



Combining Ability and Heterosis Studies in Blackgram [*Vigna mungo* (L.) Hepper]

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ABSTRACT

Background: Blackgram is one of the important pulse crops. To improve the yield levels in this crop, studies on combining ability and heterosis are a method to select suitable parents based on their general and specific combining ability and heterotic effects for use in further breeding programmes.

Methods: The present investigation was conducted during Kharif 2019. The crosses were made in line $\times$ tester mating fashion during the summer season of 2019 for obtaining 15 (Fifteen) crosses. Fifteen hybrids and their parents (3 lines and 5 testers), including one check, were grown and eleven traits were recorded to estimate general and specific combining ability in the modified line $\times$ tester method.

Result: In the present investigation the predominance of non-additive gene effect in the expression of plant height, no. of clusters per plant, no. of pods per cluster, no. of pods per plant, seed yield per plant, biological yield per plant, 100 seed weight and harvest index was found. Among parents, KUP 18-346 and KUP 18-350, Pant U-31 were found to be good general combiner for seed yield and some other characters. Hybrids viz., KUP 18-350 $\times$ Pant U-31, KUP 18-345 $\times$ T-9 and KUP 18-345 $\times$ Uttara were found promising combinations for seed yield per plant. Hybrid, KUP 18-350 $\times$ Pant U-31 recorded significant standard heterosis, heterobeltiosis and average heterosis for most of the important characters.

Key words: Blackgram, Gene action, General combining ability, Heterosis, Line $\times$ Tester, Specific combining ability.

INTRODUCTION

Blackgram [*Vigna mungo* (L.) Hepper], also known as “urdbean”, “black matpe bean” and “mash” etc., is amongst the most important Kharif and Rabi pulse crops grown in India belonging to the family: Fabaceae. The pulse crop has chromosome number $2n = 2x = 22$ (Dana, 1980) and the estimated genome size is approximately 574 megabase pairs (Arumuganathan and Earle, 1991).

India is the primary centre of origin of Blackgram and Central Asia is believed to be the secondary centre of origin (De Candolle, 1882; Vavilov, 1926; Zuckovskij, 1962). As urdbean is a tropical crop, the production of blackgram (urdbean) is mostly confined to the Asian and African countries. India is the largest producer of urdbean followed by Myanmar, Thailand and Pakistan. India produces 70% of the world's total blackgram production (DA&FW, 2018).

Blackgram is one the most important crops among all the pulses grown in India. It is commonly consumed as ‘Da’ and flour. High values of lysine make urdbean a perfect complement to rice in terms of balanced human nutrition. Blackgram seed is a rich source of phosphoric acid, proteins and minerals. As per the report, the protein content in blackgram is approximately 24%, mineral 3.2%, fat 1.4%, carbohydrates 57.3% and moisture 9.7% (Aykroyd and Doughty, 1964).

One amongst the many reasons ascribed to the low productivity is the low yield potential of the available cultivars. Low yield potential is mainly due to the crop being cultivated on marginal lands, lack of high yielding and stable variety and negligence as it has less market value. It has also been

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suspected that the lack of variability is the main reason behind the poor progress made in breeding programs of pulse crops. However, the analysis of variation made on truly diverse germplasm provides the real facts of the amount of variation which would help in assessing the variability and factors for limited progress made in black gram (Konda *et al.*, 2009).

Kempthorne (1957) developed line $\times$ tester analysis, which is one of the breeding strategies used to predict parents' general combining ability (GCA) and select suitable parents and hybrids that have good specific combining ability (SCA). It additionally provides information about hereditary mechanisms controlling the important quantitative characters (Yildirim and Cakir, 1986). Information about the gca, sca and gene action aids in deciding breeding methods that can be followed to select suitable genotypes.

MATERIALS AND METHODS

The present study consists of five lines (females) viz., KUP 18 - 345, KUP 18 - 346, KUP 18 - 349, KUP 18 - 350 and KUP 18 - 352; three testers (males) viz., Pant U - 31, T9 and, Uttara; their 15 (Fifteen) hybrids and one check (LGB 632) of blackgram [*Vigna mungo* (L.) Hepper]. The crosses were made in line $\times$ tester mating fashion during the summer season of 2019 for obtaining 15 (Fifteen) crosses. Fifteen crosses, parents and one check were sown in a randomized block design with three replications during Kharif 2019 at the Breeder Seed Production Unit Farm, Department of Plant Breeding and Genetics, TCA, Dr. R.P.C.A.U, Pusa, Samastipur, Bihar, India to estimate the combining ability and heterosis using modified line $\times$ tester method.

Experimental data were recorded on five competitive plants in each replication for the traits under study which were randomly selected from each plot. Data were recorded for days to 50% flowering, plant height (cm), no. of clusters per plant, no. of pods per cluster, number of pods per plant, pod length (cm), no. of seeds per pod, seed yield per plant (g), biological yield per plant (g), 100 seed weight (g) and harvest index (%). The recorded data were analysed using the method given by Panse and Sukhatme (1984). The analysis of combining ability was carried out following the method suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant differences among the parents and their hybrids for all the characters studied, indicating the presence of substantial amount of genetic variability in the material studied. This will offer a better opportunity to the plant breeder for selecting desirable genotypes (Table 1) and (Table 2). Earlier workers viz., Kumar *et al.* (2017), Chauhan *et al.* (2018) found a similar result. The specific combining ability variance was higher than general combining ability variance and the ratio of SCA variance to GCA variance is higher than one for plant height, no. of clusters per plant, no. of pods per cluster, no. of pods per plant, seed yield per plant, biological yield per plant, 100 seed weight and harvest index, indicating a predominance of non-additive gene effect in the expression of these traits (Table 3). Govindraj and Subramanian (2001),

Vaithiyalingan *et al.* (2002), Santha and Arulmozhi (2003), Srividhya *et al.* (2005), Selvam and Elangaimannan (2010), Gill *et al.* (2014), Chakraborty *et al.* (2010) and Thamodharan *et al.* (2017) also reported involvement of non-additive genetic component in the expression of various characters.

On the other hand, GCA variance was higher than SCA variance for days to 50% flowering, pod length and no. of seeds per pod indicating involvement of additive gene effect in the inheritance of these characters. Chakraborty *et al.* (2010) and Surashe *et al.* (2017) also reported importance of additive genetic component in the expression of various traits.

Involvement of both additive and non-additive genetic components in the expression of different characters in blackgram had been also reported by Chand (2001), Thangavel *et al.* (2004), Karthikeyan *et al.* (2007), Ram *et al.* (2013) Shalini and Lal (2019) and Bharathi *et al.* (2019).

General combining ability

The GCA effects of the parents presented in Table 4 depicted that none of the parents were found to be good general combiner for all the characters. An overall assessment of GCA effects revealed that among the lines, KUP 18-350, KUP 18-352 and KUP 18-345 were found to be a good

Table 1: Analysis of variance for 11 yield and yield attributing traits in blackgram.

Characters	Mean sum of squares		
	Replication (df = 2)	Treatment (df = 23)	Error (df = 46)
Days to 50% flowering	0.10	3.27**	0.10
Plant height (cm)	10.86	50.39**	5.42
Number of clusters per plant	0.02	11.75**	0.91
Number of pods per cluster	0.01	0.21**	0.04
Number of pods per plant	1.59	29.36**	2.85
Pod length (cm)	0.01	0.23**	0.01
Number of seeds per pod	0.02	0.26*	0.08
Seed yield per plant (g)	0.49	1.39**	0.10
Biological yield per plant (g)	3.87	3.18**	0.31
100 seed weight (g)	0.35	0.14*	0.04
Harvest index (HI) (%)	10.86	41.02**	7.70

df = Degree of freedom, * = Significant at P = 0.05 and ** = Significant at P = 0.01.

Table 2: Analysis of variance of combining ability of 11 yield and yield attributing traits in blackgram.

Source of Variations	DF	DFF	PH	NCP	NPC	NPP	PL	NSP	SYP	BYP	SW	HI
Replicates	2	0.28*	1.97	1.03	0.06	1.40	0.01	0.02	0.27	1.83*	0.09	5.19
Crosses	14	3.98***	46.52***	12.96***	0.23***	35.81***	0.25***	0.23**	1.71***	3.17***	0.14**	45.46***
Line effect	4	10.83**	89.55	16.37	0.08	60.26	0.71**	0.56*	2.02	3.26	0.10	76.24
Tester effect	2	0.68	30.08	12.47	0.14	39.97	0.02	0.10	0.85	0.91	0.05	22.29
Line x tester effect	8	1.38***	29.12***	11.39***	0.33***	22.54***	0.07***	0.10	1.76***	3.69***	0.18**	35.86**
Error	28	0.07	4.98	0.78	0.03	4.22	0.01	0.06	0.12	0.36	0.04	9.27

* = Significant at P = 0.05, ** = Significant at P = 0.01 and *** = Significant at P = 0.001.

DFF = Days to 50% flowering, PH = Plant height, NCP = No. of clusters per plant, NPC = No. of pods per cluster, NPP = No. of pods per plant, PL = Pod length, NSP = No. of seeds per pod, SYP = Seed yield per plant, BY = Biological yield per plant, TW = 100 seed weight and HI = Harvest index.

Table 3: Variance components and degree of dominance for 11 yield and yield attributing traits in blackgram.

Characters	Mean sum of squares			Degree of Dominance
	Var. GCA	Var. SCA	GCA/SCA	
Days to 50% flowering	0.472	0.427	1.105	0.673
Plant height (cm)	4.533	7.900	0.574	0.933
Number of clusters per plant	1.126	3.493	0.322	1.245
Number of pods per cluster	0.006	0.099	0.061	2.772
Number of pods per plant	3.939	6.563	0.600	0.913
Pod length (cm)	0.030	0.023	1.304	0.615
Number of seeds per pod	0.021	0.008	2.625	0.427
Seed yield per plant (g)	0.111	0.556	0.200	1.579
Biological yield per plant (g)	0.149	1.129	0.132	1.950
100 seed weight (g)	0.003	0.049	0.061	2.824
Harvest index (HI) (%)	3.464	9.387	0.369	1.164

Table 4: General combining ability effects of parents for 11 yield and yield attributing traits in blackgram.

Parents	Trait										
	DFF	PH	NCP	NPC	NPP	PL	NSP	SYP	BYP	SW	HI
Lines											
KUP 18-350	-0.77***	-2.46**	-1.88***	0.12	-2.75***	0.47***	0.26**	0.56***	-0.85***	-0.02	-2.40*
KUP 18-352	-0.66***	-1.68*	-0.16	-0.12	-1.95**	-0.16***	-0.24*	-0.39***	0.42*	-0.15*	-3.73***
KUP 18-346	1.88***	5.17***	1.87***	0.07	3.64***	0.01	-0.02	0.59***	0.55**	0.14*	2.94**
KUP 18-349	0.00	0.82	0.38	-0.05	1.40*	-0.06	0.24*	0.24*	0.27	0.02	1.18
KUP 18-345	-0.44***	-1.84*	-0.21	-0.01	-0.35	-0.24***	-0.24*	0.12	-0.40*	0.01	2.01*
CD 5%	0.21	1.59	0.65	0.13	1.15	0.06	0.19	0.21	0.37	0.13	1.89
Testers											
Pant U-31	-0.24**	1.55*	0.44	0.08	1.86***	0.03	0.07	0.11	0.11	0.05	0.38
T-9	0.08	-1.22	-1.04***	0.02	-1.16*	-0.04	0.02	-0.27**	-0.28	-0.06	-1.36
Uttara	0.15	-0.32	0.60 *	-0.11*	-0.70	0.01	-0.08	0.16	0.16	0.01	0.97
CD 5%	0.16	1.23	0.50	0.10	0.89	0.05	0.15	0.16	0.29	0.10	1.46

* = Significant at P = 0.05, ** = Significant at P = 0.01 and *** = Significant at P = 0.001.

DFF = Days to 50% flowering, PH = Plant height, NCP = No. of clusters per plant, NPC = No. of pods per cluster, NPP = No. of pods per plant, PL = Pod length, NSP = No. of seeds per pod, SYP = Seed yield per plant, BY = Biological yield per plant, TW = 100 seed weight and HI = Harvest index.

general combiner for days to 50% flowering and plant height, here early flowering and short stature plants are desirable. Line KUP 18-346 was found to be a good combiner for no. of clusters per plant, no. of pods per plant, seed yield per plant, biological yield per plant, 100 seed weight and harvest index. Line KUP 18-350 was found to be a good combiner for Pod length, no. of seeds per pod and seed yield per plant. Line KUP 18-352 was found to be a good combiner for biological yield per plant, KUP 18-349 for no. of pods per plant and KUP 18-345 for harvest index.

Among the testers, Pant U-31 was found to be a good combiner for days to 50% flowering and no. of pods per plant, while Uttara for no. of clusters per plant.

Specific combining ability

The estimates of SCA effects presented in Table 5 revealed that out of 15 crosses only three cross combinations viz., KUP 18-350 X Pant U-31, KUP 18-345 X T-9 and KUP 18-345 X Uttara exhibited positive significant SCA effect for

seed yield per plant. Out of 15 crosses, two crosses viz., KUP 18-349 X Pant U-31 (-0.53) and KUP 18-352 X T-9 (-1.20) exhibited significant negative SCA effect for days to 50% flowering, indicated the possibility to develop the early maturity blackgram varieties. Beside this, three crosses viz., KUP 18-345 X Pant U-31 (-4.99), KUP 18-352 X T-9 (-2.91) and KUP 18-349 X Uttara (-3.78) exhibited significant negative SCA effect for plant height, indicated the possibility to develop short stature blackgram varieties. Four crosses viz., KUP 18-350 X Pant U-31 (2.80), KUP 18-349 X T-9 (1.82), KUP 18-346 X Uttara (1.68) and KUP 18-345 X Uttara (1.50) exhibited significant positive SCA effect for no. of clusters per plant; three crosses viz., KUP 18-350 X Pant U-31 (0.32), KUP 18-346 X Pant U-31 (0.23) and KUP 18-345 X T-9 (0.30) exhibited significant positive SCA effect for no. of pods per cluster; two crosses viz., KUP 18-350 X Pant U-31 (3.17) and KUP 18-345 X T-9 (3.20) exhibited significant positive SCA effect for no. of pods per plant; three crosses viz., KUP 18-349 X Pant U-31 (0.16), KUP 18-352

Table 5: Specific combining ability effects of crosses for 11 yield and yield attributing traits in blackgram.

Crosses	DFF	PH	NCP	NPC	NPP	PL	NSP	SYP	BYP	SW	HI
KUP 18-350 × Pant U-31	-0.08	1.02	2.80***	0.32**	3.17**	0.02	-0.09	1.01***	1.61***	0.09	3.64*
KUP 18-352 × Pant U-31	0.80***	1.58	-0.44	-0.03	0.44	-0.18**	0.08	0.25	-0.12	-0.14	2.14
KUP 18-346 × Pant U-31	0.24	-0.68	-0.82	0.23*	1.97	-0.10	0.12	0.16	-0.18	0.22	1.72
KUP 18-349 × Pant U-31	-0.53**	3.07*	0.33	-0.03	-1.37	0.16**	-0.07	-0.12	0.35	-0.06	-1.77
KUP 18-345 × Pant U-31	-0.42*	-4.99***	-1.86**	-0.48***	-4.22***	0.10	-0.04	-1.31***	-1.66***	-0.11	-5.74**
KUP 18-350 × T-9	0.24	-0.39	-1.37*	-0.42***	-1.39	-0.00	0.22	-0.61**	-1.33***	0.15	-1.40
KUP 18-352 × T-9	-1.20***	-2.91*	0.04	0.01	-0.52	0.22***	-0.06	-0.11	-0.04	-0.04	-0.63
KUP 18-346 × T-9	-0.08	-0.24	-0.86	0.151	-2.66*	-0.01	0.04	-0.39*	-0.02	-0.36**	-2.26
KUP 18-349 × T-9	0.80***	0.71	1.82**	-0.04	1.38	-0.21***	-0.21	0.32	-0.12	0.26*	2.30
KUP 18-345 × T-9	0.24	2.84*	0.36	0.30**	3.20**	0.00	0.00	0.80***	1.51***	-0.00	2.00
KUP 18-350 × Uttara	-0.15	-0.62	-1.42*	0.10	-1.78	-0.02	-0.13	-0.40*	-0.28	-0.24*	-2.24
KUP 18-352 × Uttara	0.40*	1.32	0.39	0.01	0.08	-0.03	-0.02	-0.14	0.16	0.18	-1.50
KUP 18-346 × Uttara	-0.15	0.93	1.68**	-0.38**	0.68	0.12*	-0.17	0.23	0.20	0.14	0.54
KUP 18-349 × Uttara	-0.26	-3.78**	-2.16***	0.08	-0.00	0.04	0.28	-0.19	-0.23	-0.20	-0.53
KUP 18-345 × Uttara	0.17	2.15	1.50*	0.17	1.01	-0.11	0.04	0.51**	0.14	0.11	3.73*
CD 5%	0.37	2.75	1.12	0.22	1.99	0.12	0.34	0.37	0.65	0.23	3.28

* = Significant at P = 0.05, ** = Significant at P = 0.01 and *** = Significant at P = 0.001"

DFF = Days to 50% flowering, PH = Plant height, NCP = No. of clusters per plant, NPC= No. of pods per cluster, NPP= No. of pods per plant, PL= Pod length, NSP= No. of seeds per pod, SYP= Seed yield per plant, BY= Biological yield per plant, TW= 100 seed weight and HI= Harvest index.

X T-9 (0.22) and KUP 18-346 X Uttara (0.12) exhibited significant positive SCA effect for pod length; three crosses viz., KUP 18-350 X Pant U-31 (1.01), KUP 18-345 X T-9 (0.80) and KUP 18-349 X Uttara (0.51) exhibited significant positive SCA effect for seed yield per plant; two crosses viz., KUP 18-350 X Pant U-31 (1.61) and KUP 18-345 X T-9 (1.51) exhibited significant positive SCA effect for biological yield per plant; two crosses viz., KUP 18-350 X Pant U-31 (3.64) and KUP 18-345 X Uttara (3.73) exhibited significant positive SCA effect for harvest index. None of the crosses recorded significant positive SCA effects for no. of seeds per pod and 100 seed weight.

The cross with the highest SCA effects for seed yield per plant was KUP 18-350 X Pant U-31. This cross has also shown significant SCA effects in the desirable direction for no. of clusters per plant, no. of pods per cluster, no. of pods per plant, seed yield per plant, biological yield per plant and harvest index. Another important cross combination KUP 18-345 X T-9 showed significant SCA effect in the desired direction for no. of pods per cluster, no. of pods per plant, seed yield per plant and biological yield per plant.

Heterosis

The estimate of heterosis in blackgram is essential to identify the superior hybrids in first-generation. Additionally, the magnitude of heterosis helps to determine genetic diversity and serves as a guide to selecting desirable parents. Both positive and negative heterosis are essential for genetic advancement in crop improvement programs, depending on the breeding objectives. In general, positive heterosis is desirable for yield and most traits, whereas negative heterosis is desirable for earliness.

Out of 15 crosses, ten crosses viz., KUP 18-350 X Pant U-31 (-4.55), KUP 18-352 X Pant U-31 (-1.82), KUP 18-349 X Pant U-31 (-3.64), KUP 18-345 X Pant U-31 (-4.55), KUP 18-350 X T-9 (-2.73), KUP 18-352 X T-9 (-6.36), KUP 18-350 X Uttara (-3.64), KUP 18-352 X Uttara (-1.82), KUP 18-349 X Uttara (-1.82) and KUP 18-345 X Uttara (-1.82) exhibited significant standard heterosis for days to 50% flowering in the desirable direction.

Five crosses viz., KUP 18-350 X Pant U-31 (17.24), KUP 18-346 X Pant U-31 (21.64), KUP 18-349 X T-9 (14.17), KUP 18-345 X T-9 (16.04) and KUP 18-346 X Uttara (14.10) exhibited significant positive average heterosis; only one cross, KUP 18-346 X Pant U-31 (19.76) exhibited significant positive heterobeltiosis for number of pods per plant. None of the crosses showed significant heterobeltiosis in the desirable direction for this trait.

Eight crosses viz., KUP 18-350 X Pant U-31 (13.48), KUP 18-346 X Pant U-31 (12.36), KUP 18-349 X Pant U-31 (13.48), KUP 18-350 X T-9 (17.98), KUP 18-346 X T-9 (10.11), KUP 18-349 X T-9 (10.11), KUP 18-350 X Uttara (10.11) and KUP 18-349 X Uttara (16.85) exhibited significant positive standard heterosis for number of seeds per pod.

Six crosses viz., KUP 18-350 X Pant U-31 (15.26), KUP 18-346 X Pant U-31 (9.89), KUP 18-349 X T-9 (19.25), KUP 18-345 X T-9 (24.87), KUP 18-346 X Uttara (9.42) and KUP 18-345 X Uttara (9.33) exhibited significant positive average heterosis; only one cross, KUP 18-345 X T-9 (13.51) exhibited significant positive heterobeltiosis for seed yield per plant. None of the crosses showed significant heterobeltiosis in the desirable direction for this trait (Table 6). Thomas *et al.* (2008), Thamodharan *et al.* (2016) and Ram *et al.* (2013) have found similar kinds of results from their experiment.

Table 6: Mid-parent heterosis (HM), Heterobeltiosis (HB) and Standard heterosis (HC) for 11 yield and yield attributing traits in blackgram.

Hybrids	Days to 50% flowering			Plant height (cm)		
	HM	HB	HS	HM	HB	HS
KUP 18-350 × Pant U-31	-3.23**	-5.41**	-4.55**	1.29	0.13	8.00
KUP 18-352 × Pant U-31	0.93	0.00	-1.82*	6.08	5.10	10.76*
KUP 18-346 × Pant U-31	4.59**	1.79*	3.64**	8.80**	3.93	20.28**
KUP 18-349 × Pant U-31	0.47	0.00	-3.64**	12.44**	11.93**	19.03**
KUP 18-345 × Pant U-31	-1.87**	-2.78**	-4.55**	-11.81**	-15.22**	-3.17
KUP 18-350 × T-9	-0.93	-3.60**	-2.73**	2.93	-7.93 *	-0.69
KUP 18-352 × T-9	-3.29**	-4.63**	-6.36**	1.54	-7.47	-4.28
KUP 18-346 × T-9	5.07**	1.79*	3.64**	14.96**	-0.25	15.43**
KUP 18-349 × T-9	5.71**	5.71**	0.91	13.26**	1.95	8.41*
KUP 18-345 × T-9	1.41*	0.00	-1.82*	7.68*	-6.04	7.31
KUP 18-350 × Uttara	-3.64**	-4.50**	-3.64**	-4.26	-6.65	0.69
KUP 18-352 × Uttara	-0.46	-0.92	-1.82*	3.28	2.80	6.34
KUP 18-346 × Uttara	3.17**	1.79*	3.64**	9.73**	3.46	19.72**
KUP 18-349 × Uttara	0.93	-0.92	-1.82*	-3.3	-5.06	0.97
KUP 18-345 × Uttara	-0.46	-0.92	-1.82*	-0.57	-5.68	7.72

Contd....

Hybrids	Number of clusters per plant			Number of pods per cluster		
	HM	HB	HS	HM	HB	HS
KUP 18-350 × Pant U-31	9.39	4.02	3.1	25.37**	10.53	16.67*
KUP 18-352 × Pant U-31	-0.24	-6.25	-7.08	-2.94	-13.16*	-8.33
KUP 18-346 × Pant U-31	0.00	-4.47	3.98	12.68*	5.26	11.11
KUP 18-349 × Pant U-31	9.00	2.68	1.77	1.49	-10.53	-5.56
KUP 18-345 × Pant U-31	-6.47	-16.07**	-16.81**	-24.32**	-26.32**	-22.22**
KUP 18-350 × T-9	-18.68**	-26.73**	-34.51**	-7.69	-16.67*	-16.67*
KUP 18-352 × T-9	8.64	-1.02	-13.72*	0.00	-8.33	-8.33
KUP 18-346 × T-9	3.92	-13.82**	-6.19	10.14	5.56	5.56
KUP 18-349 × T-9	27.78**	16.16*	1.77	1.54	-8.33	-8.33
KUP 18-345 × T-9	17.06**	11.80	-11.95*	8.33	8.33	8.33
KUP 18-350 × Uttara	-20.74**	-25.86**	-23.89**	22.03**	20.00*	0.00
KUP 18-352 × Uttara	4.90	-3.02	-0.44	3.33	3.33	-13.89*
KUP 18-346 × Uttara	15.06**	11.79*	21.68**	-11.11	-15.15*	-22.22**
KUP 18-349 × Uttara	-9.30	-15.95**	-13.72*	11.86	10.00	-8.33
KUP 18-345 × Uttara	17.56**	3.88	6.64	6.06	-2.78	-2.78

Contd....

Hybrids	Number of pods per plant			Pod length (cm)		
	HM	HB	HS	HM	HB	HS
KUP 18-350 × Pant U-31	17.24**	4.42	-9.77*	12.90**	4.82**	20.57**
KUP 18-352 × Pant U-31	5.6	-2.7	-15.92**	0.24	-0.96	0
KUP 18-346 × Pant U-31	21.64**	19.76**	6.79	6.75**	5.98**	5.98**
KUP 18-349 × Pant U-31	5.94	2.95	-11.04*	7.44**	2.85	10.82**
KUP 18-345 × Pant U-31	-10.37*	-14.00*	-25.69**	4.25*	2.04	5.01*
KUP 18-350 × T-9	-5.9	-9.33	-33.97**	10.26**	2.67	18.09**
KUP 18-352 × T-9	-2.04	-2.04	-28.66**	7.83**	6.88**	7.92**
KUP 18-346 × T-9	1.7	-7.62	-17.62**	6.73**	6.30**	6.30**
KUP 18-349 × T-9	14.17**	8.07	-11.89*	-3.36*	-7.20**	0
KUP 18-345 × T-9	16.04**	11.23	-11.68*	-0.08	-1.88	0.97
KUP 18-350 × Uttara	-7.96	-13.33*	-33.76**	8.57**	3.23	18.74**
KUP 18-352 × Uttara	0.14	-2.22	-25.27**	0.39	-0.93	2.75
KUP 18-346 × Uttara	14.10**	5.95	-5.52	8.80**	6.85**	10.82**
KUP 18-349 × Uttara	7.8	4.43	-14.86**	1.6	-0.3	7.43**
KUP 18-345 × Uttara	6.27	4.28	-17.20**	-3.99*	-4.36*	-0.81

Contd....

Contd....

Hybrids	Number of seeds per pod			Seed yield per plant (g)		
	HM	HB	HS	HM	HB	HS
KUP 18-350 × Pant U-31	9.19**	5.21	13.48**	15.26**	3.46	-6.14
KUP 18-352 × Pant U-31	-0.52	-1.03	7.87	2.07	-8.02	-16.55**
KUP 18-346 × Pant U-31	6.95*	4.17	12.36**	9.89*	9.36	-0.78
KUP 18-349 × Pant U-31	7.45*	5.21	13.48**	2.87	-3.02	-12.01*
KUP 18-345 × Pant U-31	0.00	-2.08	5.62	-25.80**	-28.48**	-35.11**
KUP 18-350 × T-9	16.67**	15.38**	17.98**	-17.25**	-19.14**	-41.66**
KUP 18-352 × T-9	-1.06	-4.12	4.49	-1.18	-3.85	-30.02**
KUP 18-346 × T-9	7.69*	7.69	10.11*	3.93	-8.21	-17.53**
KUP 18-349 × T-9	7.10*	6.52	10.11*	19.25**	10.73	-11.04*
KUP 18-345 × T-9	2.73	2.17	5.62	24.87**	13.51*	-4.46
KUP 18-350 × Uttara	3.70	-2.00	10.11*	-16.77**	-26.86**	-30.34**
KUP 18-352 × Uttara	-6.60*	-8.00*	3.37	-8.00	-18.85**	-22.72**
KUP 18-346 × Uttara	-2.62	-7.00	4.49	9.42*	6.33	1.26
KUP 18-349 × Uttara	8.33*	4.00	16.85**	-0.32	-8.11	-12.49*
KUP 18-345 × Uttara	-3.13	-7.00	4.49	9.33*	2.98	-1.93

Contd....

Hybrids	Biological yield per plant (g)			100 seed weight (g)		
	HM	HB	HS	HM	HB	HS
KUP 18-350 × Pant U-31	14.28 **	9.50 **	-3.75	9.54 *	8.72	6.91
KUP 18-352 × Pant U-31	0.70	-4.25	-6.64 *	-0.14	-1.50	-3.13
KUP 18-346 × Pant U-31	2.51	-1.40	-6.17 *	19.52 **	17.06 **	15.12 **
KUP 18-349 × Pant U-31	9.39 **	8.54 *	-4.59	5.92	5.62	3.87
KUP 18-345 × Pant U-31	-8.77 **	-10.80 **	-21.60 **	-0.49	-4.64	2.30
KUP 18-350 × T-9	-7.00 *	-7.24 *	-24.90 **	8.13 *	7.42	5.44
KUP 18-352 × T-9	2.31	-6.37 *	-8.70 **	-0.52	-1.78	-3.59
KUP 18-346 × T-9	4.83	-2.99	-7.69 *	-0.67	-2.63	-4.42
KUP 18-349 × T-9	7.35 *	3.89	-10.10 **	12.04 **	11.83 *	9.77 *
KUP 18-345 × T-9	16.38 **	14.29 **	-4.02	-0.49	-4.73	2.21
KUP 18-350 × Uttara	-3.64	-10.98 **	-15.41 **	-6.34	-11.71 **	-3.41
KUP 18-352 × Uttara	-0.82	-2.09	-4.53	2.02	-4.38	4.61
KUP 18-346 × Uttara	1.53	1.45	-3.46	9.59 *	2.02	11.61 *
KUP 18-349 × Uttara	1.40	-3.12	-7.95 **	-4.63	-9.69 *	-1.20
KUP 18-345 × Uttara	0.72	-5.13	-9.86 **	-0.72	-1.68	7.56

Contd....

Hybrids	Harvest index (HI) (%)		
	HM	HB	HS
KUP 18-350 × Pant U-31	-1.47	-9.59	-3.09
KUP 18-352 × Pant U-31	-2.78	-16.91**	-10.94
KUP 18-346 × Pant U-31	5.82	-0.75	6.38
KUP 18-349 × Pant U-31	-8.37	-14.31*	-8.15
KUP 18-345 × Pant U-31	-19.65**	-22.41**	-16.83*
KUP 18-350 × T-9	-11.02	-12.77	-21.91**
KUP 18-352 × T-9	-5.55	-11.04	-23.49**
KUP 18-346 × T-9	0.61	-3.61	-9.51
KUP 18-349 × T-9	9.61	5.33	-1.74
KUP 18-345 × T-9	7.35	-0.09	-0.26
KUP 18-350 × Uttara	-13.97*	-19.12**	-17.75**
KUP 18-352 × Uttara	-9.29	-20.74**	-19.40**
KUP 18-346 × Uttara	7.12	3.00	4.74
KUP 18-349 × Uttara	-0.61	-4.71	-3.11
KUP 18-345 × Uttara	10.17	9.16	11.00

df = Degree of freedom, * = Significant at P = 0.05 and ** = Significant at P = 0.01.

HM= Average heterosis, HB= Heterobeltiosis and HS= Standard heterosis.

CONCLUSION

The variance due to specific combining ability was higher than variance due to general combining ability in most of the traits, which indicates the predominance of non-additive gene effect in these traits. Among parents, KUP 18-346 and KUP 18-350, Pant U-31 were found to be good general combiner showing significant GCA effect in desirable direction for seed yield and some other characters. These genotypes could be used to develop pure line varieties. Hybrids viz., KUP 18-350 X Pant U-31, KUP 18-345 X T-9 and KUP 18-345 X Uttara recorded significant positive SCA effect for seed yield per plant. The crosses could be used in future breeding programs. The estimate of heterosis revealed that the hybrid KUP 18-350 X Pant U-31 recorded significant standard heterosis, heterobeltiosis and average heterosis for most of the important characters and could be used for exploitation of heterosis.

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