Indian J. Genet., **65**(4): 302-304 (2005)

Short Communication

Genetic divergence and combining ability in relation to heterosis in Indian mustard [*Brassica juncea* (L.) Czern. and Coss.] for seed yield, its attributes and oil yield

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(Received: December 2004; Revised: November 2005; Accepted: November 2005)

Information on the nature and degree of divergence is helpful in selecting the desirable parents for a breeding programme, since it is known that exploitation of heterosis and success in obtaining desirable recombinants is dependent on the degree of divergence of the parents [1]. Various reports were also accumulated that high heterosis is manifested in F_1 hybrids whose parent possess high × low general combining ability (*gca*) effects [2]. Thus, the present investigation on genetic divergence and combining ability in relation to heterosis in Indian mustard [*Brassica juncea* (L.) Czern. and Coss.] for seed yield, its attributes and oil yield was taken up to give a clear-cut picture of whether the divergence studies through Mahalanobis' D^2 statistics [3] are in agreement with the results of the analysis through diallel mating design by Griffing [4].

Experiment I: The experimental materials consisted of 19 all India released strains/varieties of Indian mustard and a local cultivar 'Local Yella'. They were grown during *rabi* season of 1999-2000 in a randomised complete block design with 3 replications. Each genotype was raised in a plot of 6 m^2 size with a spacing of 30 cm × 15 cm. Recommended cultural practices and plant protection measures with a fertiliser dose of 40: 30: 30 Kg NPK/ha were followed to raise a good crop under irrigated conditions. Observations were recorded on a random sample of 10 plants from each plot on seed yield and its contributing characters including plant height (cm), primary branches/plant, siliquae/plant, seeds/siliqua, 100 seed weight (g), seed yield/plant (g) and oil content (%). For days to 50% flowering and days to maturity, data were recorded on plot basis. Statistical parameters of genetic divergence were computed using Mahalanobis' D^2 statistics. Grouping of genotypes into various clusters were carried out following the method suggested by Tocher [3].

Experiment II: Based on estimates of genetic divergence from the above study, 7 diverse genotypes were selected and crossed in a diallel mating design excluding the reciprocals. The 21 F_1s and 7 parents were grown during *rabi* season of 2000-2001. The experimental design, plot size, spacing and agronomic practices followed were the same as adopted in experiment I. Data were recorded on nine different characters *viz.* plant height (cm), days to 50 percent flowering, days to maturity, primary branches/plant, siliquae/plant, seeds/siliqua, 100-seed weight (g), seed yield/plant (g) and oil content (%). The data were subjected to combining ability analysis through Griffing's Method 2, Model I [4].

Analysis of diversity: Analysis of variance showed highly significant difference for all the characters studied indicating a wide range of genetic diversity in the material, Following Tocher's method, nineteen varieties were grouped into six clusters. The grouping pattern of the genotypes indicates that the clusters were heterogenous with regard to the geographical origin of genotypes included in the study. Genotypes from different geographic regions were pooled in the same cluster. That the genetic diversity is not related to geographical distribution has also been previously reported [5]. Maximum number of genotypes was included in cluster III with 9 genotypes and cluster IV, V and VI with one genotype each, respectively. Intra cluster distance ranged from 0 to 61866.14, the maximum being in cluster III. The highest inter cluster distance was observed between cluster II and V (4399426.77) and lowest between cluster I and II (128212.71). The contribution of siliquae/plant was maximum (33.33 %) for total genetic divergence followed by days to maturity (26.25 %) and plant height (17.32%).

Analysis of combining ability: The analysis of variance for combining ability revealed general combining ability (*gca*) and specific combining ability (*sca*) variances were highly significant for all the characters studied. Similar findings were reported in Indian mustard [6].

Table 1. Combining ability effects, clusters and heterosis over superior parents in Indian mustard

S. No.	Characters	Heterotic combination over S.P.	Cluster	*gca* effects	*sca* effects	Heterotic percent over S.P.
1	Plant height (cm)	TM-4 × NPJ-100	II & V	L × H	–5.16	–14.24
		TM-4 × Vardan	II & I	L × L	–8.10	–13.62
		Pusa bold × Vardan	III & I	A × L	–8.38	–11.39
		Varuna × Local yella	IV & II	H × L	–5.10	–11.00
		Pusa bold × Local yella	III & I	A × L	–3.15	–11.00
2	Days to 50 percent flowering	Pusa bold × Vardan	III & I	H × L	–4.43	–17.21
		Vardan × Local yella	I & II	H × L	–2.14	–14.74
		TM-4 × Vardan	II & I	L × L	0.10	–14.54
		Vardan × Pusa bold	I & III	A × H	–3.03	–12.62
		Varuna × Vardan	IV & I	A × L	–2.41	–12.24
3	Days to maturity	TM-4 × Vardan	II & I	L × L	–4.61	–13.79
		Kranti × Vardan	III & I	A × L	–5.96	–12.89
		NPJ-100 × Vardan	V & I	A × L	–3.22	–11.67
		Vardan × Local yella	I & II	L × L	–1.38	–11.53
		TM-4 × Pusa bold	II & III	L × H	–1.39	–10.79
4	Primary branches/plant	TM-4 × Local yella	II & II	L × L	0.99	28.47
		Vardan × Local yella	I & II	L × L	1.45	24.62
		TM-4 × Pusa bold	II & III	L × L	0.98	23.65
		Pusa bold × Local yella	III & II	L × L	0.53	16.22
		TM-4 × Pusa bold	II & III	L × L	1.03	1.23
5	Siliquae/plant	Varuna × Pusa bold	IV & III	L × L	67.53	172.15
		NPJ-100 × Vardan	V & I	L × H	44.16	160.75
		Pusa bold × Vardan	III & I	L × H	45.26	159.68
		NPJ-100 × Local yella	V & II	L × L	56.56	152.64
		Vardan × Local yella	I & II	H × L	36.03	149.63
6	Seeds/siliqua	Kranti × Varuna	III & IV	L × L	0.75	–0.69
		Varuna × Local yella	VI & II	L × H	0.66	–2.73
		NPJ-100 × Local yella	V & II	A × H	–0.02	–4.38
		TM-4 × NPJ-100	II & V	H × A	0.58	–4.62
		Kranti × Pusa bold	III & III	L × L	–0.09	–5.75
7	100-seed weight (g)	NPJ-100 × Vardan	V & I	L × H	0.09	100.00
		TM-4 × Vardan	II & I	L × H	0.07	89.96
		Varuna × TM-4	IV & II	H × L	0.20	70.58
		Varuna × Vardan	IV & I	H × H	0.10	58.82
		Varuna × NPJ-100	IV & V	H × L	0.14	55.88
8	Seed yield/plant (g)	Varuna × NPJ-100	IV & V	A × L	4.98	142.71
		Vardan × Local yella	I & II	A × L	4.18	131.73
		NPJ-100 × Vardan	V & I	L × A	2.19	119.73
		Varuna × Vardan	IV & I	A × A	2.29	105.12
		Varuna × Pusa bold	IV & III	A × L	2.71	90.18
9	Oil content (%)	NPJ-100 × Local yella	V & II	A × L	–0.15	20.91
		Pusa bold × Local yella	III & II	A × L	2.15	5.15
		Varuna × Pusa bold	IV & III	H × A	1.78	3.76
		Varuna × NPJ-100	IV & V	H × A	0.99	1.79
		TM-4 × Pusa bold	II & III	L × A	0.58	1.38

The relative magnitude of variances due to *gca* and *sca* suggested that most of the characters exhibited additive type of gene action. From the ratio of $\sigma^2 g/\sigma^2 s$, it can be concluded that most of the characters except plant height were controlled by non-additive gene action suggesting the scope of exploiting heterosis breeding. This is made possible through the reported discovery of cytoplasmic male sterility [7] and the method of exploitation when no pollen fertility restorer genes are available [8] in Indian mustard.

The study of *gca* effects indicated that parents Local Yella, TM-4 and Vardan possess the highest *gca* effects for days to 50 per cent flowering and days to maturity; Kranti, Varuna and NPJ-100 for primary branches/plant; TM-4, Vardan and Kranti for siliquae/plant, Local Yella and TM-4 for seeds/siliqua, Varuna, Vardan and Kranti for 100-seed weight; Varuna, TM-4 and Kranti for seed yield/plant and Varuna, Kranti and NPJ-100 for oil content. The parents such as Varuna, TM-4 and Vardan were found to be good combiner for seed yield/plant and may yield transgressive segregants in F_2 populations.

The *sca* effects obtained in the present study revealed that good general combiners, Varuna, TM-4, NPJ-100 and Vardan yield crosses with high *sca* effects in combination with other parents for plant height, days to maturity, siliquae/plant, 100-seed weight, seed yield/plant and oil content. The good general combiners generally possess high additive effects and poor combiners are often associated with non-additive gene effects. Thus, it can be inferred that high *sca* effects of crosses involving H × L combiner might have resulted due to the interaction of additive vs. non-additive components and that of L × L combiner might be due to non-additive type of gene actions [8]. In case of H × H crosses there was possibility of complementary epistatic effect acting in the direction of additive effects of good combiner and H × L may be due to dominant × recessive interaction expected to produce desirable segregates which were in agreement with Gupta *et al.* [1]. It may not always be necessary to attempt crosses between H × H *gca* parents. Crosses with low or average *gca* parents can also manifest high *sca* in suitable cross combinations and attributable to interaction effects [2].

Hybrids between lines of diverse origin generally display a greater heterosis than those between closely related parents, but maximum heterosis generally occurs at an optimal or intermediate level of diversity. Further crosses involving one high/average and another low general combiner displayed high *sca* effects thereby producing more heterotic effects in Indian mustard [5].

In the present study, it was observed that the crosses combination TM-4 × Vardan which belongs to cluster II and I respectively with D value of 116.76 ranked first among all the heterotic combinations and with medium to low inter-cluster distances displayed higher heterosis in all the characters studied as presented in Table 1. This confirmed the reports of Thakur and Zarger [5], On the other hand, medium genetically divergent parents ultimately gave high F_1 combinations. The cross combinations which exhibit high heterosis and high *sca* effects were found in cross TM-4 × Local Yella for siliquae/plant, Varuna × TM-4 for 100-seed weight, Varuna × NPJ-100 for seed yield/plant and Pusa Bold × Local Yella for oil content.

The relationship between genetic divergence and combining ability of the parents were found to be such that for most of the characters, parents with low *gca* effect along with medium genetic divergence gave high heterotic cross combinations. Medium genetic divergence combined with low or average *gca* effect in the parents gave high sea effects, which corresponded with high heterotic performance. Similar findings were reported by [1 & 5]. Thus, it can be concluded that there should be an optimum level of genetic divergence to obtain economic heterosis in F_1.

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