Chemical Science Review and Letters ISSN 2278-6783

Research Article

Extent of Heterosis for Yield and its Contributing Traits in High Yielding Varietal Crosses of *Brassica Juncea* L.

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Abstract

ANOVA for line × tester data revealed that treatment variances were highly significant for all the 13 characters. Total variance was further partitioned into parents, crosses and parent *vs* crosses. Mean squares due to parents were significant for all the characters except days to 50% flowering and days to maturity. All characters showed significant differences for parent *vs* crosses variance except days to 50% flowering and siliqua density which exhibited that there is manifestation of heterosis due to interaction of lines and testers. However, all characters were showed significant differences for crosses. Among lines, PBR-357 was good donor parent for eight traits, PYR-2009-5 for six, EJ-22 for five, PRL-2008-5 and Maya for four each; PR-20 and Sej-2 for three each; Rohini and PYR-2009-13 for two and Vaibhav for one. Similarly, among tester IC-414317 exhibited as good donor for six, IC-414322 for four; and PR-2006-14 for three traits. Among testers, IC-414317 showed high GCA for seed yield which was found to be associated with days to 50% flowering, plant height, number of primary branches and 1000 seed weight and; plant height. Results also led to identify PBR-357 as most outstanding good general combiner in as this exhibited good GCA for eight traits. Similarly, among testers IC-414317 was found as good general combiner for six traits.For seed yield, 16% crosses showed significant SCA. The desirable SCA effect for oil content was clearly reflected by 50% crosses had manifested significant SCA effects. PBR-357 × PR-2006-14 and PR-20 × PR-2006-14 were the crosses showed significant SCA for both seed yield and oil content in desirable direction. The results on mid parent heterosis revealed that desirable heterosis over MP is significantly high for seed yield per plant. 86.67% of crosses showed desirable heterosis over MP which revealed that high level of heterosis can be attainable in this crop. Based on arguments two potential crosses each for seed yield per plant as well as oil content were identified. It was found that Maya × IC-414317 for seed per plant and PBR-357 × PR-2006-14 for oil content were two promising combinations.

Keywords: Heterosis, Combining ability, *Brassica Juncea*

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Introduction

Brassica juncea L. is an important oilseed crop in India as well as in World by accounting 28% and 15% to total oilseed production respectively. The yield enhancement will definitely be rewarded by using the phenomenon of heterosis as it was exploited heavily by crops like maize, peralmillet and sorghum and at the same time by self pollinated crops. Indian mustard by nature is self pollinated crop with considerable amount of cross pollination. In India, efforts to develop F1 hybrids in *Brassica* though initiated earlier were intensified subsequent to start of ICAR project on ‘Promotion of Research and Development Efforts on Hybrids in Selected Crops’ in 1989. The high parent heterosis for seed yield from Indian × Exotic crosses were reported to average 55% with range of 30 to 90% by Pradhan [1]. In contrast, high parent heterosis for oil and protein content is rarely encountered in hybrids in Indian mustard varieties. Assessment of hybrid vigour is an important tool for making genetic improvement in yield and its attributing characters in Indian mustard. The magnitude of heterosis provides a basis for evaluation of genetic diversity and a guide for the choice of desirable parents for developing superior F_1 hybrids to exploit hybrid vigour and for building gene pools to be employed in breeding programme. Indian mustard is largely a self pollinated crop which provides immense scope for the exploitation of hybrid vigour which in turn depends on the direction and magnitude of heterosis and biological feasibility. Combining ability analysis offers an opportunity to identify superior parents, which in combinations may be hybridized either to exploit heterosis. With this background, present study was aimed with objective to estimate heterosis and combining ability for different characters related to yield in hybrids generated by crossing high yielding varieties.

Material and Method

The present research study was carried out at Norman E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture & Technology (GBPUAT), Pantnagar during 2014-15 to 2016-17. The estimation of oil content of experimental material was carried out using NIR at DRMR, Bharatpur (Rajasthan). With geographical situation 29º N latitude, 79.30º E longitude at an altitude of 243.84 meters above mean sea level. Pantnagar falls under humid sub-tropical zone in tarai belt of Shivalik range of the Himalayas. The soil texture is miscellaneous type and it is generally 1.0 to 1.5 meters deep. The characteristic features of the soil are high water table, shallow deep and calcareous nature. The experimental material was comprised of 30 hybrids which were developed by crossing10 diverse lines of Indian mustard viz. PRL-2008-5, PBR-357, Maya, PR-20, Rohini, Sej-2, Vaibhav, EJ-22, PYR-2009-5 and PYR-2009-13 used as females and three testers viz. IC-414317, IC-414322 and PR-2006-14 used as males. All crosses were made carefully by hand emasculation and pollination to avoid any mixing. The crosses and their parents evaluated in compact family block design with three replication in *rabi* 2016-17 for 13 traits including developmental traits viz. days to 50% flowering, days to maturity, plant height, length of main raceme, number of primary branches, number of secondary branches; siliqua traits viz. siliqua on main raceme, siliqua density, siliqua length, number of seeds per siliqua along with seed yield per plant, 1000 seed weight and oil content. Each plot comprised of 1 row of 3 meter long. The row to row distance was 30 cm and plant to plant distance of 10 cm was maintained by thinning after 20-25 days of sowing. Single row of Indian mustard strain Divya was grown on either side of block as guard rows. The recommended agronomic practices were followed from sowing to final harvest of the produce. Observation on oil content was determined by NIR. The Line X Tester analysis in which several testers are used [2] which was later modified by Arunachalam [3] and provides information about general and specific combining ability of parents and at the same time it is helpful in estimating various types of gene effects used here.

Results and Discussion

ANOVA for line × tester data is presented in **Table 1** revealed that treatment variances were highly significant for all the 13 characters. Total variance was further partitioned into parents, crosses and parent *vs* crosses. Mean squares due to parents were significant for all the characters except days to 50% flowering and days to maturity. All characters showed significant differences for parent *vs* crosses variance except days to 50% flowering and siliqua density which exhibited that there is manifestation of heterosis due to interaction of lines and testers. However, all characters were showed significant differences for crosses. Partitioning of variances due to crosses into lines, testers and line × tester showed significant mean squares for line × tester interactions for all characters barring siliqua length and number of seeds/siliqua. For lines and testers, mean squares were significant only for a few characters. Mean squares due to testers were significant only for number of secondary branches and seed yield per plant showed significant mean squares. For lines, characters like plant height, length of main raceme, siliqua length and seed yield per plant showed significant differences. This indicated the predominant role of non-additive genetic variation for most of the characters.

The desirable GCA effects observed for different characters may serve as a guide-line in sorting out outstanding parents with favourable alleles for different component traits. Results (**Table 2**) showed that none of line/tester was good general combiner for all the traits; instead the parents differed considerably in building-up their GCA effects for different characters. Among lines, PBR-357 was good donor parent for eight traits, PYR-2009-5 for six, EJ-22 for five, PRL-2008-5 and Maya for four each; PR-20 and Sej-2 for three each; Rohini and PYR-2009-13 for two and Vaibhav for one. Similarly, among tester IC-414317 exhibited as good donor for six, IC-414322 for four; and PR-2006-14 for three traits. The high GCA of PBR-357 for seed yield was associated with high GCA for siliquae in main raceme, siliqua density, number of primary branches, number of secondary branches, siliqua length and 1000 seed weight. High GCA for seed yield in case of Maya was associated with number of seeds per siliqua and 1000 seed weight. Among testers, IC-414317 showed high GCA for seed yield which was found to be associated with days to 50% flowering, plant height, number of primary branches and 1000 seed weight and; plant height and number of secondary branches in case of IC-414322. These findings showed similarity with results reported earlier [4], [5], [6], and [7] on accounts that high GCA status for seed yield in different lines differed considerably in constellation of components traits with high GCA. For oil content, PBR-357, Maya, PR-20, EJ-22 and PYR-2009-13 among lines and IC-414322, and IC-414317 among testers emerged as promising donors. IC-414317 as tester exhibited good GCA for seed yield and oil content. Results also led to identify PBR-357 as most outstanding good general combiner in as this exhibited good GCA for eight traits. Similarly, among testers IC-414317 was found as good general combiner for six traits. Based on GCA status of parents, promising parents for different characters identified have been presented in **Table 3**.

Table 1 ANOVA for Line × Tester Analysis for different characters in hybrids in Indian mustard

Mean Squares / Source of Variation	Replication	Treatment	Parents	Parents vs. Crosses	Crosses	Lines	Testers	L×T	Error
Df	2	42	12	1	29	9	2	18	84
Days to 50% flowering	15.979	47.569**	2.743	7.195	67.509**	87.655	61.741	58.078**	4.461
Days to maturity	11.343	32.075**	7.323	20.75*	42.708**	59.937	62.338	31.913**	4.222
Plant height (cm)	18.913	433.937**	223.787**	534.563**	517.425**	1183.21**	469.667	189.84**	41.043
Length of main raceme (cm)	25.480	161.491**	105.611**	597.25**	169.589**	360.667**	105.082	81.217**	22.666
Siliquae on main raceme	11.382	34.954**	23.351**	60.523**	38.873**	60.675	4.010	31.845**	5.963
Siliqua density	0.000	0.008**	0.007**	0.001	0.008**	0.005	0.003	0.011**	0.001
Number of primary branches	0.723	1.029**	0.798*	3.244**	1.048**	0.820	1.520	1.109**	0.363
Number of secondary branches	0.917	13.759**	9.964**	128.092**	11.387**	10.083	34.741*	9.444**	1.604
Siliqua length (cm)	0.343	0.477**	0.588**	0.843*	0.418**	0.715*	0.191	0.295	0.194
Number of seeds per siliqua	1.164	4.207**	3.407*	64.768**	2.450*	2.992	0.415	2.405	1.423
Seed yield per plant (g)	2.278	15.300**	5.999**	208.326**	12.493**	20.525**	38.723**	5.562**	1.008
1000 seed weight (g)	0.006	2.217**	3.164**	2.723**	1.808**	2.333	2.444	1.475**	0.002
Oil content (%)	0.012	5.585**	2.147**	3.980**	7.063**	6.755	8.191	7.092**	0.002

* and **; significant at 5 % and 1% probability level, respectively

Table 2 Summary table showing GCA status of parents for different characters in hybrid crosses in Indian mustard

Lines/testers	DF	DM	PH	LMR	SMR	SD	NPB	NSB	SL	NSS	SY	TW	OC
PRL-2008-5	G	A	P	G	A	P	A	A	P	A	P	G	G
PBR-357	P	P	P	A	G	G	G	G	G	A	G	G	G
Maya	A	A	P	A	P	P	A	A	A	G	G	G	G
PR-20	P	P	G	P	P	A	P	P	A	P	P	G	G
Rohini	P	P	G	A	P	P	A	G	P	A	P	P	P
Sej-2	A	G	G	P	P	A	P	P	G	P	P	P	P
Vaibhav	P	P	G	P	P	P	P	P	P	P	P	P	P
EJ-22	G	G	P	G	G	P	P	P	A	P	P	P	G
PYR-2009-5	G	G	P	G	G	P	P	G	P	G	P	A	P
PYR-2009-13	A	A	P	A	A	P	P	P	P	P	A	G	G
IC-414317	G	P	G	P	P	P	G	A	A	A	G	G	G
IC-414322	P	P	G	P	A	A	P	G	P	P	G	P	G
PR-2006-14	G	G	P	G	A	P	P	P	P	A	P	P	P

Note: G, Good; A, Average and P, Poor; DF-Days to 50 % flowering, DM-Days to maturity, PH-Plant height (cm), LMR-Length of main raceme (cm), SMR- Siliquae on main raceme, SD-Siliqua density, NPB- Number of primary branches, NSB- Number of secondary branches, NSS-Number of seeds per siliqua, SL-Siliqua length (cm), SY-Seed yield per plant (g), TW-1000 seed weight (g) and OC-Oil content (%).

Table 3 Promising parents identified on basis of their GCA effects for different characters in Indian mustard

S. No.	Characters	Best Combiners
1	Days to 50% Flowering	PRL-2008-5, EJ-22, PYR-2009-5
2	Days to Maturity	EJ-22, PYR-2009-5, PR-2006-14
3	Height (cm)	PR-20, Sej-2, Vaibhav
4	Length of Main Raceme (cm)	PRL-2008-5, EJ-22, PYR-2009-5
5	Siliquae on main raceme	PBR-357, EJ-22, PYR-2009-5
6	Siliqua density	PBR-357
7	Number of primary branches	PBR-357, IC-414317
8	Number of secondary branches	PBR-357, Rohini, PYR-2009-5
9	Siliqua Length (cm)	PBR-357, Sej-2
10	No. of seeds/siliqua	Maya, PYR-2009-5
11	Seed yield per plant (g)	PBR-357, Maya, IC-414317
12	1000 seed weight (g)	PBR-357, Maya, PR-20, PYR-2009-13, IC-414317
13	Oil Content (%)	PBR-357, Maya, PR-20, IC-414322

Table 4 Promising Specific cross combinations based on SCA in Indian mustard

S. No.	Characters	Promising specific cross combinations	No.
1	Days to 50% Flowering	PRL-2008-5×IC-414317, PBR-357×IC-414322, Vaibhav×IC-414317, EJ-22×IC-414322, PYR-2009-5×PR-2006-14	5
2	Days to Maturity	PBR-357×IC-414322, RohiniI×IC-414317, Vaibhav×IC-414317, PYR-2009-13×IC-414322	4
3	Height (cm)	PRL-2008-5×IC-414317, PRL-2008-5×IC-414322, PBR-357×IC-414322, Maya×IC-414317, Maya×PR-2006-14, PR-20×IC-414317, RohiniI×PR-2006-14, Sej-2×IC-414322, Vaibhav×PR-2006-14, EJ-22×IC-414322, PYR-2009-5×IC-414317, PYR-2009-5×IC-414322, PYR-2009-13×IC-414322	13
4	Length of Main Raceme (cm)	RohiniI×IC-414317	1
5	Siliquae on main raceme	PRL-2008-5×IC-414322, PBR-357×IC-414317, Maya×IC-414322, PYR-2009-13×PR-2006-14	4
6	Siliqua density	PRL-2008-5×IC-414322, Maya×IC-414322, RohiniI×PR-2006-14, Sej-2×IC-414322, Vaibhav×IC-414317, PYR-2009-13×PR-2006-14	6
7	Number of primary branches	PBR-357×IC-414322, PYR-2009-5×PR-2006-14	2
8	Number of secondary branches	RohiniI×IC-414322, Sej-2×PR-2006-14, PYR-2009-13×IC-414317	3
9	Siliqua Length (cm)	Vaibhav×PR-2006-14	1
10	No. of seeds/siliqua	------	0
11	Seed yield per plant (g)	PBR-357×PR-2006-14, Maya×IC-414317, PR-20×PR-2006-14, PYR-2009-5×IC-414322, PYR-2009-13×IC-414322	5
12	1000 seed weight (g)	PRL-2008-5×IC-414322, PBR-357×IC-414322, Maya×PR-2006-14, PR-20×IC-414317, RohiniI×IC-414322, Sej-2×IC-414317, Sej-2×PR-2006-14, Vaibhav×PR-2006-14, EJ-22×IC-414322, EJ-22×PR-2006-14, PYR-2009-5×IC-414317, PYR-2009-5×IC-414322, PYR-2009-13×IC-414317	13
13	Oil Content (%)	PRL-2008-5×IC-414322, PRL-2008-5×PR-2006-14, PBR-357×PR-2006-14, Maya×IC-414322, Maya×PR-2006-14, PR-20×PR-2006-14, RohiniI×PR-2006-14, Sej-2×IC-414322, Sej-2×PR-2006-14, Vaibhav×IC-414317, Vaibhav×IC-414322, EJ-22×IC-414317, EJ-22×PR-2006-14, PYR-2009-5×IC-414317, PYR-2009-13×PR-2006-14	15

The success of any crop improvement programme through genetic recombination primarily depends on selection of superior cross combinations and their subsequent advancement using appropriate breeding methodology, thus analysis of SCA becomes essential. While presenting the results (**Table 4**), the negative estimates of SCA effects were considered desirable for days to 50% flowering, days to maturity and plant height. In view of desirability for higher expression of remaining characters, the estimates with positive SCA effects were considered desirable. A cursory view on character-wise presentation of SCA effects revealed that there is a considerable difference for manifestation of significant SCA effects for different characters in hybrid crosses for instance number of crosses showing significant SCA effects in desired direction for days to maturity was five. Similarly, one out of 30 crosses manifested significant SCA for length of main raceme and; two for number of primary branches. For seed yield, 16% crosses showed significant SCA. The desirable SCA effect for oil content was clearly reflected by 50% crosses had manifested significant SCA effects. PBR-357 × PR-2006-14 and PR-20 × PR-2006-14 were the crosses showed significant SCA for both seed yield and oil content in desirable direction. Further, it was revealed from the present study that there is no consistency in GCA status of the parent involved in the crosses having significant SCA effects. The superior crosses identified for seed yield per plant as well as oil content are having H × L GCA parents. Thus, it could be inferred at this stage that high estimates of GCA effects did not necessarily results in manifestating high estimates of SCA effects in such crosses. These results also indicated the operation of additive × dominance and/or dominance × dominance gene interaction for expression of yield and oil content in these crosses. Similar results have been reported earlier [8-10].

Table 5 Percentage of heterotic crosses over MP and BP for different characters in Indian mustard

S. No.	Characters	Heterosis over MP in %		Heterosis over BP in %	
		% of crosses showing significant heterosis	% of crosses showing desirable heterosis	% of crosses showing significant heterosis	% of crosses showing desirable heterosis
1	Days to 50 % flowering	56.67	23.33	70	53.33
2	Days to Maturity	36.67	10.00	23.33	3.33
3	Plant height (cm)	36.67	10.00	30.00	0.00
4	Length of main raceme (cm)	83.33	60.00	56.67	30.00
5	Siliquae on main raceme	73.33	43.33	90.00	30.00
6	Siliqua density	90.00	40.00	93.33	30.00
7	Number of primary branches	96.67	70.00	86.67	36.67
8	Number of secondary branches	93.33	100.00	93.33	66.67
9	Siliqua length (cm)	93.33	93.33	93.33	50.00
10	Number of seeds per siliqua	90.00	83.33	90.00	43.33
11	Seed yield per plant (g)	96.67	86.67	100.00	63.33
12	1000-seed weight (g)	100.00	66.67	100.00	36.67
13	Oil Content (%)	96.67	3.00	96.67	16.67

In pursuance of heterosis exploitation knowledge of SCA effects assumes greater significance. The desirable SCA effects may not be of practical utility until and unless *per se* performance of the combinations are compared to that of respective mid parent (MP) and better parent (BP). The results on mid parent heterosis revealed that desirable heterosis over MP is significantly high for seed yield per plant. 86.67% of crosses showed desirable heterosis over MP which revealed that high level of heterosis can be attainable in this crop as earlier reported [11-13]. In addition to this, more than 80% of desirable heterosis also achieved by traits like number of secondary branches, siliqua length and number of seeds per siliqua. These traits are directly associated with seed yield. Length of main raceme, number of primary branches and 1000 seed weight were the traits for which more than 60% crosses showed desirable heterosis. Only developmental traits showed less heterosis where only 23.33% crosses for days to 50% flowering, 10% crosses each for plant height and days to maturity showed desirable heterosis. Such a low magnitude of heterosis and also less number of crosses displaying heterosis may be, possibly, due to quantitatively photosensitive nature of these traits in oilseed *Brassicas* as has been argued in earlier reports [14]. Similar trends were observed for heterosis over BP but with lower magnitude of heterotic crosses (**Table 5**). Only 3% and 16.67% crosses showed desirable heterosis over MP and BP respectively. The low expression of heterosis for oil content was observed in the present study is in accordance with earlier reports [15], [16] and this could be attributed to the fact that physiologically, a specific metabolic system of plant species sets an absolute limit to the directional partitioning of available photosynthates into more valuable compounds like oil at the cost of carbohydrates [17].

Overall results on heterosis for seed yield and oil content vis-à-vis *per se* performance and SCA effects of crosses have been identified (**Table 6**). Besides, this table also presents significant SCA effects of the related traits and suggested breeding methodology for genetic improvement. Based on arguments two potential crosses each for seed yield per plant as well as oil content were identified. It was found that Maya × IC-414317 for seed per plant and PBR-357 × PR-2006-14 for oil content were two promising combinations. The GCA status of parents involved in this cross for seed yield per plant in both sets was high but other promising crosses for this attribute combined parents with differing in their GCA status. Similar is the case for oil content. Thus, it was obvious that high GCA status of both the parents involved in highly heterotic cross combinations will not be necessary instead it can also be results from H × L GCA status. The high expression of the traits due to H × L GCA status combination is possible due to complemention of additive genetic effects of good general combiner and epistatic effect of poor combiner.

Table 6 Promising cross combinations based on heterosis, vis-à-vis *per se* performance and combining ability for seed yield and oil content in Indian mustard

Cross Combinations	Mean	SCA effect	Heterosis (%)		GCA status of parents	Suggested breeding methods
			MP	BP		
Seed yield (g/plant)						
Maya × IC-414317	13.5	1.38**	196.70**	134.10**	H × H	Heterosis breeding, conventional breeding methods with selection pressure on PH, NSS, NPB, TW and OC
PBR-357 × PR-2006-14	9.76	2.57**	115.22**	80.68**	H × L	Heterosis breeding/mass selection with concurrent mating
Oil content (%)						
PBR-357 × PR-2006-14	40.44	0.87**	2.30**	2.25**	H × L	Heteosis breeding/mass selection with concurrent mating
Rohini × PR-2006-14	39.57	1.10**	1.09**	0.08**	L × L	Heterosis breeding, biparental mating and diallel selective mating

References

[1] Pradhan, A. K., Sodhi, Y. S., Mukhopadhyay, A. and Pental, D. Heterosis breeding in Indian mustard (B. juncea L.): Analysis of component characters contributing to hterosis for yield. Euphytica, 1993, 69: 219-229.

[2] Kempthorne O. An Introduction to Genetics Statistics. John Wiley and Sons, New York.1957, p 458-465.

[3] Arunachalam V. The fallacy behind the use of modified linextester design. Indian Journal of Genet. and Plant Breed. 1974, 34:280- 287.

[4] Singh, S. K. Genetic studies for yield, its components and quality traits in Indian mustard (Brassica juncea L. Czern& Coss). Thesis, M. Sc. (Ag), NDUAT, Kumarganj, Faizabad, 1989.

[5] Dhillon, S.S., Labana, K.S. and Banga, S.K. Studies on heterosis and combining ability in Indian mustard [B.juncea (L) Czern&Coss].J. Res. Punjab Agri.Uni. 1990, 27(1):1-8.

[6] Choudhary, R., Patil, S., Bohare, T., Gowthami, R. And Dandade, B. Combining ability analysis of mustard land races through diallel mating. J. of Soils and Crops. 2015. 25(2): 368-373.

[7] Dahiya, N., Ram Bhajan, Rashmi and Usha, P. Heterosis and combining ability for different traits in local germplasm and varietal crosses in Brassica juncea L. International Journal of Chemical Studies 2018, 6(1): 1884-1887

[8] Singh, A.K., Ram Bhajan and Verma, O.P. Genetic divergence analysis in yellow sarson (B. rapa var. yellow sarson).Pantnagar Journal of Research 2009, 7: 161-175.

[9] Srivastava, S.B.L., Rajshekhar., Singh, M. and Rao, M. Combining ability analysis for yield and contributing characters in Indian mustard (Brassica juncea (L.) Czern and Coss.). J. Oil seeds Res. 2009, 26: 58-61.

[10] Singh, P.K, Akansha., Verma, O.P. and Kumar, K. Genetic analysis for seed yield and its related attributes in yellow sarson. J. of Oilseed Brassica, 2017, 8 (1): 43-51.

[11] Gupta, P., Chaudhary, H. B. and Kumar, S. L. Heterosis and combining ability analysis for yield and its components in Indian mustard (Brassica juncea L. Czern & Coss). Front. Agric. 2012, 4(3): 299–307.

[12] Singh, R.K., Lohia, R.S. and Singh, M. Study on gene action on inheritance of seed yield and its contributing traits in Indian mustard (Brassica juncea L. Czern & Coss). Progressive Research, 2013, 8(1).78-81.

[13] Meena, H. S., Ram, B., Kumar, A., Singh, B.K., Meena, P. D., Singh, V.V. and Singh, D. Heterobeltiosis and standard heterosis for seed yield and important traits in B. juncea. J. Oilseed Brassica, 2014, 5(2): 134-140.

[14] Singh SP. Heterosis and combining ability estimates in Indian mustard, Brassica juncea (L) Czem and Coss. Crop Sci 1973, 13: 497–499.
[15] Dar, Z. A., Wani, S. A., Wani, G., Khan, M. H., Habib, M., Ahmed, Z. and Ishfaque, A. Heterosis and combining ability analysis for seed yield and its attributes in Brassica rapassp. brown sarson. J. Oilseed Brassica, 2011, 2(1): 21-28.
[16] Tomar, A., Singh, M. and Singh, S. K. Genetic analysis of yield and its components based on heterotic response and combining ability parameters in Indian Mustard (Brassica juncea (L.) Czern & Coss.). Prog. Agric. 2015, 15 (1): 85-91.
[17] K.S. Labana, S.S. Banga and S.K. Banga (Ed.) Breeding oilseed Brassicas, chapter 5, Bioenergetic limitations to breeding better Brassicas, Bhatia C.R. and Mitra, R. Narosa Publishing House, New Delhi, 1992, p 67-75.

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Publication History
Received 17th Dec 2018
Revised 16th Jan 2019
Accepted 24th Jan 2019
Online 30th Jan 2019