Diallel Analysis for Yield and Yield Component Traits in Toria (*Brassica rapa* L.)

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Combining ability and reciprocal effects were estimated for yield and its components along with protein and oil content from a study of 8 x 8 full diallel set. Genotypes being open-pollinated and self-incompatible were bud pollinated to get the parental seed before inclusion into diallel mating. Significant *sca* variances exhibited their importance for all the traits except for oil content, while the *gca* variance were non-significant for, for plant height, siliqua length and oil content and significant for rest of the characters. However, preponderance of non-additive gene action was observed for all the traits as reflected by the ratio of *gca* and *sca* variances. Reciprocal variances were greater than both the *gca* and *sca* variances for plant height, number of primary branches/plant, siliquae on main shoot, siliquae length and seeds/siliquae indicating importance of maternal effects for the expression of these traits. The maternal effect, reflected in most of the crosses involved good general combiner as female parent. Genotypes PT-30, PT-9701, PT-9600 and PT-9700 were good general combiners for seed yield and yield contributing characters along with high *per se* performances. The high performing crosses for seed yield involved parents with high x high, high x low, low x low and low x high *gca* effects.

Key Words: Toria, Yield components, Diallel analysis, Combining ability, *Brassica rapa*

Introduction

Toria (*Brassica rapa* L. var. *toria*) is an important oilseed crop grown as a catch crop in between *kharif* and *rabi* season in northern and eastern part of the country. Increase in production through development of high yielding varieties necessitates selection of transgressive segregants segregating generation (F_2) of crosses. The nature and magnitude of combining ability help in identifying elite parents and desirable cross combinations. The information on additive and non-additive gene effects associated with yield and its component characters play important role in deciding the breeding strategies. In toria, information on gene action and relationship between combining ability effects and *per se* performance of parents and crosses is scanty and contradictory (Yadav and Yadava, 1996; Kumar *et al*., 1997). The present study was therefore, undertaken to understand the nature of gene action for different yield contributing characters following combining ability analysis for 8 diverse genotypes of toria.

Materials and Methods

A set of 8 × 8 full diallel crosses was obtained using eight toria genotypes, *viz.*, PT-9600, MSP-9212, PT-9700, PT-9701, PT-9719, PT-507, PT-30 and T-9. The 56 F_1s (including reciprocals) along with their parents were grown in a Randomized Block Design with two replications, in single row of 5 m length. The planting distances between and within the row were 30 cm and 10 cm, respectively. A single non-experimental row was grown all around the experimental area in each replication to neutralize border effect.

Observations were recorded on a sample of five randomly selected plants for 12 out of 16 characters studied, whereas, days to flowering and maturity recorded on plot basis and protein and oil contents estimated on random sample of seeds. Protein content was estimated by micro-kjeldahl method as per Jackson (1967), multiplying percentage ‘N’ by 6.25. Oil content was estimated using nuclear magnetic resonance (NMR) technique. The data was analysed with Model II and Method 1 of Griffing (1956) and estimates of *gca*, *sca*, reciprocal effects and gene action were obtained. The relative significance of additive versus non-additive gene effects was assessed by the ratio $\left(\frac{Mg - M'e}{2n}\right) \Big/ (Ms - M'e)$ as described by Singh and Chaudhary (1996).

Results and Discussion

Analysis of variance for combining ability revealed that variances due to general combining ability (*gca*), specific combining ability (*sca*) and reciprocal effects were highly significant for all characters except oil content, while for

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Table 1. Analysis of variance for *gca*, *sca* and reciprocal effects

Source of variation	Degree of freedom	Mean sum of squares								
		Days of flower Intiation	Days to maturity	Plant height (cm)	Length of main shoot (cm)	No. of primary branches	No. of secondary branches	No. of siliquae on main shoot	No. of siliquae per plant	Siliqua length (cm)
General combining ability *(gca)*	7	2.813**	2.294*	27.834	94.738**	1.837**	15.037**	36.206**	5503.75**	0.119
Specific combining ability *(sca)*	28	3.090**	4.919**	86.708**	40.788**	0.777**	12.369**	27.252**	2932.487**	0.122**
Reciprocal effect	28	2.494**	2.522**	93.949**	43.943**	1.947**	14.408**	43.025**	3294.58**	0.191**
Error	126	0.577	1.106	24.766	11.066	0.401	0.801	4.893	168.910	0.064
$\left(\frac{Mg - M'e}{2n}\right) \Big/ (Ms - M'e)$		0.06	0.19	0.004	0.18	0.24	0.08	0.09	0.12	0.06

Table 1. Contd.

Source of variation	Degree of freedom	Mean sum of squares						
		No. of seeds per siliqua	1000-seed weight (gm)	Seed yield per plant (gm)	Biological yield per plant (gm)	Harvest index	Oil content (%)	Protein content (%)
General combining ability (*gca*)	7	2.865**	0.1393**	35.845**	521.943**	12.531**	0.177	3.243**
Specific combining ability (*sca*)	28	2.660**	0.0687**	22.377**	430.349**	24.311**	0.277	5.027**
Reciprocal effect	28	3.337**	0.079**	22.507**	365.981**	19.807**	0.255	4.677**
Error	126	0.546	0.011	0.9219	12.465	0.008	0.233	0.366
$\left(\frac{Mg - M'e}{2n}\right) \Big/ (Ms - M'e)$		0.07	0.14	0.10	0.08	0.03	0.07	0.03

plant height and siliquae length *gca* variance were found to be non-significant (Table 1). This indicates existence of genetic variability in experimental material. Significance of *gca*, *sca* and reciprocal effects have also been reported by Rawat (1992) and Yadava *et al*. (1974). Wang and Qiu (1990) suggested significance of *gca*, and *sca* variances for protein content. Significance of both *gca* and *sca* variances indicated importance of both additive and dominance gene action in the expression of the characters. The results are in accordance with Rishipal and Singh (1980) for rapeseed and Gupta and Sharma (1999) for Indian mustard. However, the ratio of non-additive/additive variance showed that the non-additive type of gene effects were more important than the additive type in the expression of different characters. None of the lines was found to be good general combiner for all the characters. PT-30 was found as the best general combiner with highest *gca* effects for length of main shoot (4.39) followed by PT-9719 (2.48), number of secondary branches (2.02) followed by PT-9719 (0.08ns), siliquae on main shoot (2.06), followed by PT-507 (1.27), siliquae per plant (28.87) followed by PT-9700 (19.91), 1000-seed weight (0.14), followed by MSP-9212 (0.12), seed yield (2.78) followed by PT-9701 (1.85) and biological yield per plant (9.68) followed by PT-9701 (7.31). PT-9600 was good general combiner for days to flower initiation (-0.84), maturity (-0.63) and harvest index (1.35). PT-9700 was good general combiner for number of siliquae per plant and PT-9701 for seed yield per plant and biological yield per plant, PT-9719 for length of main shoot, number of siliquae per plant and PT-507 for number of siliquae on main shoot were found to be good general combiner (Table 2). These parents can be used in crossing programme for improving seed yield, its contributing characters and evolving early genotypes to suit particular crop rotation because of high general combining ability effects, additive effects and additive × additive epitasis. Singh and Lallu (2004) also reported similar results in Indian mustard. Alternatively desirable parents can be put into a central gene pool through multiple crossing to generate useful segregates as suggested by Jenson (1970). Presence of significant reciprocal effects suggested the scope for choosing the parents either as female or male to exploit the heterotic effect of the cross to its maximum potential.

The order of ranking of toria genotypes was unpredictable as mean value did not correlate with *gca* effects for all the characters and all the genotypes. Higher

Table 2. Correspondence of best parent, best general combiner, best specific cross combination and best reciprocal cross combination

S.No.	Character	Best parent (mean value)	Best general combiner	Best specific cross combination	Best reciprocal cross combination
1.	Days to flower initiation	PT-9600 (33.3)	PT-9600 (-0.84**)	PT-9600 × T-9 (-1.99**)	PT-30 × PT9700 (-2.17**)
2.	Days to maturity	PT-9719 (92.3)	PT-9600 (-0.63**)	PT-9600 × PT-50 (-2.59**)	PT-30 × PT9700 (-3.00**)
3.	Plant height (cm)	PT-9719 (103.7)	PT-9600 (-2.15ns)	PT-9600 × PT-30 (-12.65**)	PT-30 × PT-507 (-19.51**)
4.	Length of main shoot (cm)	MSP-9212 (68.7)	PT-30 (4.39**)	PT-9700 × PT-9719 (8.43**)	PT-507 × PT-9701 (10.03**)
5.	Number of primary branches	T-9 (8.4)	PT-9700 (0.58**)	MSP-9212 × PT-9700 (0.88*)	T-9 × MSP-9212 (2.23**)
6.	Number of secondary branches	T-9 (16.3)	PT-30 (2.02**)	PT-9701 × PT-9719 (4.18**)	T-9 × MSP-9212 (5.38**)
7.	Siliquae on main shoot	PT-9600 (42.4)	PT-30 (2.06**)	PT-507 × PT-30 (8.43**)	T-9 × MSP-9212 (9.11**)
8.	Siliquae per plant	T-9 (229.7)	PT-30 (28.87**)	PT-9719 × T-9 (79.79**)	T-9 × MSP-9212 (88.57**)
9.	Siliquae length (cm)	PT-9719 (6.3)	MSP-9212 (0.12ns)	PT-9701× PT-507 (0.51**)	PT-507 × PT-9719 (0.49**)
10.	Seeds per siliqua	MSP-9212 (22.6)	PT-9719 (0.59**)	PT-9719 × PT-30 (2.81**)	PT-507 × MSP-9212m (2.66**)
11.	1000-seed weight (g)	PT-30 (3.05)	PT-30 (0.14**)	PT-9700 × T-9 (0.28**)	PT-507 × PT-9700 (0.96**)
12.	Seed yield per plant (g)	PT-9600 (10.8)	PT-30 (2.78**)	PT-9701× PT-9719 (5.66**)	PT-9700 × MSP-9212 (8.21**)
13.	Biological yield per plant (g)	PT-9700 (85.8)	PT-30 (9.68**)	PT-9701 × PT-9719 (25.08**)	T-9 × PT-30 (31.84**)
14.	Harvest index	PT-9701 (47.4)	PT-9600 (1.35**)	PT-9600 × T-9 (6.44**)	T-9 × PT-9701 (8.34**)
15.	Oil content (%)	PT-507 (43.8)	PT-9700 (0.13ns)	MSP-9212 × PT-30 (0.65*)	PT-30 × MSP-9212 (0.94**)
16.	Protein content (%)	PT-30 (42.9)	PT-507 (0.64**)	PT-9701 × T-9 (1.81**)	PT-30 × PT-9600 (3.76**)

sca effects were not necessarily associated with higher mean value in F_1 for most of the characteristics except for number of primary branches and 1000-seed weight. In most of the crosses where reciprocal effects were higher, it was observed that parents of these crosses had high mean values but they could not be able to set high *sca* effects, when crossed. This suggested that it is important to select parent as male or female in toria breeding programme for higher expression of heterotic effects in F_1s. Also it is important that when the character mean is desirable, still due weightage needs to be given to *gca/sca* scored in F_1, depending upon the objective, and nature of the crop.

A critical perusal of top five crosses with desirable *sca* effects and top five crosses with highest reciprocal effects for seed yield per plant (Table 3) indicated high × high, high × low and low × low combinations with respect to parental *gca* effects. Crosses PT-9701 × PT-9719 (high × low *gca*) and MSP-9212 × PT-30 (low × high *gca*) exhibited high seed yield per plant coupled with desirable *sca* effect for number of siliquae per plant and seeds per siliquae, respectively. Result suggested the presence of non-additive allelic interactions. The present study suggested that recurrent selection for *sca* could be followed in the segregation of such crosses as this type of relation was proposed on the assumption (Sharma *et al.*, 2002) that an important part of heterosis results from non-linear interaction of genes at different loci, from interaction between alleles at the same locus or from both causes in combination as also suggested by Sharma *et al.* (2002). It was found that *sca* of yield may be influenced by the *sca* of yield components; therefore, combining ability of the parents may serve as a reliable guide in assessing the yield potential of a cross. For the cross PT-9700 × PT-9719, significant *sca* effects were the reflection of low × low *gca* effects of parents, suggesting a non-additive type of gene action. The cross PT-9700 × MSP-9212, with highest reciprocal effect for seed yield (8.21) also included both the parents with low *gca* effect (-0.15ns and -0.40ns, respectively).

Crosses involving high × low and low × low general combiners in the present study are of considerable interest with reference to the possibilities of producing good transgressive segregates if additive effects of one parent and complementary effects of other parent act in same direction to maximize the expression of the character under study as suggested by Khulbe *et al*. (1998). Therefore, it is not necessary that parents having higher *gca* effects would also provide higher *sca* effects. On the basis of combining ability effects, the selection of parents can be done for hybridization. Like-wise, crosses can also be selected for handling of segregating generations with

Table 3. Top five crosses for *sca* and reciprocal effects for seed yield

Cross	F_1 mean	*sca* effect	Cross	RF_1 mean	Reciprocal effect
PT-9701 × PT-9719	7.56	5.67**	PT-9701 × MSP-9212	10.38	8.12**
PT-9701 × PT-30	13.30	4.94**	T-9 × PT-30	11.95	5.39**
MSP-9212 × PT-507	23.29	4.94**	T-9 × PT-9719	8.43	5.19**
PT-9700 × PT-9719	14.19	3.70**	T-9 × MSP-9212	15.49	5.14**
MSP-9212 × PT-30	16.55	3.68**	T-9 × PT-9701	8.79	4.17**

an aim to obtain transgressive segregates for commercial exploitation of heterosis as suggested by Gupta and Sharma (1999). An overall view of the results suggested that genetically diverse parents with good *per se* performance and general combining ability should be selected for breeding programmes aimed at improvement for yield and other characters in toria.

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