM 4	GDM 4 x SKM 518	GDM 4 x RH-0555	7.55**	24.05 **	31.62 **

Table 3.Continue....

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	GM 3 x RGN-303	0.87**	15.08 *	-
	SKM 815	GDM 4	GDM 4 x SKM 815	GM 3 x SKM 904	0.85**	21.73 **	-
	SKM 904	SKM 904	GDM 4 x SKM 904	SKM 518 x RGN-303	0.82**	0.39	-
Harvest Index (%)	GM 3	GM 3	GM 3 x RSK-29	GM 3 x RH-0555	8.42**	4.76	35.08 **
	RSK-29	GDM 4	GM 3 x GDM 4	GDM 4 x SKM 815	8.09**	28.95 **	28.95 **
	SKM 518	SKM 518	GM 3 x RH-0555	GM 3 x RSK-29	7.23**	8.84	40.34 **
Oil content (%)	RGN-303	RGN-303	SKM 518 x RGN-303	SKM 518 x RGN-303	4.23**	5.19 **	21.16 **
	RSK-29	RSK-29	GDM 4 x RGN-303	SKM 815 x RW-1-02	2.97**	7.19 **	12.52 **
	SKM 815	SKM 518	SKM 815 x RGN-303	GM 3 x GDM 4	2.52**	3.07 **	7.60 **
Oleic acid (%)	GDM 4	GM 3	GM 3 x RGN-282	GM 3 x RGN-282	5.50**	54.63 **	50.47 **
	GM 3	RGN-282	GM 3 x RSK-29	GDM 4 x SKM 904	1.79**	13.18 **	13.15 **
	SKM 815	GDM 4	GDM 4 x SKM 904	GM 3 x RSK-29	1.66**	20.58 **	17.32 **
Linoleic acid (%)	SKM 518	SKM 518	GM 3 x RGN-282	GM 3 x RGN-282	7.44**	59.00 **	56.58 **
	RH-0555	SKM 904	SKM 518 x RH-0555	SKM 518 x RH-0555	5.85**	21.88**	53.70 **
	SKM 904	RGN-282	RW-1-02 x RSK-29	RW-1-02 x RSK-29	5.47**	47.62 **	40.08**
Linolenic acid (%)	RH-0555	SKM904	SKM 518 x RW-1-02	SKM 518 x RW-1-02	-1.78**	-16.50 **	-20.50 **
	SKM 904	RH-0555	SKM 518 x RH-0555	SKM 815 x RW-1-02	-1.36**	-17.28**	-11.46**
	RGN-282	SKM 518	RH-0555 x RSK-29	GDM 4 x SKM 815	-1.35**	-6.94**	-6.94**
Erucic acid (%)	RW-1-02	GM 3	GM 3 x RGN-282	GM 3 x RGN-282	-27.39**	-65.16 **	-65.88 **
	RGN-303	RGN-282	GM 3 x RSK-29	RW-1-02 x RSK-29	-3.92**	-6.51 **	-8.87 **
	RSK-29	RSK-29	RW-1-02 x RSK-29	SKM 518 x RH-0555	-3.85**	-6.00 **	-7.66 **

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

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