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Combining ability studies in different species of mustard

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Abstract
Combining ability analysis was carried out in Indian mustard by crossing 6 lines and 3 testers in line x tester mating design. The parents, crosses and checks were grown in randomized block design replicated trice and observations were taken on days to 50% flowering, days to maturity, plant height, number of branches plant^{-1}, point to first siliqua, siliqua length, number of seeds siliqua^{-1}, number of siliquae plant^{-1}, siliquae density on main branch, 1000 seed weight, seed yield plant^{-1}, oil content and powdery mildew incidence. The predictability ratio was found less than unity for all characters indicated the predominant role of non-additive gene action in the expression of characters. Line Bio-902 and tester Chhattisgarh Sarson were recorded as good general combiners for seed yield and it's contributing characters. The crosses ACN-9 × PC-6, TAM 108-1 × Chhattisgarh Sarson, and Bio-902 × Chhattisgarh Sarson showed significant negative SCA effect for seed yield and most of its contributing characters. These crosses can be forwarded to next generation to develop as a variety.

Keywords: Mustard, specific combining ability, general combining ability, line x tester

Introduction
Indian mustard [*Brassica juncea* (L.) Czern and Cross] is an important oilseed crop of the world. It is popularly known as Rai, Raya or Laha in India. Indian mustard belongs to family Cruciferae (syn. Brassicaceae) and genus *Brassica*. Indian mustard is a natural amphidiploid (AABB, 2n=36) of *Brassica rapa* (2n=20) and *Brassica nigra* (2n=16) (Nagaheru, 1935) [11]. It is largely a self-pollinated crop (85-90%). However, owing to insects, especially the honeybees, the extent of cross-pollination varies from 5-18%. (Labana and Banga, 1984) [8].
Mustard is predominantly grown in India for extraction of oil. Nowadays mustard is maintaining its increasing trend in productivity while the area is continuously declining resulting in its stagnant production in India. Yet, India meets 57% of the domestic edible oil requirement through import and ranked 7th largest importer of edible oils in the world. The average productivity of Indian mustard in India is very low ((1324 kg ha^{-1}), which mainly attributed to yield stagnation in new varieties and increasing pressure posed by various biotic and abiotic stresses. So, there is need of producing high yielding varieties with early maturity, high oil content and disease powdery mildew resistance varieties. Improving the genetic potential of crop for increasing yield with quality characters should be over emphasized. line × tester analysis which involves 'l' line and 't' tester is an extension of the analysis of two factorial experiment developed by Kempthorne (1957) [6], which provides a reliable information on the general and specific combining ability effects of parents and their hybrid combinations are used to generate the information. Information on combining ability provides guidelines to the plant breeder in selecting the elite parents and desirable cross combinations to be used in the formulation of systematic breeding programme. Combining ability studies emphasized the predominant effect of GCA on the yield and most of the yield component indicating the importance of additive gene action.

Material and Methods
This study aimed to evaluate GCA effects of parents and SCA effects of crosses. The experimental material consisted 6 lines *viz*., TAM 108-1, ACN 9, Kranti, PM-26, Bio-902, and PM-28 and 3 testers *viz.*, Chhattisgarh Sarson, PC-6 and *Synapsis alba* which were crossed in line x tester fashion during the year2020-21 in *rabi* season. The crosses along with their parents were planted in randomized block design in three replications at Research field of AICRP (Linseed and Mustard), College of Agriculture, Nagpur in *rabi* 2021-22.

Each genotype was grown in two rows with spacing 45 ×15 cm^2 for row to row and plant to plant respectively. Where, length of each row was 2m and 5 plants were used for observation. Observations were recorded on 12 quantitative characters *viz.*, days to 50% flowering, days to maturity, plant height, number of branches $plant^{-1}$, point to first siliqua, siliqua length, number of seeds $siliqua^{-1}$ number of siliquae $plant^{-1}$, siliquae density on main branch, 1000 seed weight, seed yield $plant^1$ and oil content. All recommended agronomical practices were followed to raise healthy crop. The combining ability analysis were carried out following the methodology of Kempthorn (1957) [6] with fixed effect model.

Results and Discussions

Analysis of variance for combining ability are presented in table 1. The components of variance attributable to lines and testers were used as a measure of general combining ability effects and the variance due to interaction between lines and testers was used as a measure of specific combining ability effects. Mean square due to lines, testers and line × tester were significant for all the 12 characters *viz.*, days to 50% flowering, days to maturity, plant height, number of branches $plant^{-1}$, point to first siliqua, siliqua length, number of seeds $silique^{-1}$ number of siliquae $plant^{-1}$, siliquae density on main branch, 1000 seed weight, seed yield $plant^{-1}$ and oil content (%) under study. Kumar *et al.* (2014) [7], Patel *et al.* (2015) [12], Akabari *et al.* (2017) [1], Malviya *et al.* (2019) [9] and Choudhary *et al.* (2020) [3] also reported significant mean square due to lines, testers and line × tester for seed yield and it's contributing characters. The predictability ratio ranged from 0.58 for number of branches $plant^{-1}$ to 0.92 for days to 50% flowering. All the characters studied the predictability ratio was observed to be more than 0.50. This reveals that both GCA effects of parents and SCA effect of crosses for their exploitation to recover transgressive segregantes. Earlier workers Kumar *et al.* (2014) [7], Meena *et al.* (2015) [10] and Akabari *et al.* (2017) [1] also reported predictability ratio close to unity in their study in mustard.

General combining effect of parents and specific combining ability effect of crosses are present in Table. Among the 9 parents i.e. 6 lines and 3 testers, four parents showed the negative significant general combining ability effect in desirable direction for days to 50% flowering of which line PM-28 showed highest negative significant general combining ability effect. Negative significance is also desirable for the trait days to maturity. Four parents were reported negative significant general combining ability effect for days to maturity in which ACN 9 recorded the highest negative significant general combining ability effect. Positive significance is desirable for plant height. Among 9 parents, three parent found positive significant general combining effect for plant height, whereas Bio-902 recorded highest positive significant general combining ability effect. For the character number of branches $plant^{-1}$, three parents were reported the positive significant general combining effect. Point to first siliqua is also the trait where, negative significant general combining ability is desirable. From 9 parents, three parents showed the negative significant general combining ability effect of which ACN 9 was highest. Siliqua length is the trait where positive significant is desirable. Only two parents showed the positive significant general combining ability effect *viz.*, PM-28 and Chhattisgarh Sarson. Again two parents i.e. Chhattisgarh Sarson and TAM 108-1 found positive significant general combining ability effect for number of seeds $siliqua^{-1}$. For the character number of siliquae $plant^{-1}$, four parents reported positive significant general combining ability effect in which PM-26 had highest positive significant general combining ability effect.

The estimates of GCA effects among lines and testers showed wide variation in level of significance for various characters. Among the lines, it was reported that line Bio-902 was recorded highly significant positive GCA effect for days to maturity, plant height, number of branches $plant^{-1}$, point to first siliqua, number of siliquae $plant^{-1}$, siliquae density on main branch, 1000 seed weight and seed yield $plant^{-1}$. Among the testers Chhattisgarh Sarson found to be best general combiner as it observed highly significant positive GCA effect for plant height, siliqua length, number of seeds $siliquae^{-1}$, number of siliquae $plant^{-1}$, siliquae density on main branch, 1000 seed weight, seed yield $plant^{-1}$ and oil content. Similar results also found by Kaur *et al.* (2019) [5], Choudhary *et al.* (2020) [3] and Kaur *et al.* (2020) [4].

Specific combining ability effect of crosses is also presented in Table. For the character days to 50% flowering, five cross combinations showed negative significant specific combining ability effect in which Kranti x PC-6 was recorded as highest negative significant specific combining ability effect. Similar effects also observed for days to maturity in three crosses and point to first siliqua in one cross. Negative significant specific combining ability effect for days to maturity and point to first siliqua for parents also observed by Meena *et al.* (2015) [10] in their study on mustard. Positive significance is desirable for plant height and three crosses showed positive significant specific combining ability effect for plant height. For number of branches $plant^{-1}$ seven cross combinations exhibited positive significant specific combining ability effect. Siliqua length is also the character where positive significance is desirable, among 18 crosses six crosses exhibited positive significant specific combining ability effect. For the trait number of seeds $siliqua^{-1}$, four hybrids showed positive significant specific combining ability effect. Similar effects also found for character number of siliquae $plant^{-1}$ in six crosses in which PM-26 x PC-6 had highest positive significant specific combining ability effect. Four cross combinations expressed positive significant specific combining ability effect for the character siliquae density on main branch. Out of 18 crosses, five cross combinations recorded the positive significant specific combining ability effect for 1000 seed weight. For the trait Seed yield $plant^{-1}$ positive significance is desirable. Six cross combinations showed positive significant specific combining ability effect for seed yield $plant^{-1}$ in which TAM 108-1 x PC-6 showed highest positive significant specific combining ability effect. For oil content four crosses exhibited positive significant specific combining ability effect.

The negative SCA effect, high GCA effect of one of the parent involved in cross with mean performance is the crucial criteria for selection of hybrids. On the basis of above criteria these crosses *viz.*, ACN 9 x PC-6, TAM 108-1 x Chhattisgarh Sarson and Bio-902 x Chhattisgarh Sarson are selected as promising crosses. The cross ACN 9 × PC-6 showed negative significant SCA effect for seed yield $plant^{-1}$, number of siliquae $plant^{-1}$, days to maturity and point to first siliqua. Similarly the same cross was significantly superior over the best check for seed yield $plant^{-1}$, number of siliquae $plant^{-1}$, point to first siliquae, days to maturity and number of branches plant^{-1}. The GCA effect involved in the cross possessed medium × low GCA effect for seed yield plant^{-1}, medium × high for number of siliquae plant^{-1}, low× medium for point first siliqua and low × high for days to maturity.

The cross TAM 108-1 × Chhattisgarh Sarson showed significant negative SCA effect for seed yield plant^{-1} and siliquae density on main branch and showed negative SCA effect for number of siliquae plant^{-1} and oil content. Same cross was significantly superior over the best check for seed yield plant^{-1} and the cross was at par for number of siliquae plant^{-1}, 1000 seed weight, siliquae density on main branch and oil content. The GCA effect of parents involved in the cross possessed low × high for seed yield plant^{-1}, medium × high for number of siliquae plant^{-1}, siliquae density on main branch and low × high for oil content.

The cross Bio-902 × Chhattisgarh Sarson showed significant negative SCA effect for seed yield plant^{-1} and negative SCA effect for siliquae density on main branch and 1000 seed weight. Same cross was significantly superior over best check for seed yield plant^{-1} and at par for siliquae density on main branch and 1000 seed weight. The GCA effect of parents involved in the cross possessed high × high GCA effect for seed yield plant^{-1}, siliquae density on main branch and 1000 seed weight. Above crosses were therefor found to be best cross which can be forwarded to the next generation. Biparental mating may be used in selected progeny and further selection of segregant generation or recurrent selection or diallel mating may also be used for improvement of yield and yield components. Meena *et al.* (2015) [10] and Synrem *et al.* (2015) [13] also identified superior crosses based on SCA and *per se* performance and suggested the suitability of biparental mating in selected progeny and further selection in segregating generation in mustard.

Table 1: Mean performance of parents and their crosses for different characters

Sr. No.	Lines	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches plant^{-1}	Point to first siliqua (cm)	Siliqua length (cm)	Number of seeds siliqua^{-1}	Number of siliquae plant^{-1}	Siliquae density on main branch	1000 seed weight (g)	Seed yield plant^{-1} (g)	0il content (%)
1	TAM 108-1 (Check)	49.67	108.00	197.52	3.40	93.33	4.46	12.28	279.37	0.74	5.20	12.16	34.62
2	ACN 9	42.33	103.67	163.07	3.81	85.98	4.34	13.12	266.97	0.71	4.03	15.42	33.83
3	Kranti (Check)	44.67	107.33	180.39	3.33	108.53	4.38	11.25	283.87	0.66	5.11	10.73	34.61
4	PM-26	44.00	109.67	187.84	3.93	85.38	4.47	11.58	240.09	0.58	4.77	16.91	33.17
5	Bio-902	46.67	105.33	186.95	2.93	93.43	4.51	12.40	288.98	0.60	5.28	15.87	31.16
6	PM-28	41.33	103.00	142.19	2.93	77.33	5.88	11.23	139.69	0.46	4.12	8.60	38.30
	Testers												
7	Chhattisgarh Sarson	46.67	112.33	185.33	3.65	98.58	4.17	14.93	321.38	0.75	3.78	15.81	32.94
8	PC-6	58.33	117.33	157.47	2.73	96.20	3.95	9.90	147.00	0.65	3.71	7.02	36.99
9	*Synapsis alba*	40.67	102.33	56.75	2.95	48.18	6.55	30.10	18.68	0.16	3.65	9.03	31.44
	Crosses												
1	TAM 108-1 X Chhattisgarh Sarson	46.67	106.33	174.93	3.07	92.50	4.86	13.98	345.53	0.75	5.57	15.67	34.90
2	TAM 108-1 X PC-6	49.33	120.33	170.63	3.37	109.40	4.68	12.60	320.42	0.64	4.30	20.41	36.10
3	TAM 108-1 X *Synapsis alba*	48.67	112.67	183.80	3.87	88.52	3.85	12.13	326.62	0.71	4.18	14.50	31.95
4	ACN 9 X Chhattisgarh Sarson	47.00	107.67	168.88	4.10	94.73	4.93	14.86	472.23	0.88	4.42	29.14	33.07
5	ACN 9 X PC-6	56.33	100.67	184.21	4.60	73.23	3.83	10.67	347.30	0.74	5.62	15.81	39.18
6	ACN 9 X *Synapsis alba*	49.00	105.67	118.56	3.05	76.37	3.39	11.38	230.32	0.44	4.25	17.72	31.00
7	Kranti X Chhattisgarh Sarson	46.00	109.00	168.43	4.07	96.07	4.49	12.47	319.07	0.74	5.70	25.59	41.34
8	Kranti X PC-6	46.00	124.33	185.08	3.14	88.95	4.41	11.07	242.68	0.68	5.17	12.21	37.12
9	Kranti X *Synapsis alba*	44.00	108.67	167.03	3.22	92.08	3.92	11.63	284.54	0.65	4.51	13.16	32.18
10	PM-26 X Chhattisgarh sarson	44.67	103.33	182.13	3.20	90.80	4.75	14.22	294.27	0.91	3.84	28.04	38.85
11	PM-26 X PC-6	51.33	126.33	196.58	6.27	99.16	2.48	3.39	977.95	0.71	3.62	14.74	34.69
12	PM-26 X *Synapsis alba*	42.00	106.00	136.97	3.44	77.07	5.26	11.77	213.78	0.36	3.89	16.58	35.03
13	Bio-902 X Chhattisgarh Sarson	48.00	111.00	192.58	3.22	103.40	4.34	12.40	407.42	0.85	5.42	21.74	33.48
14	Bio-902 X PC-6	50.00	122.67	191.51	4.13	108.09	4.31	14.00	361.67	0.64	5.67	30.26	32.96
15	Bio-902 X *Synapsis alba*	44.67	106.33	185.80	5.63	95.37	4.30	11.35	380.01	0.74	4.04	31.83	35.59
16	PM-28 X Chhattisgarh Sarson	41.00	102.33	183.53	3.47	89.87	4.82	14.15	335.27	0.81	5.46	19.79	41.60
17	PM-28 X PC-6	51.33	112.33	147.89	4.02	87.76	4.88	9.74	222.33	0.68	4.46	10.84	35.74
18	PM-28 X *Synapsis alba*	42.33	104.67	115.21	3.20	72.83	5.35	12.94	99.85	0.41	3.47	15.11	31.12
	Mean	47.13	110.57	169.65	3.84	90.90	4.38	11.93	343.40	0.69	4.64	19.62	35.33
	S.E. (m) ±	1.14	1.90	10.26	0.13	5.87	0.19	0.73	20.10	0.04	0.13	1.21	1.04
	C.D (5%)	3.24	5.38	29.12	0.36	16.67	0.54	2.07	57.03	0.13	0.36	3.42	2.96

Table 2: Analysis of varience for combining ability.

Sources of variation	D.F.	Mean squares											
		Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches plant^{-1}	Point to first siliqua (cm)	Siliqua length (cm)	Number of seeds siliqua^{-1}	Number of siliquae plant^{-1}	Siliquae density on main branch	1000 seed weight (g)	Seed yield plant^{-1} (g)	Oil content (%)
Females (f)	5	43.57**	143.04**	1916.95**	1.51**	566.32**	1.05**	11.24**	79291.10**	0.01**	2.12**	188.21**	13.36**
Males (m)	2	175.13**	702.90**	4587.32*	2.57**	698.55**	1.64**	53.14**	114622.74**	0.34**	4.96**	188.35**	92.42**
Females X Males (f x m)	10	18.60**	98.62**	1166.60**	2.86**	173.784**	1.65**	16.76**	101259.20**	0.045**	0.98**	93.63**	28.61**
Error	34	4.33	11.87	321.92	0.04	120.88	0.11	1.46	1456.95	0.01	0.06	5.35	2.56
GCA *vs* SCA		0.92	0.89	0.85	0.58	0.87	0.62	0.79	0.66	0.89	0.88	0.80	0.79

Table 3: GCA effects of parents and SCA effects of crosses.

Sr. no.	GCA/ SCA	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches plant^{-1}	Point to first siliqua (cm)	Siliqua length (cm)	Number of seeds siliqua^{-1}	Number of siliquae plant^{-1}	Siliquae density on main branch	1000 seed weight (g)	Seed yield plant^{-1} (g)	Oil content (%)
	GCA												
1	TAM 108-1	1.09	2.54*	6.80	-0.40**	5.91	0.08	0.97*	-12.54	0.01	0.04	-2.76**	-1.01*
2	ACN 9	3.65**	-5.91**	-12.44*	0.08	-9.45**	-0.33**	0.37	6.55	0.00	0.12	1.27	-0.91
3	Kranti	-1.80**	3.43**	3.86	-0.36**	1.47	-0.11	-0.21	-61.31*	0.00	0.48**	-2.63**	1.55**
4	PM-26	-1.13	1.31	2.24	0.47**	-1.89	-0.22*	-2.14**	151.93**	-0.02	-0.86**	0.17	0.86
5	BIO-902	0.43	2.76**	20.31**	0.49**	11.39**	-0.07	0.65	39.63**	0.06*	0.40**	8.32**	-1.32*
6	PM-28	-2.24**	-4.13**	-20.78**	-0.27**	-7.41*	0.64**	0.35	-124.25**	-0.05	-0.18*	-4.37**	0.82
	S.E. (lines)	0.63	1.05	5.46	0.06	3.35	0.10	0.37	11.61	0.03	0.07	0.70	0.49
7	Chhattisgarh Sarson	-1.57**	-3.96**	8.76*	-0.32**	3.66	0.32**	1.75**	18.89*	0.14**	0.42**	3.71**	1.88**
8	PC-6	3.59**	7.20**	9.66*	0.42**	3.53	-0.28**	-1.68**	68.66**	-0.04	0.16**	-2.24**	0.64*
9	*Synapsis alba*	-2.02**	-3.24**	-18.43**	-0.10*	-7.19**	-0.03	-0.06	-87.55**	-0.14**	-0.59**	-1.47**	-2.52**
	S.E. (tester)	0.40	0.66	3.45	0.04	2.12	0.06	0.23	7.35	0.02	0.05	0.44	0.31
	SCA												
10	TAM-108-1 X Chhattisgarh Sarson	0.02	-2.81	-10.28	-0.05	-7.97	0.08	-0.67	-4.22	-0.09*	0.46**	-4.90**	-1.30
11	TAM-108-1 X PC-6	-2.48**	0.02	-15.49	-0.49**	9.06	0.50**	1.38*	-79.09**	-0.06	-0.55**	5.79**	1.14
12	TAM-108-1 X *Synapsis alba*	2.46**	2.80	25.77**	0.54**	-1.09	-0.58**	-0.71	83.31**	0.14**	0.08	-0.89	0.15
13	ACN 9 X Chhattisgarh Sarson	-2.20*	6.96**	2.90	0.50**	9.63*	0.56**	0.81	103.39**	0.06	-0.77**	4.54**	-3.22**
14	ACN 9 X PC-6	1.96*	-11.20**	17.33*	0.26**	-11.74*	0.06**	0.05	-71.31**	0.06	0.69**	-2.84**	4.12**
15	ACN 9 X *Synapsis alba*	0.21	4.24**	-20.23*	-0.76**	2.12	-0.63**	-0.86	-32.08	-0.11**	0.07	-1.70	-0.90
16	Kranti X Chhattisgarh Sarson	2.24*	-1.04	-13.84	0.91**	0.04	-0.10	-1.05	18.08	-0.09*	0.15	4.89**	2.58**
17	Kranti X PC-6	-2.93**	3.13**	1.90	-0.75**	-6.95	0.42**	1.03	-108.07**	-0.01	-0.12	-2.54*	-0.40
18	Kranti X *Synapsis alba*	0.68	-2.09	11.94	-0.15	6.91	-0.31*	-0.02	89.99**	0.09*	-0.03	-2.35*	-2.18**
19	PM-26 X Chhattisgarh Sarson	0.24	-4.59**	1.48	-0.79**	-1.87	0.27	2.67**	-219.96**	0.11**	-0.37**	4.54**	0.78
20	PM-26 X PC-6	1.74	7.24**	15.02	1.55**	6.62	-1.40**	-4.71**	413.96**	0.05	-0.32**	-2.80**	-2.14**
21	PM26 X *Synapsis alba*	-1.98*	-2.65	-16.50*	-0.76**	-4.75	1.13**	2.04**	-194.01**	-0.16**	0.70**	-1.74	1.35
22	BIO-902 X Chhattisgarh Sarson	2.02*	1.63	-6.15	-0.79**	-2.55	-0.29*	-1.93**	5.49	-0.03	-0.05	-9.91*	-2.41**
23	BIO-902 X PC-6	-1.15	2.13	-8.11	-0.62**	2.27	0.27	3.10**	-90.02**	-0.10*	0.47**	4.56**	-1.68*
24	BIO-902 X *Synapsis alba*	-0.87	-3.76*	14.26	1.41**	0.28	0.02	-1.17*	84.53**	0.13**	-0.42**	5.35**	4.09**
25	PM-28 X Chhattisgarh Sarson	-2.31*	-0.15	25.89**	0.22*	2.72	-0.51**	0.12	97.22**	0.04	0.57**	0.83	3.57**
26	PM-28 X PC-6	2.85**	-1.31	-10.65	0.04	0.74	0.15	-0.85	-65.47**	0.05	-0.16	-2.16*	-1.05
27	PM-28 X *Synapsis alba*	-0.54	1.46	-15.24	-0.26*	-3.46	0.36**	0.72	-31.75	-0.09*	-0.41*	1.33	-2.52**
	S.E. (crosses)	0.89	1.48	7.72	0.09	4.73	0.14	0.52	16.43	0.04	0.11	0.99	0.69

Table 4: Potential crosses identified on the basis of mean performance, GCA effect of parents and SCA effect of crosses for yield and other traits.

Sr. no.	Crosses	characters	Mean	SCA effects	GCA effects	
					P1	P2
1	ACN 9 X PC-6	Yield	15.81	-2.84**	1.27	-2.24**
		NOS	347.30	-71.31*	6.55	68.66**
		Point to 1st S	73.23	-11.74*	-9.45**	3.53*
		DTM	100.67	-11.21**	-5.91**	7.20**
2	TAM 108-1 X Chhattisgarh Sarson	Yield	15.67	-4.90**	-2.76**	3.71**
		NOS	345.53	-4.22	-12.55	18.89*
		SD	0.77	-0.09*	0.01	0.14**
		Oil content	34.90	-1.30	-1.01*	1.88**
3	Bio-902 X Chhattisgarh Sarson	Yield	21.41	-9.91*	8.32**	3.71**
		SD	0.85	-0.3	0.06*	0.14**
		1000 SW	5.42	-0.5	0.40**	0.42**

Reference

1. Akabari VR, Sasidharan N, Kapadiya V. Combining ability and gene action study for grain yield and its attributing traits in India mustard. Ele. J Plant Breed. 2017;8(1):226-235.
2. Anonymous, Statistical Division, State Department of Agriculture, Govt. of Maharashtra; c2021.
3. Choudhary P, Sharma H, Sanadya SK, Dodhiya NS, Bishop V. Combining ability for agronomic and quality traits in Indian mustard. Int. J Chem. Studies. 2020;8(5):720-724.
4. Kaur G, Kaur M, Kuma R. Line × Testers analysis for quantitative traits in Indian mustard (*Brassica juncea* L.). J Oilseed *Brassica*. 2020;11(1): 77-87.
5. Kaur S, Kumar R, Kaur R, Singh I, Singh H, Kumar V. Heterosis and combining ability analysis in Indian mustard (*Brassica juncea*). J Oilseed *Brassica*. 2019;10(1): 38-46.
6. Kempthorne O. An Introduction to General Statistics. John Wiley and Sons. Inc. New York. Chapman and Hall Ltd. London; c1957. p. 468-470.
7. Kumar B, Pandey A, Singh SK. Combining ability and economic heterosis for yield and oil quality traits in Indian mustard (*Brassica juncea* (L.) Czern and Coss). Ele. J Pl. Breed. 2014;5(2):203-207.
8. Labana KS, Ahuja KL, Banga SS. Evaluation of some

Ethiopian mustard (*Brassica carinata*) genotypes under Indian conditions. Proceedings of the 7th International Rapeseed Congress; c1984. p. 115.
9. Malviya N, Kumar K, Upadhyay DK. Combining ability and heterosis for seed yield, its component traits and oil content in Indian mustard [*Brassica juncea* (L.) Czern and Coss]. J Pharmacogn. Phytochem. 2019;8(3):696-699
10. 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 juncea* L.). J Agr. Sci. Tech. 2015;17:1861-1871.
11. Nagaharu U. Genome analysis in *Brassica* with special reference to the experimental formation of *B. napus* and peculiar mode of fertilization. Japan J Bot. 1935;7:389-452.
12. Patel R, Solanki SD, Gami RA, Prajapati KP, Patel PT, Bhadauria HS. Genetic study for seed yield and seed quality traits in Indian mustard [*Brassica juncea* (L.) Czern and Coss]. Ele. J Pl. Breed 2015;6(3):672-679.
13. Synrem GJ, Rangare NR, Choudhari AK, Kumar S, Myrthong I. Combining ability analysis for seed yield and component traits in Indian mustard [*Brassica juncea* (L.) Czern and Coss]. Ele. J of Pl. Breed. 2015;6(2):445-453.
14. Vaughan OP, Singh RK and Singh PV. Multidisciplinary subject of taxonomy and origin. Bioscience. 1977;27(1):35.