



Combining ability and heterosis analysis for seed yield and yield components in Indian mustard (*Brassica juncea* L.)

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Abstract

To determine combining ability and heterosis analysis for seed yield and yield components, eight genotypes of Indian mustard (*Brassica juncea* L.) were crossed using a line X tester design. A randomised block design with three replicates was used after fifteen crossings, and their parents were assessed in the field. None of the cross combinations displayed both positive and negative significant SCA effects for seed yield/plant, while the GCA impacts of the parents, IC-571655, demonstrated positive significant effects for the majority of the characteristics. Each trait in the crosses underwent a distinct analysis of variance, and the hybrids exhibited significant heterosis. According to estimations of heterosis and per se performance, the most promising cross for seed yield/plant was IC-508692 x Ashirwad, which was followed by IC-424414 x Ashirwad, IC-571655 x CS 54, and IC-571655 x Ashirwad.

Keywords: *Brassica juncea* L., combining ability, cross combinations, heritability, heterosis

Introduction

Indian mustard is a naturally occurring amphidiploid ($2n = 36$) of *Brassica rapa* ($2n = 20$) and *Brassica nigra* ($2n = 16$), which is followed by a similar chromosome multiplying gene (Shrimali *et al.*, 2016). After soybean, mustard is the second most important oilseed crops in the world (Anonymous, 2015). Mustard seed contains 40-42% oil content with a high nutritive value as compared to other edible oils because it has lowest amount of harmful saturated fatty acids and adequate amount of linoleic and linolenic acid which are necessary fatty acids (Porter and Crompton, 2008) and contributes for 32% of total edible oil. Heterosis is the best method for enhancing crop variety. When compared to similar inbred species, cross-bred organisms typically exhibit greater size, vigour, fruitfulness, resistance to pests and diseases, or climatic vigour (Shull, 1952; Jinks and Jones, 1958). Combining ability analysis system is the sole effective or significant tool for this aim, as opposed to evaluating the value of parental lines to develop superior hybrids and valuable recombinants (Singh *et al.*, 2013). According to Nasrin *et al.* (2011), GCA effect was significant for plant height, days to 50% flowering and 1000-seed weight. With the exception of days to flowering and the quantity of seeds per siliquae, days to maturity and considerable SCA were also found for the entire trait. This study compares the relative significance of GCA and SCA variance and heterosis for yield and its contributing traits. According to Singh and Sharma (2017), the GCA and SCA combining

ability variance in Indian mustard were extremely significant for practically all of the characters, with emphasis on the high GCA for 1000 seed weight and oil content and the high SCA for seed yield and oil content. It has been extensively used to assess the performance of genotypes in hybrid combinations in agricultural plants using the line x tester mating design to determine the quantity and nature of gene action (Kempthorne, 1957). Most of the yield effect of GCA and the majority of the yield components are present in the combined ability evaluated; demonstrating the presence of additive gene action (Wos *et al.*, 1999). It is advantageous to cluster parental material with substantial heterosis in order to get genetic characteristics and yield when developing or producing new cultivars. It is important or necessary to know the ideal parental combinations that can exhibit a high degree of heterosis response (Kumar *et al.*, 2019). Effective selection requires knowledge of several characteristics, including heritability in a broad sense, phenotypic and genotypic coefficients of variation, and genetic advance as a percentage of mean (Lodhi, 2014). To achieve huge increases in output and productivity, heterosis breeding may be a practical solution. Since then, the commercial exploitation of heterosis in a variety of agricultural species has led to a significant increase in yield levels. If the heterosis is partially and economically feasible, it can help to obtain high yield levels, which will increase the output of oil in mustard. The magnitude of heterosis, specifically for yield, is of the paramount importance.

Materials and Methods

The experimental material consisted of five lines, viz., IC 571655, IC 424414, IC 311734, IC 598692, IC 447111 and three testers viz., Ashirwad, Geeta, CS 54 were collected from the National Bureau of Plant Genetic Resources, New Delhi and Indian Institute of Rapeseed Mustard Research, Bharatpur (Rajasthan). The experiments conducted at Experimental Farm, Mata Gujri College, Fatehgarh Sahib. It is situated at an altitude of 246 km above mean sea level at 30°27' and 30°46' North latitude and 76°04' and 76°38' East with annual precipitation rate is around 770 mm and soil is sandy loam. SBH-118 hybrid variety is used as a standard check. The competitive plants were selected randomly from each plot in each replication for recording the observations for all the characters. During the Rabi season of the years 2021–22 and 2022–23, all eight parents were crossed in a line x tester mating design as per the method suggested by Kempthorne (1957). The seeds were collected separately at maturity from all the crosses and stored for the next season. In the next season, the seeds collected from crosses along with parents were sown in the field under randomized block design (RBD) with three replications. The data were recorded on different traits including days to first flowering, days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, plant height (cm), number of siliquae per plant, siliquae length (cm), number of seeds per siliquae, days to maturity, biological yield per plant (g), harvest index (%) and seed yield per plant (g). The recorded data were subjected to analysis of variance to determine the genotypic difference for selected parameters.

Results and Discussion

Analysis of variance for combining ability

The analysis of variance for 8 parents (IC-571655, IC-424414, IC-311734, IC-598692, IC-447111, Ashirwad, Geeta, CS-54) and their 15 crosses was done for twelve yield and yield characters in the winter season of 2022-2023. The source of variation showed positive significance for all the yield traits.

General combining ability (GCA) and specific combining ability (SCA) analysis

The results of GCA effects are given in Table 1. The GCA effects allowed concluding that the experimental material lacked good general combiners for number of siliquae/plant, siliquae length and number of seeds/siliquae. The parents IC 571655, IC 424414 and Ashirwad showed positive GCA effects for seed yield and IC 311734, IC 447111 and IC 508692 showed negative significant GCA effect. The similar findings were reported by Teklewold and Becker, (2005). The results of specific combining ability (SCA) effects are presented in Table 2. The cross

Table 1: Estimates of General combining Ability (GCA) effects for yield and yield traits in *Brassica juncea* L.

Characters	Days to first flowering	Days to 50% flowering	Days to maturity	Primary branches/plant (no.)	Secondary branches per plant (no.)	Plant height (cm)	Siliquae per plant (no.)	Siliquae length (cm)	Seeds per siliqua (no.)	Biological yield/plant (g)	Seed yield/plant (g)	HI (%)
IC571655	14.061 **	0.443	1.484	1.082 *	3.003 **	-8.453 *	18.949	-0.418	1.622 **	54.723 **	33.496 **	-0.719
IC424414	-11.964 **	-8.395 **	1.837	-0.102	0.168	4.434	8.852	0.861 *	0.289	21.282 **	11.972 **	0.988
IC311734	13.109 **	4.487 *	7.202 *	-0.639	-0.470	6.541	11.153	-0.586	-0.274	-39.316 **	-18.317 **	1.334
IC508692	-4.517	3.694	-14.648 **	-0.028	-2.892 **	5.562	-9.180	-0.366	-0.719	4.878	-12.614 **	-5.741 **
IC447111	-10.689 **	-0.228	4.126	-0.314	0.191	-8.084 *	-29.774	0.510	-0.918	-41.567 **	-14.536 **	4.139 *
Ashirwad	5.572 *	-0.750	4.939	1.234 **	0.072	0.315	-18.678	0.017	-0.024	58.687 **	6.266 **	-1.272

Table 2: Estimates of Specific Combining Ability (SCA) effects for yield and yield traits in Brassica juncea L.

Characters	Days to first flowering	Days to 50% flowering	Days to maturity	Primary branches/plant (no.)	Secondary branches per plant (no.)	Plant height (cm)	Siliquae per plant (no.)	Siliquae length (cm)	Seeds per siliqua (no.)	Biological yield/plant (g)	Seed yield/plant (g)	HI (%)
IC 571655 x Ashirwad	-2.684	1.732	7.624	-1.297	-0.482	-3.457	-11.099	0.184	-0.482	-0.036	-6.119	0.317
IC 571655 x Geeta	0.567	-6.147	-0.265	1.564 *	2.850	5.472	18.760	0.076	0.050	-73.619 **	1.220	-2.122
IC 571655 x CS 54	2.117	4.415	-7.358	-0.266	-2.368	-2.015	-7.661	-0.260	0.432	73.655 **	4.899	1.804
IC 424414 x Ashirwad	-4.426	-6.674	1.904	0.887	1.310	-4.537	10.897	-0.105	-0.436	-44.375 **	-2.248	0.794
IC 424414 x Geeta	0.838	0.124	-3.445	-0.862	-1.971	-0.931	-26.790	0.260	0.830	45.285 **	1.008	-0.838
IC 424414 x CS 54	3.588	6.550	1.542	-0.025	0.661	5.469	15.893	-0.155	-0.395	-0.911	1.240	0.044
IC 311734 x Ashirwad	13.345 *	1.461	-3.121	0.567	0.418	-1.214	-1.267	0.419	0.301	25.720 **	4.147	-0.743
IC 311734 x Geeta	-3.477	1.472	7.114	-1.092	-1.543	-2.711	12.626	-0.120	0.050	7.613	-0.543	-3.355
IC 311734 x CS 54	-9.867	-2.932	-3.993	0.525	1.125	3.925	-11.358	-0.299	-0.352	-33.333 **	-3.604	4.098
IC 508692 x Ashirwad	-2.770	1.091	-2.251	-0.620	1.404	1.472	-7.524	-0.191	0.552	-10.737	2.624	-3.934
IC 508692 x Geeta	1.468	1.188	-11.366 *	0.130	0.369	-0.082	-7.948	0.263	-0.342	20.133 *	-1.103	7.444 *
IC 508692 x CS 54	1.302	-2.279	13.617 *	0.490	-1.772	-1.389	15.472	-0.072	-0.210	-9.396	-1.521	-3.510
IC 447111 x Ashirwad	-3.464	2.390	4.155	0.463	-2.650	7.737	8.993	-0.307	0.064	29.428 **	1.596	3.566
IC 447111 x Geeta	0.604	3.364	7.963	0.260	0.296	-1.747	3.352	-0.479	-0.590	0.588	-0.581	-1.129
IC 447111 x CS 54	2.860	-5.754	-3.807	-0.723	2.354	-5.990	-12.345	0.786	0.525	-30.015 **	-1.015	-2.437
CD 95% SCA	10.537	7.068	11.245	1.497	3.264	13.663	64.371	1.339	1.681	18.577	8.557	6.980

combinations namely, IC-571655 x CS 54 was found to be most significant for seed yield per plant followed by IC-311734 x Ashirwad and IC-508692 x Ashirwad, IC-447111 x Ashirwad and IC-424414 x CS 54. Similar findings have been reported by Bhushan *et al.* (2014) and Gupta *et al.* (2010) in Indian mustard.

Estimation of heterosis

Exploitation of hybrid vigour for yield characters content provides an individual opportunity to improve and develop hybrids for yield traits along with adaptability for specific production environments. Estimates of mean square for all the characters studied highly significant indicating wide genetic differences among the genotypes. The magnitude of heterosis has been expressed as a percent increase and decrease of F₁ generation over better parent (Heterobeltiosis) and standard check (standard heterosis) in Table 3, 4, 5.

Days to first flowering is desirable for significant negative heterosis. Two cross combinations ranging from -32.02 (IC-311734 x Geeta) to -39.60 (IC-311734 x CS 54) showed significant negative heterosis over better parent. A significant and high degree of heterosis for days to first flowering was observed in comparison to the better parent and the commercial genotypes as well. Thirteen cross combinations showed significant negative heterosis ranging from -20.20 (IC-571655 x CS 54) to -57.28 (IC-424414 x Geeta) over the commercial check. The similar findings were reported by Barupal *et al.* (2018). For days to 50% flowering, nine crosses showed significant negative heterosis ranging from -20.57 (IC-571655 x CS 54) to -37.62 (IC-424414 x Ashirwad) while none of the cross combination showed significant positive heterosis over better parent. Fifteen cross combinations ranging from -34.08 (IC-571655 x CS 54) to -58.52 (IC-424414 x Ashirwad) showed negative significant heterosis over commercial check. These findings were reported by Dholu *et al.* (2014). Eleven cross combinations ranging from -12.74 (IC-311734 x Ashirwad) to -33.47 (IC-447111 x CS 54) showed significant negative heterosis over better parent days to maturity. Seven cross combinations ranged -19.01 (IC-508692 x Ashirwad) to -27.03 (IC-571655 x CS 54) showed significant negative heterosis over commercial check. The present findings are in accordance with the findings of Dar *et al.* (2012), Barupal *et al.* (2018).

For number of primary branches per plant, one cross combination IC-424414 x Ashirwad (28.91) showed significant positive heterosis. Eight cross combinations namely from 53.28 (IC-424414 x Ashirwad) to 31.89 (IC-508692 x Ashirwad) showed significant positive heterosis over standard check. None of the cross combinations

Table 3: Estimation of percent heterosis based on days to first flowering, days to 50% flowering, days to maturity and number of primary branches per plant in *Brassica juncea* L.

Cross combinations	Days to first flowering				Days to 50% flowering				Days to maturity				Number of primary branches per plant			
	Mean	Better Parent	Standard	Check	Mean	Better Parent	Standard	Check	Mean	Better Parent	Standard	Check	Mean	Better Parent	Standard	Check
	IC 571655 x Ashirwad	63.15	-2.13	-15.8	-39.64 **	55.13	-27.27 **	-39.64 **	134.8	-5.91	0.35	9.27	14.02	38.36 *		
IC 571655 x Geeta	57.8	-10.43	-22.94 *	-48.42 **	47.11	-37.85 **	-48.42 **	133.9	-13.09 *	-0.33	9.51	16.97	41.94 *			
IC 571655 x CS 54	59.85	-7.26	-20.20 *	-34.08 **	60.21	-20.57 **	-34.08 **	98.02	-31.58 **	-27.03 **	9.22	13.41	37.61 *			
IC 424414 x Ashirwad	35.39	-27.98	-52.82 **	-58.52 **	37.89	-37.62 **	-58.52 **	129.44	-6.5	-3.65	10.27	28.91 *	53.28 **			
IC 424414 x Geeta	32.04	-19.89	-57.28 **	-51.23 **	44.54	-24.12 **	-51.23 **	131.07	-14.93 **	-2.43	5.9	31.99	-11.94			
IC 424414 x CS 54	35.29	-29.41	-52.94 **	-41.42 **	53.5	-13.24	-41.42 **	107.28	-19.18 **	-20.14 **	8.28	18.24	23.53			
IC 311734 x Ashirwad	78.23	0.72	4.31	-35.51 **	58.9	-34.55 **	-35.51 **	129.78	-12.74 *	-3.39	9.41	18.16	40.50 *			
IC 311734 x Geeta	52.8	-32.02 **	-29.60 **	-35.65 **	58.77	-34.70 **	-35.65 **	146.99	-4.59	9.42	5.13	19.38	-23.38			
IC 311734 x CS 54	46.91	-39.60 **	-37.45 **	-37.70 **	56.9	-36.77 **	-37.70 **	107.11	-27.99 **	-20.27 **	8.29	18.43	23.73			
IC 508692 x Ashirwad	44.49	-9.45	-40.68 **	-36.78 **	57.74	-4.93	-36.78 **	108.8	-21.41 **	-19.01 **	8.84	10.92	31.89 *			
IC 508692 x Geeta	40.12	0.3	-46.51 **	-36.83 **	57.69	-1.71	-36.83 **	106.66	-30.77 **	-20.60 **	6.97	20.11	3.98			
IC 508692 x CS 54	40.45	-19.09	-46.06 **	-37.85 **	56.76	-7.96	-37.85 **	102.87	-15.22 *	-23.42 **	8.87	26.67	32.34 *			
IC 447111 x Ashirwad	37.62	-23.43	-49.84 **	-39.65 **	55.12	-9.25	-39.65 **	125.67	-19.78 **	-6.45	9.63	20.92	43.78 **			
IC 447111 x Geeta	33.08	-17.29	-55.89 **	-38.74 **	55.95	-4.69	-38.74 **	144.77	-7.59	7.77	6.81	20.11	1.64			
IC 447111 x CS 54	35.84	-28.32	-52.21 **	-45.95 **	49.37	-19.95 *	-45.95 **	104.22	-33.47 **	-22.42 **	7.37	5.24	9.95			
S.E.Diff		7.2743	7.2743	4.8798		4.8798	4.8798		7.7634	7.7634		1.0338	1.0338			
C.D at 5%		14.9009	14.9009	9.9958		9.9958	9.9958		15.9026	15.9026		2.1176	2.1176			
C.D at 1%		20.101	20.101	13.4841		13.4841	13.4841		21.4523	21.4523		2.8566	2.8566			

Table 4: Estimation of percent heterosis based on number of secondary branches per plant, plant height, number of siliquae per plant and siliqua length in *Brassica juncea* L.

Cross combinations	Secondary branches per plant				Plant height				Number of siliquae per plant				Siliqua length			
	Mean	Better Parent	Standard Check	Mean	Better Parent	Standard Check	Mean	Better Parent	Standard Check	Mean	Better Parent	Standard Check	Mean	Better Parent	Standard Check	
IC 571655 x Ashirwad	21.23	21.62	22.7	169.4	-2.26	11.4	222.77	0.31	9.65	5.3	8.1	21.48				
IC 571655 x Geeta	22.82	30.75 *	31.91 *	174.11	4.32	14.49 *	257.65	16.02	26.82	5.27	23.02	20.95				
IC 571655 x CS 54	20.86	19.54	20.6	174.13	4.03	14.51 *	277.21	24.83	36.45	4.72	11.77	8.18				
IC 424414 x Ashirwad	20.18	33.22 *	16.67	181.21	1.99	19.16 **	234.67	28.58	15.5	6.29	9.33	44.19 *				
IC 424414 x Geeta	15.16	30.72	-12.35	180.59	1.65	18.76 **	202.01	10.69	-0.57	6.74	17.16	54.51 *				
IC 424414 x CS 54	21.06	25.96	21.71	194.5	9.47	27.90 **	290.67	59.27 *	43.07	6.1	6.09	39.91				
IC 311734 x Ashirwad	18.65	23.12	7.82	186.64	5.32	22.74 **	224.8	34.34	10.65	5.36	9.46	23.01				
IC 311734 x Geeta	14.95	28.91	-13.56	180.92	2.09	18.97 **	243.72	33.94	19.96	4.91	14.54	12.61				
IC 311734 x CS 54	20.88	24.93	20.71	195.06	10.07	28.27 **	265.72	61.00 *	30.79	4.51	15.54	3.44				
IC 508692 x Ashirwad	17.22	13.64	-0.48	188.35	8.31	23.86 **	198.21	12.94	-2.44	4.97	1.5	14.07				
IC 508692 x Geeta	14.44	24.51	-16.51	182.57	4.98	20.06 **	202.82	11.46	-0.17	5.51	28.62	26.45				
IC 508692 x CS 54	15.56	-6.9	-10.04	188.77	8.55	24.13 **	272.22	55.11 *	33.99	4.96	20.31	13.69				
IC 447111 x Ashirwad	16.25	7.24	-6.09	180.97	4.41	19.00 **	194.14	16.02	-4.44	5.73	17.01	31.5				
IC 447111 x Geeta	17.45	40.56 *	0.89	167.26	4.31	9.99	193.52	6.35	-4.75	5.65	25.67	29.51				
IC 447111 x CS 54	22.77	36.23 *	31.64 *	170.52	1.88	12.14	223.81	35.6	10.16	6.69	48.89 *	53.44 *				
S.E.Diff		2.2535	2.2535		9.433	9.433		44.4414	44.4414		0.9242	0.9242				
C.D at 5%		4.6161	4.6161		19.3228	19.3228		91.0345	91.0345		1.8931	1.8931				
C.D at 1%		6.2271	6.2271		26.066	26.066		122.8037	122.8037		2.5538	2.5538				

Table 5: Estimation of percent heterosis based on number of seeds per siliqua, biological yield, seed yield per plant and harvest index in *Brassica juncea* L.

Cross combinations	Number of seeds per siliqua				Biological yield				Seed yield per plant				Harvest index			
	Mean	Better Parent	Standard Check	Mean	Better Parent	Standard Check	Mean	Better Parent	Standard Check	Mean	Better Parent	Standard Check	Mean	Better Parent	Standard Check	
IC 571655 x Ashirwad	16.05	2.88	11.72	270.68	18.53 **	353.14 **	78.24	25.64 *	326.75 **	27.76	8.74	19.78				
IC 571655 x Geeta	16.39	5.06	14.08	91.37	-59.99 **	52.96 *	76.2	22.36 *	315.62 **	28.01	-12.52	20.89				
IC 571655 x CS 54	17.23	10.45	19.93 *	274.03	20.00 **	358.76 **	79.84	28.21 **	335.47 **	30.36	0.34	31.03				
IC 424414 x Ashirwad	14.76	1.61	2.76	192.9	11.28	222.93 **	60.58	34.84 *	230.45 **	29.94	-0.45	29.2				
IC 424414 x Geeta	15.84	8.99	10.23	176.83	26.30 **	196.03 **	54.46	21.21	197.05 **	31	-3.19	33.79				
IC 424414 x CS 54	15.07	3.72	4.9	166.03	18.58	177.95 **	54.65	21.64	198.11 **	30.31	0.17	30.8				
IC 311734 x Ashirwad	14.94	4.23	3.97	202.39	16.76 *	238.83 **	36.69	27.99	100.13 **	28.75	13.76	24.07				
IC 311734 x Geeta	14.49	1.14	0.88	78.56	22.12	31.52	22.62	26.56	23.38	28.83	-9.96	24.42				
IC 311734 x CS 54	14.55	1.54	1.28	73.01	13.49	22.22	19.52	19.44	6.47	34.71	14.71	49.78 *				
IC 508692 x Ashirwad	14.74	8.41	2.62	210.13	21.22 **	251.78 **	40.87	42.57 *	122.93 **	18.48	3.61	-20.24				
IC 508692 x Geeta	13.66	0.42	-4.94	135.27	17.63	126.46 **	27.76	35.1	51.44	32.56	1.67	40.49				
IC 508692 x CS 54	14.25	4.75	-0.84	141.14	22.73	136.28 **	27.31	32.88	48.95	20.03	-33.82 *	-13.58				
IC 447111 x Ashirwad	14.06	7.03	-2.16	203.85	17.60 *	241.27 **	37.92	32.28	106.84 **	35.86	13.68	54.76 *				
IC 447111 x Geeta	13.21	1.1	-8.05	69.28	24.16	15.99	26.36	47.5	43.8	33.86	5.75	46.13 *				
IC 447111 x CS 54	14.78	19.90 *	2.9	74.07	43.73	24.01	25.89	46.33	41.22	30.98	-1.8	33.69				
S.E.Diff		1.1603	1.1603		12.8256	12.8256		5.908	5.908		4.8191	4.8191				
C.D at 5%		2.3768	2.3768		26.2722	26.2722		12.1021	12.1021		9.8715	9.8715				
C.D at 1%		3.2062	3.2062		35.4407	35.4407		16.3255	16.3255		13.3165	13.3165				

exhibited significant negative useful heterosis standard check for this trait. These findings are in accordance with the Patel *et al.* (2010) and Meena *et al.* (2014). In case of number of secondary branches per plant, four cross combinations ranging from 30.75 (IC-571655 x Geeta) to 40.56 IC-447111 x Geeta showed significant positive heterosis while none of the cross combinations exhibited significant negative useful heterosis over better parent. Two cross combinations namely from 31.64 (IC-447111 x CS 54) to 31.91 (IC-571655 x Geeta) showed significant positive heterosis over standard check. The similar findings were reported by Aher *et al.* (2009). Similarly, twelve cross combinations ranging from 14.49 (IC-571655 x Geeta) to 28.27 (IC-311734 x CS 54) showed significant positive useful over commercial check while none of the cross combinations showed significant negative useful heterosis for plant height. These findings were reported by Meena *et al.* (2014). For number of siliquae per plant, three crosses showed significant positive useful heterosis ranged 55.11 (IC-508692 x CS 54) to 61.00 (IC-311734 x CS 54). The present studies are in accordance with reports of Akabari *et al.* (2017). For siliqua length, one cross showed significant positive heterosis namely IC-447111 x CS 54 (48.89) over better parent. Three crosses showed significant positive useful heterosis ranging from 44.19 (IC-424414 x Ashirwad) to 54.51 (IC-424414 x Geeta) over standard check. Present study is similar to the findings of Kumar *et al.* (2013).

For number of seeds per siliquae, one cross showed significant positive useful heterosis namely IC-447111 x CS 54 (19.90). One cross combination showed significant positive useful heterosis 19.93 (IC-571655 x CS 54) over standard check. The results of this study are in agreement with Mahto and Haider (2004). For biological yield per plant, seven crosses ranging from 17.60 (IC-447111 x Ashirwad) to 26.30 (IC-424414 x Geeta) showed significant positive heterosis while one cross namely IC-571655 x Geeta (-59.99) was found to be significant negative heterosis over better parent. Eleven crosses showed significant positive useful heterosis namely from 52.96 (IC-571655 x Geeta) to 358.76 (IC-571655 x CS 54) standard check. Similar findings have been reported by Gupta *et al.* (2010). For seed yield per plant, five crosses showed significant positive heterosis ranging from 22.36 (IC-571655 x Geeta) to 42.57 (IC-508692 x Ashirwad) heterosis for this trait. Nine crosses showed significant positive heterosis namely from 100.13 (IC-311734 x Ashirwad) to 335.47 (IC-571655 x CS 54) over standard check. These findings are in accordance with the results reported by Tripathi *et al.* (2016) and Bharti *et al.* (2018). For harvest index, none of the cross showed significant positive heterosis for harvest index while one cross showed

significant negative heterosis namely -33.82 (IC-508692 x CS 54) over better parent. Three crosses showed significant positive heterosis ranging from 46.13 (IC-447111 x Geeta) to 54.76 (IC-447111 x Ashirwad) over standard check. The similar findings were reported by Mahto and Haider (2004) and Dholu *et al.* (2014).

Conclusion

GCA effects revealed that the IC-571655 having significant and positive GCA effects was found to be the best combiner for most of the yield contributing traits, while on the basis of SCA, IC-571655 x CS 54 was recorded best specific combination for most of the yield contributing traits *viz.*, biological yield/plant, days to maturity, days to first flowering and number of primary branches/plant. It may conclude that IC-571655 is good general combiners and IC-571655 x CS 54 is a best cross combination for higher yield. On the basis of *per se* performance and estimates of heterosis, the IC-508692 x Ashirwad found to be most promising cross followed by IC-424414 x Ashirwad, IC-571655 x CS 54 and IC-571655 x Ashirwad for seed yield/plant, hence could be evaluated further to exploit the heterosis and utilized in future breeding programmes to obtain desirable and superior genotypes.

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