The Pharma Innovation Journal 2022; 11(5): 393-398

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(5): 393-398

www.thepharmajournal.com
Received: 04-02-2022
Accepted: 14-04-2022

Vivek Singh
Research Scholar, School of Agriculture, Forestry and Fisheries, Himgiri Zee University, Dehradun, Uttarakhand, India

Sharad Pandey
Dean, School of Agriculture, Forestry and Fisheries, Himgiri Zee University, Dehradun, Uttarakhand, India

Gideon Synrem
Assistant Professor, School of Agriculture, Forestry and Fisheries, Himgiri Zee University, Dehradun, Uttarakhand, India

Corresponding Author:
Vivek Singh
Research Scholar, School of Agriculture, Forestry and Fisheries, Himgiri Zee University, Dehradun, Uttarakhand, India

Line x Tester analysis for seed yield and its components in Toria (*Brassica campestris* L. var. Toria)

Vivek Singh, Sharad Pandey and Gideon Synrem

Abstract
Combining ability of fifteen quantitative traits was studied in 7 lines, 3 testers and 21 F1 's in Line x Tester mating design to know the inheritance pattern of yield attributes of *Brassica campestris* L. var. toria. The analysis of variance revealed the treatments were highly significant for all the traits under study except for the character siliqua length. Amongst the parents, PT-303 was a good general combiner for seed yield and other contributing characters. The hybrids PT-303 x Uttara, Tapeswari x Uttara and PHT-1 x Uttara showed high better parent heterosis and high *per se* performance for seed yield. The hybrid Bhawani x G-14 showed high positive significant sca effect for seed yield, biological yield, siliqua length and length of main raceme. The hybrid SDS-22 x Uttara also showed high positive significant sca effect for seed yield, siliqua length and length of main raceme. Based on the estimates of components of variances for all the traits studied, it reveal that sca variance was higher than gca variance, indicating the preponderance of non-additive gene action which includes dominance and epistasis where hetrosis breeding would be helpful in utilizing maximum proportion of fixable genetic variation for future crop improvement.

Keywords: General combining ability, L x T, Toria, heterosis

Introduction

Oilseed Brassicas, commonly grouped as rapeseed-mustard, have a considerable role in agriculture and economy of the country. Almost all part of the plant is useful and has it utility either for human beings or animals. At the national level, it is the second important oilseed crop contributing upto 27% of the total edible oil obtained from various oilseeds across the country (Singh *et al.*, 2013) [21]. Rapeseed-mustard crops in India comprises of species like toria (*Brassica campestris* L. var. toria), yellow sarson (*B. campestris* L. var. yellow sarson) brown sarson (*B. campestris* L. brown sarson), black mustard (*B. nigra*), Indian mustard (*B. juncea* L. Czernj and cosson), and taramira (*Eruca sativa/vesicara* Mill.). Amongst these, few traditionally grown species was cultivated way back as 3,500 BC. Although Indian mustard is the most widely cultivated form in the Indian subcontinent, toria crop has gained its own importance, due to short duration, fitment in crop rotation and its oil quality.

Toria (*B.campestris*) is a short duration crop and finds its fitment under various cropping systems. It is grown as a catch crop in north Indian states, in between two agricultural seasons of monsoon (*Kharif*) and winter (*Rabi*). The crop is grown in early *rabi* season in India and adjoining country like Bangladesh. (Rahman, 2011) [14] In north-eastern parts of India, it is cultivated as main season crop. Toria has the potential to elevate farmer's income by increasing cropping intensity, provided suitable cultivars are available with desired traits. Early maturity along with enhanced yield and yield contributing characters, adoptive to local conditions are the major breeding objectives.

There exist wide yield gaps when productivity of India is compared with western countries (Yadava *et al.*, 2012) [26]. Increasing and stabilizing the production and productivity of toria crop is much needed. This can be done by proper use of germplasm resources and combination of various genetic tools to develop efficient recombinants. (Banga, 2012) [2]. Exploitation of Heterosis and its commercial utilization plays an important role in increasing the production and productivity of toria crop; hence, heterosis breeding can be one of the most technically feasible way for breaking various yield barrier. A detailed analysis of the combining ability among parents and crosses, the mechanism of inheritance of quantitative traits and the phenomenon of heterosis is necessary for further evaluation of various breeding procedures (Allard, 1960) [1]. Combining ability analysis is a tool to judge the potential of parental lines for producing superior hybrids and desirable recombinants (Singh *et al.*, 2013) [21].

Further, to develop better genotypes by means of hybridization, the choice of appropriate parents is of great importance. Considering these aspects, the present investigation was taken up to have an in depth view on both the general combining ability of the parents as well as specific combining ability of the crosses. Results from Better parent heterosis of different cross will help in identifying better combinations in *B. campestries* L. var. Toria.

Materials and Methods

The study was conducted at Agriculture Research Farm, Himgiri Zee University, Dehradun during two consecutive years 2019-2020 (Crossing Blocks) and in 2020-2021 (Evaluation of parents and hybrids). The experimental material comprised of 21 hybrids (F_1) of Toria (*Brassica campestris* L. var. toria) involving 10 parents, 8 out of which were released/notified high yielding varieties and 2 local collections that were utilized as lines and testers. The parental genotypes (with 7 Lines and 3 Testers) were crossed following line×tester fashion, producing 21 F_1 hybrids. The 7 lines used as female were SDS-22, PT-303, Tapeswari, PT-508, PT-30, Bhawani and PHT-1. Uttara, PT-507, G-14 were used as Tester. (Table 1). These parents along with the F_1's were planted with 3 replications in randomized block design during *rabi* 2020–2021. Each treatments was sown in plots of 3 rows, each of 3 m length. The row to row distance of 45 cm and plant to plant spacing of 15 cm was maintained by thinning. Recommended package of practice was followed to raise the crop. The applied fertilizers were as per recommendation, i.e. 60:30:30:40 kg/ha of N:P:K:S, respectively. The field was irrigated thrice which includes pre-sowing irrigation. Data was taken on five randomly selected plants from every plot, for fifteen characters *viz.*, seed yield/plant (g), plant height (cm), days to 50% flowering, number of primary branches, number of secondary branches, length of main raceme (cm), siliqua on main raceme, siliqua per plant, siliqua length (cm), number of seeds per siliqua, biological yield, harvest index, days to maturity, oil content (%) and 1000-seed weight (g). The approach to study combining ability analysis was as per the procedure of Kempthorne (1957) [9] and better parent heterosis (heterobeltiosis) was calculated using WINDOSTAT version 9.2 provided by INDOSTAT Services, Hyderabad, India.

Results and Discussion

The analysis of variance (Table 2) revealed the treatments were highly significant for all the traits under study except for the character siliqua length. The mean sum of squares dues to lines showed significant differences except for the characters siliqua length, seeds per silique, thousand seed weight and oil content. The mean sum of square due to testers were significant for plant height, primary branches per plant, secondary branches per plant, siliqua on main raceme, siliqua/plant, biological yield, harvest index and seed yield/plant. Interaction effect for lines and testers was found to be significant for primary branches/plant, secondary branches/plant, length of main raceme, siliqua/plant, biological yield, harvest index and seed yield/plant. The mean sqares due to females were greater than those due to male for all the traits except plant height and seeds/siliqua indicating large diversity among the females than in males for these characters. The lower magnitude of variance in LxT interaction suggest greater uniformity among the crosses than among the parent varieties. The results were supported by the findings of Chaudhary *et al.* (1997) [4], Meena *et al.* (2013) [10], Sharma *et al.* (2008) [17] and Rameeh (2019).

The variance components of general combing ability (gca) and specific combining ability (sca) were significant for most of the character. Components of variance (Table 3) revealed that the sca variance was higher than gca variance for all the fifteen characters, except for siliqua on main raceme. The variance ratio obtained by equating gca and sca, ranged from 0.07 in siliqua length to 0.5 in percent oil content. This was less than unity for all the characters under study. The results indicates the preponderance of non-additive gene action which includes dominance and epistasis. Under such results, heterosis breeding would be helpful in utilizing maximum proportion of fixable genetic variation comprising of additive and additive x additive epitasis as well as non-additive genetic component consisting of dominance, additive x dominance and dominance x dominance may give better results while conducting crop improvement. The above results were well supported by the findings of Meena *et al.* 2015 [11], and Rameeh (2019).

Results of general combining ability (Table 4 and 5) revealed the female parent PT-303 exhibited significant general combining ability for Seed yield per plant (3.24**), this indicates the presence of additive gene action or additive x additive gene interaction effects. when general combining effects are significant, additive or additive x additive gene effects are responsible for the inheritance of that particular trait. Similar results were reported by Spragme (1966) and Meena *et al*. (2015) [11]. The parent PT-303 also showed positive significant general combining ability for number of silique per plant (37.90**), biological yield (25.95**), harvest index (4.71**), number of seeds/silique (1.93**), days to 50% flowering (1.19*), number of primary branches/plant (0.90**), number of secondary branches/plant (0.79**) and silique length (0.30**). Parent PT-303 showed significant negative gca value (-1.75) resembling presence of desired trait of early maturity. The above identified female parent could be selected as a suitable parent for hybridization as it revealed good general combining ability for most of the important yield contributing characters in future breeding program. In the testers, G-14 had significant GCA effects in positive directon for seed yield (1.07**) and other yield contributing characters like harvest index (1.50**), siliqua/plant (19.76**), siliqua on main raceme (4.02**), length of main raceme (1.49**) and biological yield (14.273**). Verma *et al.* (2000) [25], Singh *et al.* (2005) [19], Singh *et al.* (2013) [21], Synrem *et al.* (2015) [22] and Rahman *et al.* (2011) [14] reported similar results while working with different material. The results from the present investigation clearly suggest that there exist scope for improving combining ability of parents for yield contributing trait, since good combiner, for the trait seed yield were not good for other yield-contributing traits, hence focus should be at improving the combining ability of yield contributing traits which will contribute to the GCA for seed yield directly. These parents can be used in further breeding programmes in Toria for accumulating favorable alleles, including yield and its contributing characters in a single genetic background.

The results of specific combining ability (Table-6) for seed yield per plant revealed the hybrids SDS-22 x Uttara (3.26**), PT-303 x PT-507 (2.06**), PT-30 x PT-507 (2.37**), Bhawani x G-14 (4.41**), PHT-1 x PT-507 (3.11**) showed positive significant specific combining ability effects for seed yield per plant. The experimental findings were well supported by Yadava *et al.* (1992), Chaudhary *et al.* (1997) [4], Shiekh and Singh (1998), Verma *et al.* (2000) [25], Lalta *et al* (2002**),** Monalisha *et al.* (2005) [12] and Chauhan *et al.* (2017) [5]. The hybrids PT-508 x G-14 (1.36**), PHT-1 x Uttara (0.98*), PHT-1 x PT-507 (1.84**) showed positive significant specific combining ability effects for oil content. Hybrids SDS-22 x PT-507(-2.62**), PT-303 x Uttara (-4.19**), Tapeswari x Uttara (-3.19**), PT-30 x G-14 (-4.19**), PHT-1 x G-14 (-1.86*) showed desirable negative significant specific combining ability effects for days to 50% flowering. The breeding for early flowering is important in crop improvement for the trait early flowering. The experimental results were well supported by findings of Meena *et al.* (2015) [11] for early flowering. The hybrids PT-303 x PT-507 (-1.96*), Tapeswari x Uttara (-2.54**), Bhawani x G-14 (-4.16**) showed desirable negative significant, specific combining ability effects for days to maturity. Similar results were obtained by Yadava *et al.* (2012) [26], Tomar *et al.* (2018) [23], Chaurasia *et al.* (2018) [6], and Singh *et al.* (2010) [20].

Highly significant and positive sca effects were observed for seed yield in 5 hybrids, 1000 seed weight in 2 hybrids, oil content in 3 hybrids, number of siliqua on main raceme in 5 hybrids, number of seeds/siliqua in 2 hybrids, siliqua length in 4 hybrids and number of primary branches in 5 hybrids, silliqua/plant in 5 hybrids, harvest index in 5 hybrids. Similarly, negative significant sca values were obtained in 5 hybrids for the traits plant height, days to 50% flowering, and days to maturity. The cross Tapeswari x Uttara showed significant negative values for both days to 50% flowering (-3.19**) and Days to maturity (-2.54**) indicating presence of a combination of required trait of early maturity.

The information regarding six best performing parents as best performing hybrids along with their percent heterosis over mid parent as well as better parent and with highly significant sca effects and higher *per se* performance for seed yield per plant is presented in Table 7. The promising hybrids PT-303 x Uttara (36.34**), PT-303 x PT-507 (21.97**), Tapeswari x Uttara (26.59**), PT-508 x Uttara (22.33**) and PHT-1 x Uttara (22.89*) possessed positive significant relative heterosis (Ha) and heterobeltiosis (Hb) for seed yield per plant. Yadava *et al.* (2012) [26] reported 54.38% heterobeltosis and Vaghela *et al.* (2011) reported 44.8% heterobeltosis with highly significant sca effects and higher *per se* performances.

These results were supported by similar findings of Gupta *et al.* (1999), Pradhan *et al.* (1993) [13], Bharti *et al.* (2018) [3], Chauhan *et al.* (2017) [5] and Rameeh, (2012) [15].

Table 1: List of Toria (*Brassica campestris* L.) parents used as lines and testers in the present study

S. No	Lines	S. No	Testers
1.	SDS-22	1.	Uttara
2.	PT-303	2.	PT-507
3.	Tapeswari	3.	G-14
4.	PT-508		
5.	PT-30		
6.	Bhawani		
7.	PHT-1		

Table 2: Analysis of variance for fifteen morphological traits in line x tester analysis in Toria (*Brassica campestris* L.)

Characters Sources of variation	D.F.	Days to 50% Flowering	Plant height (cm)	Primary branches	Secondary branches	Length of main raceme	Siliqua on main raceme	Siliqua / plant	Siliqua length	Seeds / siliqua	Days to Maturity	Biological Yield	Harvest Index	1000 seed weight	Oil content	Seed yield / plant
Replication	2	1.58	10.08	0.02	0.16	10.58	8.84	870.03	0.02**	0.11	2.68	484.81	64.41**	0.00	8.97*	24.89 **
Treatments	30	19.57**	221.31**	2.29**	1.91**	186.73**	198.94**	11795.83**	0.33	5.51**	10.74**	11821.97**	99.96**	0.16 **	6.06**	26.71**
Parents	9	22.30**	283.29**	1.99**	1.54**	152.33**	96.03**	12330.66**	0.12*	2.12	10.13**	17447.08**	49.31**	0.08	3.35	32.88 **
Parents (Lines)	6	31.71**	157.83**	2.34**	1.45**	215.19**	128.08**	15559.32**	0.14	1.67	14.71**	20966.11**	53.80**	0.09	4.08	35.63 **
Parents (Testers)	2	4.00	793.69**	1.12 **	0.96**	17.37	47.91*	5052.8*	0.05	2.58	1.00	1653.49**	38.59**	0.08	2.83	28.15 **
Parents (LxT)	1	2.41	15.21	1.60**	3.27**	45.12*	0.00	7514.45*	0.16	3.88	0.91	27920.06**	43.80**	0.00	0.01	25.91 **
Parents vs crosses	1	16.81**	0.83	7.49**	5.36**	709.41**	782.90**	4181.26	0.05**	3.22	20.90**	1542.14**	151.84**	0.19	0.36	10.98**
Crosses	20	18.48**	204.44**	2.17**	1.91**	176.08**	216.05**	11935.89**	0.45	7.16**	10.51**	9804.66**	120.16 **	0.20 **	7.57 **	24.72 **
Line effects	6	9.61	288.80	2.00	1.52	298.19	486.70**	6574.06	0.34	10.11	8.28	4503.90	96.59	0.16	12.59	29.43
Tester effects	2	11.28	89.07	1.99	2.65	35.25	256.38	9793.28	0.14**	1.70	3.39	8337.87	48.84	0.28	6.10	19.10
LxT effects	12	24.11**	181.49**	2.28**	1.98**	138.49**	74.00**	14973.90**	0.55	6.59**	12.81**	12699.51**	143.83**	0.21 **	5.31*	23.30 **
Error	60	1.98	21.74	0.06	0.12	9.35	14.11	1306.12	0.06	2.61	1.76	186.18	5.72	0.07	2.73	1.18
Total	92	7.70	86.56	0.79	0.71	67.22	74.27	4717.19	0.15	3.50	4.71	3986.95	37.72	0.11	3.96	10.02

* = Significant at 0.5% level, ** = Significant at 0.1% level, Df = Degrees of Freedom

Table 3: Estimates of components of variance for morphological traits in Toria (*Brassica campestris* L.)

Components of variation	Characters														
	Days to 50% Flowering	**Plant height (cm)**	**Primary branches**	**Secondary branches**	**Length of main raceme**	**Siliqua on main raceme**	**Siliqua / plant**	**Siliqua length**	**Seeds / siliqua**	**Days to Maturity**	**Biological Yield**	**Harvest Index**	**1000 seed weight**	**Oil content**	**Seed yield / pant**
σ^2 Lines	0.84	29.67	0.21	0.15	32.09	52.51	585.32	0.03	0.83	0.72	479.74	10.09	0.01	1.09	3.13
σ^2 Tester	0.44	3.20	0.09	0.12	1.23	11.53	404.15	0.00	-0.04	0.07	388.17	2.05	0.01	0.16	0.85
σ^2 GCA	0.56	11.14	0.12	0.13	10.49	23.82	458.50	0.01	0.22	0.27	415.64	4.46	0.01	0.44	1.53
σ^2 SCA	7.37	53.25	0.73	0.61	43.04	19.96	4555.92	0.16	1.32	3.68	4171.11	46.03	0.04	0.85	7.37
σ^2 GCA/σ^2 SCA	0.08	0.21	0.17	0.21	0.24	1.19	0.10	0.07	0.17	0.07	0.10	0.10	0.22	0.51	0.21

Table 4: Estimates of GCA effects of line and testers for fifteen quantitative characters in Toria (*Brassica campestris* L.)

S. No.	Lines	Days to 50% Flowering	Plant Height	Primary branches	Secondary Branches	Length of main raceme	Siliqua on main raceme	Siliqua per Plant	Siliqua Length
1.	SDS-22	-1.81**	2.44	-0.03	0.03	2.81**	10.53**	-11.25	-0.11
2	PT-303	1.19*	1.54	0.90**	0.79**	-0.07	-1.58	37.90**	0.30**
3	Tapeswari	0.19	-5.35**	-0.32**	-0.27*	-5.21**	-3.57**	-9.54	0.15
4	PT-508	-0.47	5.56**	-0.47**	-0.41**	1.15	-7.77**	-18.36	-0.02
5	PT-30	1.19*	7.04**	0.27**	0.21	10.03**	10.22**	-36.16**	0.10
6	Bhawani	-0.14	-8.04**	-0.01	-0.03	-7.80**	-5.07**	4.89	-0.23**
7	PHT-1	-0.14	-3.18*	-0.34**	-0.32**	-0.90	-2.74*	32.53*	-0.18*
SE lines		0.66	2.19	0.12	0.16	1.44	1.77	17.03	0.11
CD (P=0.05)		1.34	4.44	0.24	0.33	2.91	3.57	34.43	0.23
CD (P=0.01)		1.79	5.94	0.33	0.45	3.89	4.79	46.07	0.30
8	Uttara	0.19	-2.37*	-0.33**	-0.39**	-0.65	-2.20*	-23.04**	-0.08
9	PT-507	0.61	1.10	0.27**	0.28**	-0.83	-1.82*	3.28	0.00
10	G-14	-0.81*	1.26	0.05	0.10	1.49*	4.02**	19.76*	0.07
SE tester		0.43	1.43	0.08	0.10	0.94	1.15	11.15	0.07
CD (P=0.05)		0.87	2.90	0.16	0.22	1.90	2.34	22.54	0.15
CD (P=0.01)		1.17	3.89	0.21	0.29	2.55	3.13	30.16	0.20

* = Significant at 0.5% level, ** = Significant at 0.1% level

Table 5: Estimates of GCA effects of line and testers for fifteen characters in Toria (*Brassica campestris* L.)

S.N.	Parents	Seeds/siliqua	Days to maturity	Biological yield	Harvest index	1000 seed weight	Oil content	Seed yield per plant
1.	SDS-22	0.40	-0.08	-11.00*	0.70	0.04	0.15	0.70
2	PT-303	1.93**	-1.74**	25.95**	4.71**	0.08	-0.87	3.24**
3	Tapeswari	-1.64**	0.58	-15.75**	-1.20	-0.13	1.24*	-0.99**
4	PT-508	-0.16	-0.18	37.51**	-5.13**	-0.25*	-1.99**	-0.96*
5	PT-30	-0.21	1.25**	-5.28	-0.93	0.08	0.43	-0.15
6	Bhawani	-0.23	0.58	-11.77*	-1.43	0.09	1.34*	-2.49**
7	PHT-1	-0.07	-0.41	-19.64**	3.29**	0.07	-0.31	0.66
SE lines		0.76	0.62	6.432	1.12	0.13	0.78	0.51
CD (P=0.05)		1.53	1.26	13.00	2.27	0.26	1.57	1.03
CD (P=0.01)		2.05	1.69	17.39	3.04	0.35	2.10	1.38
8	Uttara	0.15	-0.45	-22.76**	0.03	0.078	0.58	-0.31
9	PT-507	0.17	0.30	8.49**	-1.54**	0.055	-0.47	-0.75**
10	G-14	-0.32	0.15	14.27**	1.50**	-0.13*	-0.11	1.072**
SE tester		0.49	0.40	4.21	0.73	0.08	0.51	0.33
CD (P=0.05)		1.00	0.82	8.51	1.49	0.17	1.03	0.67
CD (P=0.01)		1.34	1.10	11.38	1.99	0.23	1.38	0.90

* = Significant at 0.5% level, ** = Significant at 0.1% level

Table 6: Significant positive Specific combining ability (sca) effects for fifteen yield and yield attributing characters in crosses of Toria

S.N.	Characters	Specific combining ability (sca)
1	Days to 50% Flowering	SDS-22 x PT-507(-2.62**), PT-303 x Uttara (-4.19**), Tapeswari x Uttara (-3.19**), PT-30 x G-14 (-4.19**), PHT-1 x G-14 (-1.86*)
2	Plant height	PT-508 x PT-507 (-8.92**), PT-30 x G-14(-5.69*), Bhawani x PT-507 (-8.18**), PHT-1 x G-14(-12.84**)
3	Primary branches	PT-303 x Uttara (0.37)*, PT-303 x PT-507(0.57)**, Tapeswari x G-14 (0.25*), PT-508 x G-14 (1.30**), PT-30 x PT-507 (1.05**)
4	Secondary Branches	PT-303 x PT-507 (0.60**), PT-508 x G-14 (1.25**), PT-30 x PT-507 (0.98**), Bhawani x G-14 (0.94**)
5	Length of main raceme	PT-303 x G-14 (6.08**), PT-508 x Uttara (5.17**), PT-30 x Uttara (4.52*), Bhawani x G-14 (6.97**), PHT-1 x Uttara (5.26**)
6	Siliqua on main raceme	PT-508 x Uttara (4.87*), PT-30 x PT-507 (6.69**)

7	Siliqua per Plant	PT-303 x PT-507 (55.31*), Tapeswari x Uttara (57.33**), PT-508 x G-14 (66.61**), PT-30 x PT-507 (81.42**), Bhawani x G-14 (121.81**)
8	Siliqua Length	SDS-22 x Uttara (0.39**), Tapeswari x PT-507 (0.45**), PT-30 x Uttara (0.63**), Bhawani x G-14 (0.58**)
9	Seeds/ Siliqua	PT-508 x Uttara (2.38*), Bhawani x G-14 (2.30*)
10	Days to maturity	PT-303 x PT-507 (-1.97*), Tapeswari x Uttara (-2.54**), Bhawani x G-14 (-4.16**)
11	Biological Yield	PT-303 x PT-507 (37.59**), PT-508 x G-14 (33.06**), Bhawani x G-14 (114.42**), PHT-1 x Uttara (60.72**), PHT-1 x PT-507 (47.59**)
12	Harvest Index	SDS-22 x Uttara (8.18**), PT-303 x PT-507 (7.33**), Tapeswari x Uttara (5.86**), PT-30 x PT-507 (5.29**), PHT-1 x G-14 (9.66**)
13	1000 seed wt.	Tapeswari x PT-507 (0.26**), PT-30 x G-14 (0.32*)
14	Oil content	PT-508 x G-14 (1.36**), PHT-1 x Uttara (0.98*), PHT-1 x PT-507 (1.84**)
15	Seed yield/plant	SDS-22 x Uttara (3.26**), PT-303 x PT-507 (2.06**), PT-30 x PT-507 (2.37**), Bhawani x G-14 (4.41**), PHT-1 x PT-507 (3.11**)

* = Significant at 0.5% level, ** = Significant at 0.1% level

Table 7: Mean Performance and estimates of mid parent, better parent heterosis for seed yield in Toria genotypes

Promising Crosses	Mean seed yield (g)	Mid Parent Hetrosis	Better Parent Heterosis	Specific combining ability	General combining ability for seed yield
PT-303 x Uttara (L2 x T1)	13.76	37.13**	36.34**	-1.94**	H x A
PT-303 x PT-507 (L2 x T2)	17.32	43.30**	21.97**	2.06**	H x L
Tapeswari x Uttara (L3 x T1)	12.77	50.54**	26.59**	1.31*	L x A
PT-508 x Uttara (L4 x T1)	13.49	27.78**	22.33**	-1.94**	L x A
PHT-1 x Uttara (L7 x T1)	12.40	27.89**	22.89*	-0.72	A x A
PHT-1 x PT-507 (L7 x T2)	15.79	34.32**	11.17	3.11***	A x L

* = Significant at 0.5% level, ** = Significant at 0.1% level
H = positive significant, A = positive non-significant, L = negative significant

Conclusion

The female parent PT-303 showed positive significant general combining ability for seed yield per plant (3.24**) which could be considered as a parent for hybrid seed production.

The genetically diversed parents with good *per se* performance for seed yield and good general combining ability should be selected for breeding programmes aimed at the improvement for yield and other characters in Toria. The crosses with favorable traits obtained from this study can be utilized in further breeding program for development of high seed yielding cultivars of Toria (*Brassica campestris* L.).

References

1. Allard RW. Principles of Plant Breeding. John Wiley and Sons. New York, 1960.
2. Banga SS. Germplasm Enhancement in Indian Mustard: Some Exiting New Developments. In: Souvenir of XIX Annual AICRP Group Meet on Rapeseed-Mustard, Birsa Agricultural University, Ranchi, India, 2012,29-34.
3. Bharti R, Gupta SK, Chaudhary N, Rai SK. Estimate the relative heterosis and heterobeltiosis for yield components in Indian mustard (*Brassica juncea* (l.) Czern & coss). International journal of engineering sciences & research technology. 2018;7(2):682-689.
4. Chaudhary SPS, Sharma SN, Singh AK. Line x Tester analysis in Indian mustard [*Brassica juncia* (L.) Czern and Coss.]. Indian J Genet. 1997;57(2):168-173.
5. Chauhan MP, Singh T, Sharma RM, Singh V, Singh KP. Line x Tester Analysis in Indian Mustard (*Brassica juncea* L.) Czern and Coss. Int. J Curr. Microbiol. App. Sci. 2017;6(8):1514-1522.
6. Chaurasia JP, Singh M, Yadava RK, Singh L, Yadava HC. Genetic analysis for estimates components of genetic variance in Indian mustard [*Brassica juncea* (L.) Czern & Coss] the Pharma Innovation Journal. 2018;7(2):104-107.
7. Falconer DS, Mackey TFC. Introduction to Quantitative Genetics. Pearson Education, Ltd., England, 1996.
8. Gupta VP, Sekhon MS, Satija DR. Studies on genetic diversity, heterosis and combining ability in Indian mustard [*Brassica juncea* (L.) Czern & Coss] Indian J Genet. 1991;51(4):448-453.
9. Kempthorne O. An Introduction to Genetic Statistics. Wiley, New York, 1957, 545.
10. Meena HP, Kumar H, Lal P. Combining ability analysis in Indian Mustard (*Brassica juncia* L. Czern & Coss.). J Oilseeds Res. 2013;30(1):55-59.
11. Meena HS, Kumar A, Ram B, Singh VV, Meena PD, Singh BK, *et al*. Combining ability and heterosis for seed yield and its components in Indian Mustard (*Brassica juncia* L.) J. Agr. Sci. Tech. 2015;17:1861-1871.
12. Monalisa P, Singh NB, Singh NG, Laishram JM. Heterosis in Indian mustard [*Brassica juncea* (L.) Czern. and Coss.] For seed yield, its attributes and oil yield. Indian J Genet. 2005;65(4):302-304.
13. Pradhan AK, Sodhi YS, Mukhopadhyay A, Pental D. Heterosis breeding in Indian mustard (*Brassica juncea* L. Czern & Coss): Analysis of component characters contributing to heterosis for yield. Euphytica. 1993;69:219-229.
14. Rahman MM, Chowdhury MAZ, Hossain MG, Amin MN, Muktadir MA, Rashid MH. Gene action for seed yield and yield contributing characters in turnip rape *Brassica rapa* L.) J. Expt. Biosci. 2011;2(2):67-76.
15. Rameeh V. Combining ability analysis of plant height and yield components in spring type of rapeseed varieties (*Brassica napus* L.) using line × tester analysis. Int. J Agric. For. 2012;2(1):58-62.
16. Rameeh V. Line × tester analysis in rapeseed: Identification of superior parents and combinations for seed yield and its components. Annales-Universitatis Mariae curie-Sklodowska Lublin, Poland, 2015.
17. Sharma, P, Pant DP, Singh SP, Singh AK, Singh, R. Diallel analysis for yield and yield component traits in Toria (*Brassica rapa* L.) J Plant Genet. Resour.

2008;21(2):121-124.
18. Singh RK, Chaudhary BD. Biometrical Methods in Quantitative Genetic Analysis. Kalyani Publishers, New Delhi, 2004.
19. Singh SK, Haider ZA, Ram S. Combining Ability and Heterosis for Seed Yield and Its Components in Indian Mustard (*Brassica juncea*). Indian J Agri. Sci. 2005;75:228-229.
20. Singh AK, Mall AK, Bhajan R, Singh ON. Environmental sensitivity of parents and their crosses for combining ability and rank correlation in *Brassica rapa* L. var. Yellow Sarson. Indian J Genet. 2010;70(2):197-200.
21. Singh A, Avtar R, Singh D, Sangwan O, Thakral NK, Malik VS, *et al*. Combining ability analysis for seed yield and component traits in Indian mustard [*Brassica juncea* (L.) Czern and Coss.]. Res. Plant Biol. 2013;3(2):26-31.
22. Synrem GJ, Rangare NR, Choudhary AK, Kumar S, Myrthong I. Combining ability analysis for seed and component traits in Indian mustard [*Brassica juncia* (L.) Czern & Coss.] Electronic J of plant breeding. 2015;6(2):445-453.
23. Tomar A, Singh M, Tiwari LP. Inbreeding depression and heterotic response analysis for seed yield and its related attributes in yellow Sarson (*Brassica rapa* var. yellow Sarson) International Journal of Fauna and Biological Studies. 2018;5(3):118-122.
24. Vaghela PO, Thakkar HS, Bhadauria S, Sutariya DA, Parmar SK, Prajapati DV. Heterosis and Combining Ability for Yield and Its Component Traits in Indian Mustard (*Brassica juncea*). J Oilseed Brassica. 2011;2:39-43.
25. Verma RR. Combining Ability Analysis for Yield and Its Components through Diallel Crosses in Indica Coiza [*Brassica juncea* (L.) Czern and Coss.]. Indian J Agric. Res. 2000;34(2):91-96.
26. Yadava DK, Singh N, Vasudev S, Singh R, Singh S *et al*. Combining Ability and Heterobeltiosis for Yield and Yield-Contributing Traits in Indian Mustard (*Brassica juncea*). Indian J. Agri. Sci. 2012;82(7):563-567.