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STUDIES ON GENE ACTION AND HETEROSIS FOR YIELD AND YIELD ATTRIBUTES IN BLACKGRAM (*Vigna mungo* L. Hepper)

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ABSTRACT

To identify parents with high combining ability and to select hybrids that show superior performance in blackgram, twenty-four crosses derived by crossing six lines and four testers effected in line x tester analysis at ARS, Madhira were subjected to combining ability and heterosis studies. The study revealed predominance of non-additive gene action for plant height, no. of clusters per plant, 100 seed weight, biological yield, harvest index, days to 50 % flowering and days to maturity. The lines LBG-904, VBN-8 and TBG-104 and tester IC-436762 were identified as good combiners for seed yield per plant and also for no. of pods per plant, 100 seed weight, biological yield and harvest index. Crosses LBG-904 x LBG-787, VBN-8 x MASH-114, VBN-8 x IC-436762, TU-68 x LBG-787, TU-68 x MASH-114, and TB4-104 x IC-436762 were found significantly favorable specific combiners for seed yield per plant as well as plant height, no. of pods per plant, pod length, 100 seed weight, biological yield and harvest index. The Superior crosses LBG-904 x LBG-787, VBN-8 x IC-436762, TBG-104 x IC-436762 and VBN-8 x MASH-114 recorded significant standard heterosis, heterobeltiosis and average heterosis for most of the important characters such as 100 seed weight, harvest index and seed yield per plant which could be utilized for the development of superior varieties.
***Keywords* :** Blackgram, LxT Analysis, GCA, SCA, Gene action, Heterosis.

Introduction

Kharif pulses are vital to Indias food security providing sustainable path for soil health and environment. Blackgram (*Vigna mungo* L. Hepper) is an important pulse crop grown in India belonging to leguminaceae family with a chromosome number 2n=22. It plays a important role in terms of nutrition with protein (20-26%), carbohydrates (57%), fat (1.41%), minerals (3.2%) (Priyanka et. al. 2022). In India, during 2025-26 the crop is grown in an area of about 3.15 mha with a production of 2.24 MT. (AICRP *Kharif* Pulses-Annual Report, 2025-26). Being short duration crop, it has special advantage of growing during all seasons *Kharif*, *Rabi*, *Summer*, *Ricefallows* and as inter and multi cropping systems. Lack of stable and high yielding diversified varieties is a major bottleneck for growing this crop, hence identification of best parents and superior crosses is an important task for pulse breeders. Kempthorne(1957) developed Line X Tester analysis a breeding strategy to select best lines and testers by general combining ability (GCA) and choosing superior crosses that have good specific combining ability (SCA) for crop improvement programme. GCA reveals the presence of additive gene effects, which indicate that a parent is likely to produce superior offspring regardless of specific cross. SCA reveals the presence of non-additive gene effects which are responsible for hybrid vigor. In addition, heterosis measures the degree to which a hybrid is superior to its parents for a given trait. Therefore the objective of the present study was to unravel to identify desirable parents to be used in multiple and specific hybrid crosses that exhibit the most promising heterosis for effective crop improvement programme in blackgram.

Materials and Methods

The experimental material comprised of high yielding and diversified six lines *viz.*, LBG-752, GBG-

1, TU-68, VBN-8, LBG-904 and TBG-104 and four testers *viz.*, PU-31, IC 436768, and LBG- 787 and MASH - 114 were crossed in L x T design. All the six lines, four testers and 24 crosses were grown in RBD with two replications at Agricultural Research Station, Madhira during *Rabi*, 2022. Each entry was sown in two rows of 4m length with 30x10 cm spacing. All the recommended cultural practices were followed to obtain healthy crop. Observations were recorded on five randomly selected plants without boarder effect for eleven yield attributes plant height(cm), no. of clusters per plant, no. of pods per plant, pod length(cm), no. of seeds per pod, 100 seed weight(g), biological yield(g), harvest index(%) and seed yield per plant(g) except for days to 50% flowering and days to maturity on plot basis. The data was subjected to statistical analysis. Analysis for Line x Tester was carried out using Windostat software as per the procedure suggested by Kempthorne (1957) along with heterosis estimates (Hays *et al*., 1955).

Results and Discussion

Analysis of variance

The analysis of variance of Line x Tester for eleven yield attributing traits were presented in Table-1. The Anova revealed that the mean squares due to parents were shown significant for yield and its attributes except for pod length at P= 0.01 or 0.05 level. Lines were recorded significance for all traits except no. of pods per plant and pod length. Testers have shown significance for most of the traits except no. of clusters per plant. The mean square due to line x tester interaction showed significance for all the important yield attributing traits except for days to maturity and 100 seed weight. This revealed that all the traits shown significant variation and was controlled by both additive and non-additive type of gene action. Hence any approach that facilitates simultaneous exploitation of both additive and non-additive gene effects would be more desirable for the improvement of the traits. (Rukminidevi *et al*., 2025). The greater magnitude of SCA variance than GCA variance indicated the role of non-additive gene action for all the eleven characters. Similar results were reported by Thamodharan *et al.* (2017) and Chakraborty *et al.* (2010) for plant height, days to 50% flowering, days to maturity, no. of clusters per plant and 100 seed weight were governed by non-additive gene-action.

Table 1 : Analysis of variance for combining ability in Line x Tester design for 11 yield and yield attributing traits in blackgram (*Vigna mungo* L. Hepper)

Source of variation	DF	DFF	DM	PH	NCP	NPP	PL	NSP	100SW	BY	HI	SYP
Replicates	2	0.71	2.12	1.64	0.62	6.70	0.11	1.09	0.01	0.22	1.09	0.03
Treatments	33	20.59**	25.70**	115.88**	1.93**	12.62**	0.16**	1.22**	0.78**	11.56**	353.02**	7.03**
Parents	9	25.70**	13.88**	59.31**	2.10**	9.68**	0.07	1.12**	0.56**	16.94**	183.99**	2.03**
Parents (Line)	5	22.58**	15.28**	34.14**	2.75**	5.28	0.05	1.25*	0.54**	5.96**	43.55**	2.01**
Parents (Testers)	3	11.00**	16.08**	71.28**	0.75	9.55**	0.11*	1.11*	0.78**	11.57**	41.50**	2.71**
Parents (L vs T)	1	85.42**	0.27	149.24**	2.93*	32.08**	0.02*	0.55*	0.01	87.92**	1313.65**	0.06**
Parents vs Crosses	1	9.72**	146.53**	3.52	1.26	70.31**	0.06	2.97	0.26	4.51**	28.66**	0.01**
Crosses	23	19.06**	25.07**	142.90**	1.90**	11.26**	0.19**	1.18**	0.89**	9.77**	433.27**	9.30**
Line effect	5	20.12	42.14	316.10*	2.32	8.92	0.33	1.12	0.40	14.37	312.77	14.39
Tester effect	3	13.88	12.75	66.87	0.55	24.48	0.02	0.60	2.13	4.32	593.12	10.57
Line × Tester effect	15	19.74**	21.84**	100.36**	2.03**	9.40**	0.18**	1.31**	0.81**	9.32**	441.46**	7.34**
Error	66	0.91	2.53	3.28	0.45	2.29	0.04	0.76	0.05	0.09	3.46	0.04
Total	101	7.33	10.09	40.04	0.94	5.75	0.08	0.92	0.29	3.84	117.62	2.32

DFF: Days to 50 percent flowering, **DM**: Days to maturity, **PH**: Plant height (cm), **NCP**: Number of clusters per plant**, NPP**: Number of pods per plant, **PL:** Pod length (cm), **NSP**: Number of seeds per plant, **100 SW**: 100 seed weight (g), **BY**: Biological yield (g), **HI**: Harvest Index (%) and **SYP**: Seed yield per plant (g).

General Combining Ability

The GCA effects of both lines and testers are depicted in Table-2 shown that among the six lines and four testers studied neither the lines nor the testers recorded significant positive GCA for all the quantitative traits. Based on the combining ability effects, the lines and testers values were categorized in three groups as Good (G), Average (A) and Poor (P) general combiners. The parents with significant GCA effects were considered as good general combiners, while positive GCA effects were noted as average general combiners. The parents with negative GCA effects were designated as poor general combiners. The line LBG-904 was found to be good general combiner which had recorded significant positive general combiners for important traits seed yield per plant followed by no. of pods per plant, plant height, pod length, biological yield and harvest index whereas negative significant for days to maturity in desired directions. Therefore, the line can be used for developing the early maturity lines with high yield. Similar results were also reported by Patel *et al.* (2010). The line TBG-104 has also shown significant positive GCA for seed yield per plant and biological yield. The results obtained are in accordance with the results of Panigrahi *et al.* (2015), Toppo *et al.* (2020). Another line VBN-8 was found positive GCA for seed yield per plant was recorded significant positive GCA for traits no. of clusters per plant, no. of pods per plant, 100 seed weight and biological yield whereas negative significant GCA effects for days to 50% flowering, days to maturity and plat height, therefore this line can be used for developing dwarf stature, early duration variety with high yield. The results were in accordance with studies reported by Haque *et al.* (2013), Thamodharan *et al.* (2016), Toppo *et al.* (2020) and Debbarma *et al.* (2022).

Similarly, the tester IC-436762 was a good general combiner showing positive significant GCA effects for seed yield per plant, no. of pods per plant, 100 seed weight, biological yield and harvest index. The negative estimates of GCA for the tester PU-3l for days to maturity and plant height were effective for developing early and short stature plant type in desirable direction.

Table 2 : Estimation of general combing ability (GCA) effects in parents for yield andyield components in blackgram(*Vigna mungo* L. Hepper)

Parents	DFF	DM	PH	NCP	NPP	PL	NSP	100 SW	BY	HI	SYP
LINES											
LBG - 752	-0.97**	1.23*	-2.32**	-0.26	0.29	-0.02	0.70**	0.06	-0.99**	1.75**	-0.39**
TBG - 104	1.11**	-0.43	-3.06**	-0.18	-1.37**	-0.22**	-0.45	0.06	1.28**	-0.99	0.63**
GBG - 1	-0.05	2.90**	-3.54**	-0.18	-1.45**	-0.12	-0.45	-0.19**	-1.06**	-2.56**	-0.96**
VBN - 8	-1.88**	-1.51**	-1.43**	0.56**	1.29**	-0.02	0.12	0.26***	0.46**	-1.70**	0.01
TU - 68	1.61**	0.06	0.26	-0.18	0.20	0.21**	-0.29	-0.23**	-0.16	-6.39**	-0.97**
LBG - 904	0.19	-2.26**	10.11**	0.23	1.04*	0.17**	0.37	0.03	0.48*	9.90**	1.69**
SE (Lines)	0.27	0.46	0.52	0.20	0.44	0.06	0.23	0.06	0.08	0.56	0.05
(gi-gj)	0.39	0.65	0.74	0.29	0.62	0.09	0.33	0.09	0.12	0.80	0.08
TESTERS											
PU - 31	0.88**	-0.98*	-2.56**	-0.34*	-1.34**	-0.03	-0.09	0.10	0.10	0.16	-0.02
IC - 436762	0.38	0.23	0.82	0.15	0.76*	-0.01	0.06	0.42**	0.98**	2.99**	1.00**
LBG - 787	-1.16**	1.01*	1.95**	0.31	0.20	-0.00	-0.04	-0.14*	-0.48**	0.32	-0.16**
MASH - 114	-0.11	-0.26	-0.22	-0.12	0.37	0.05	0.06	-0.38**	-0.60**	-3.48**	-0.80**
SE (Testers)	0.22	0.37	0.43	0.16	0.35	0.05	0.19	0.05	0.06	0.46	0.04
(gi-gj)	0.32	0.53	0.60	0.23	0.51	0.07	0.27	0.07	0.09	0.65	0.06

DFF: Days to 50 percent flowering, **DM**: Days to maturity, **PH**: Plant height (cm), **NCP**: Number of clusters per plant**, NPP**: Number of pods per plant, **PL:** Pod length (cm), **NSP**: Number of seeds per plant, **100 SW**: 100 seed weight (g), **BY**: Biological yield (g), **HI**: Harvest Index (%) and **SYP**: Seed yield per plant (g).

Specific Combining Ability

SCA is the deviation from the performance predicted on the basis of general combining ability and is due to non- additive gene effect. The usefulness of a particular cross in exploiting heterosis is judged by SCA effects presented in Table-3. Significant positive highest SCA effects for seed yield per plant was recorded by crosses LBG- 904 x LBG-787 (2.92), VBN-8 X IC-436762 (2.50), TBG-104 X IC-436762(2.44), VBN- 8 X MASH - 114 (1.14) , GBG-1 x PU-31 (0.93). Therefore, these crosses can be used to develop varieties with high seed yield. In addition, the cross LBG-904 x LBG-787 was found to be a good specific combiner for plant height, no. of pods per plant, pod length, no. of seeds per pod, 100 seed weight, biological yield, harvest index and seed yield per plant. The cross VBN-8 X IC-436762 for no. of seeds per pod, harvest index, seed yield per plant and negative for plant height, TBG-104 X IC-436762 for no. of seeds per pod, biological yield and seed yield per plant, VBN-8 X MASH-114 recorded significant SCA effects for plant height, no. of cluster per plant, 100 seed weight, biological yield, harvest index and seed yield per plant where as negative significant SCA for days to 50% flowering, GBG-1 X PU-31 showed for 100 seed weight, harvest index and seed yield per plant, TU-68 X LBG-787 for 100 seed weight, biological yield, harvest index and seed yield per plant and negative for days to 50% flowering. Hence, these crosses can be used as specific combiner to develop varieties with high seed yield. The results obtained are in similar with the findings of Srividhya *et al.* (2005), Selvam *et al.* (2010), Gill *et al.* (2014), Reddy *et al.* (2021), Singh *et al.* (2022), Surendhar *et al.* (2023) and Rukminidevi *et al.* (2025). However, no cross combined all the values in a desirable direction indicating the necessity of previous breeding value of the parent to combine desirable SCA effects in a single cross. Majority of the crosses with high SCA effects are involved with high x low combinations indicating additive x dominance, dominance x dominance type of gene interactions. Similar findings are recorded by Yashpal *et al.* (2015), Prasad and Murugan (2015), Ragul *et al.* (2021), Nandini *et al.* (2022) and Singh *et al.* (2022).

Table 3 : Estimation of specific combining ability (SCA) effects in hybrids for yield and yield components in blackgram(*Vigna mungo* L. Hepper)

Crosses	DFF	DM	PH	NCP	NPP	PL	NSP	100SW	BY	HI	SYP
LBG-752 × PU-31	0.52	-0.84	0.62	0.59	0.43	-0.10	0.01	0.25	-0.71**	5.25**	0.33**
LBG-752 × IC-436762	-1.63**	0.26	-4.50**	-0.56	-2.34*	0.10	-0.48	0.35*	-0.30	-5.41**	-0.89**
LBG-752 × LBG-787	-0.08	-1.18	-1.33	0.93*	0.20	0.10	-0.37	-0.49**	-0.30	1.22	-0.09
LBG-752 × MASH-114	1.19*	1.76	5.21**	-0.95*	1.70	-0.10	0.84	-0.09	1.31**	-1.06	0.64**
TBG-104 × PU-31	-0.22	2.15*	3.16**	0.18	-2.23*	0.0	-0.81	-0.01	-0.59**	0.02	-0.28*
TBG-104 × IC-436762	-0.72	1.93*	-0.32	0.01	-0.68	-0.22	1.34**	-0.06	3.59**	2.03	2.44**
TBG-104 × LBG-787	1.83**	-0.84	-3.22**	-0.48	1.54	-0.03	0.45	-0.16	-2.04**	2.09	-1.01**
TBG-104 × MASH-114	-0.88	-3.23**	0.38	0.29	1.37	0.16	-0.98*	0.24	-0.95**	-4.15**	-1.14**
GBG-1 × PU-31	0.94	1.48	1.08	-0.15	-0.48	0.19	0.51	0.37**	-0.34	8.30**	0.93**
GBG-1 × IC-436762	0.77	-0.73	2.68*	-0.31	2.40**	0.00	-0.31	-0.14	-1.15**	-2.49*	-1.02**
GBG-1 × LBG-787	-2.66**	-0.84	-1.34	0.51	-1.70	-0.03	-0.20	-0.31*	0.80**	-6.46**	-0.42**
GBG-1 × MASH-114	0.94	0.09	-2.42*	-0.04	-0.20	-0.16	0.01	0.09	0.69**	0.65	0.51**
VBN-8 × PU-31	2.11**	1.56	0.39	-1.23**	1.43	0.12	-0.06	0.18	1.19**	-14.26**	-1.39**
VBN-8 × IC-436762	-0.38	-3.31**	-0.16	0.26	-0.01	0.10	1.43**	0.09	-0.89**	21.67**	2.50**
VBN-8 × LBG-787	1.83**	2.90**	-2.65*	0.09	-1.12	-0.10	-1.45**	-0.67**	-0.69**	-14.22**	-2.25**
VBN-8 × MASH-114	-3.55**	-1.15	2.42*	0.87*	-0.29	-0.13	0.09	0.39**	0.39*	6.82**	1.14**
TU-68 × PU-31	-2.05**	-3.01**	-1.86	0.51	0.51	-0.03	0.68	-0.78**	0.81**	-6.60**	-0.41**
TU-68 × IC-436762	2.77**	3.76**	-4.58**	0.01	0.73	-0.16	-0.81	-0.00	-0.90**	-1.26	-0.71**
TU-68 × LBG-787	-4.33**	1.31	-1.01	-0.15	-0.70	-0.30*	0.29	0.69**	0.46**	4.86**	0.86**
TU-68 × MASH-114	3.61**	-2.06*	7.46**	-0.37	-0.54	0.50 **	-0.15	0.09	-0.38*	3.01*	0.26*
LBG-904 × PU-31	-1.30*	-1.34	-3.41**	0.09	0.34	-0.27*	-0.31	-0.01	-0.35*	7.30**	0.82**
LBG-904 × IC-436762	-0.80	-1.90*	6.89**	0.59	-0.09	0.17	-1.15*	-0.20	-0.34	-14.52**	-2.31**
LBG-904 × LBG-787	3.41**	-1.34	9.56**	-0.90*	1.79*	0.36**	1.29**	0.96**	1.75**	12.50**	2.92**
LBG-904 × MASH-114	-1.30*	4.59**	-13.05**	0.20	-2.04*	-0.26*	0.18	-0.73**	-1.05**	-5.20**	-1.43 *
SE (Crosses)	0.55	0.93	1.05	0.41	0.88	0.12	0.47	0.13	0.17	1.13	0.11
SE (Sij-skl)	0.78	1.31	1.49	0.58	1.24	0.18	0.67	0.19	0.24	1.60	0.16
SE (Sij-sik)	1.04	1.74	1.97	0.77	1.64	0.24	0.88	0.25	0.32	2.12	0.22

DFF: Days to 50 percent flowering, **DM**: Days to maturity, **PH**: Plant height (cm), **NCP**: Number of clusters per plant**, NPP**: Number of pods per plant, **PL:** Pod length (cm), **NSP**: Number of seeds per plant, **100 SW**: 100 seed weight (g), **BY**: Biological yield (g), **HI**: Harvest Index (%) and **SYP**: Seed yield per plant (g).

Heterosis

The estimates of mid parent heterosis, heterobeltiosis and standard heterosis for yield and its attributes were depicted in Table-4. The results disclosed that out of 24 crosses, five crosses LBG-752 X IC-436762, LBG-752 X LBG-787, GBG-1 X LBG-787, VBN-8 X IC-436762 and VBN-8 X MASH-114 exhibited significant negative average heterosis, heterobeltiosis and standard heterosis for days to 50% flowering, the crosses LBG-752 X IC-436762, LBG-752 X LBG-787, TBG-104 X LBG- 787, GBG-1 X LBG-787, GBG-1 X MASH-114, VBN-8 X LBG-787, LBG-904 X MASH-114 for plant height. These crosses are desirable for development of earliness and short plant stature type. The cross LBG-752 X MASH-114 has recorded significant positive heterosis for no. of clusters per plant and also for the trait no. of pods per plant along with VBN-8 X PU-31. None of the crosses have recorded significant positive for mid parent heterosis, standard and heterobeltiosis for the traits pod length and no. of seeds per pod. The crosses LBG-752 X IC-436762, VBN-8 X IC-436762 and LBG-904 X LBG-787 have recorded significant positive for all the types of heterosis for the trait 100 seed weight. Biological yield has shown significant positive heterosis for crosses TBG-104 X IC-436762 followed by VBN-8 X PU-31. Four crosses *i.e.*, VBN-8 X IC-436762, VBN-8 X LBG-787, LBG-904 X PU-31 and LBG-904 X LBG-787 have recorded positive significant average heterosis, standard heterosis and heterobeltiosis for harvest index. The crosses TBG-104 X IC-436762, VBN-8 X IC-436762, LBG-904 X PU-31 and LBG-904 X LBG-787 have recorded significant positive heterosis for the trait seed yield per plant. The results obtained are in accordance with the results found by Vijay Kumar *et al.* (2017) and Rukminidevi *et al.* (2025). It was found that majority of the crosses having high SCA effects exhibited high heterosis. The cross VBN-8 X IC-436762 recorded significant heterosis for traits such as 100 seed weight, harvest index, seed yield per plant while negative for days to 50% flowering. The crosses showing significant SCA effects have best chances for producing transgressive segregates. All the crosses with high heterosis involved either one high or low GCA line or tester. Based on the analysis, superior crosses identified were VBN-8 X IC-436762, TBG-104 X IC-436762, VBN-8 X MASH-114 and LBG-904 X LBG-787.

Table 4 : Estimation of Mid parent Heterosis (MH), Heterobeltiosis (HB) and Standard heterosis (SH) for yield and yield components in blackgram(*Vigna mungo* L. Hepper)

Crosses	Days to 50 % flowering			Days to maturity			Plant height (cm)		
	MH	HB	SH	MH	HB	SH	MH	HB	SH
LBG-752 × PU-31	-3.40*	-5.88**	-0.78	3.84*	2.68	2.68	-5.01	-21.84**	-19.16**
LBG-752 × IC-436762	-7.34**	-11.76**	-6.98**	7.73**	7.24**	5.80**	-23.04**	-27.41**	-24.92**
LBG-752 × LBG-787	-4.38**	-11.76**	-6.98**	3.75*	0.43	4.91**	-14.56**	-15.50**	-10.63*
LBG-752 × MASH-114	-1.93	-6.62**	-1.55	9.84**	9.59**	7.14**	10.29*	0.43	3.88
TBG-104 × PU-31	-4.00**	-9.59**	2.33	4.00*	3.54*	4.46*	5.59	-11.11*	-13.18*
TBG-104 × IC-436762	-4.09**	-11.64**	0.00	6.04**	4.87**	5.80**	-8.65	-11.45*	-13.51**
TBG-104 × LBG-787	1.15	-9.59**	2.33	0.43	-1.28	3.13	-20.74**	-23.77**	-19.38**
TBG-104 × MASH-114	-5.58**	-13.01**	-1.55	-0.90	-2.65	-1.79	-6.49	-12.59*	-14.62**
GBG-1 × PU-31	-0.38	-2.94	2.33	7.08**	6.14**	8.04**	-9.36	-26.12**	-21.71**
GBG-1 × IC-436762	0.39	-4.41*	0.78	6.46**	4.82**	6.70**	-3.98	-10.45*	-5.09
GBG-1 × LBG-787	-8.37**	-15.44**	-10.85**	4.33**	2.99	7.59**	-19.46**	-19.54**	-14.73**
GBG-1 × MASH-114	-0.39	-5.15**	0.00	7.62**	5.26**	7.14**	-22.04**	-29.78**	-25.58**
VBN-8 × PU-31	0.78	0.78	0.78	3.62*	2.23	2.23	-5.54	-23.86**	-16.94**
VBN-8 × IC-436762	-3.97*	-6.20**	-6.20**	-0.68	-1.36	-2.68	-7.89	-15.23**	-7.53
VBN-8 × LBG-787	0.82	-4.65*	-4.65*	5.75**	2.14	6.70**	-18.14**	-19.39**	-12.07*
VBN-8 × MASH-114	-12.70**	-14.73**	-14.73**	2.29	2.29	-0.45	0.57	-10.56*	-2.44
TU-68 × PU-31	1.59	-0.78	-0.78	-0.23	-1.79	-1.79	8.43	-2.14	-18.83**
TU-68 × IC-436762	14.63**	14.63**	9.30**	11.42**	10.41**	8.93**	-4.50	-9.06	-16.61**
TU-68 × LBG-787	-3.36	-6.50**	-10.85**	5.99**	2.14	6.70**	4.93	-6.39	-1.00
TU-68 × MASH-114	15.45**	15.45**	10.08**	3.45*	3.21	0.45	42.88**	41.20**	19.93**
LBG-904 × PU-31	-1.56	-2.33	-2.33	-4.80**	-6.84**	-2.68	19.39**	-5.76	8.75
LBG-904 × IC-436762	0.80	-0.79	-2.33	-3.30*	-5.98**	-1.79	48.98**	33.69**	54.26**
LBG-904 × LBG-787	10.74**	5.51**	3.88*	-4.27**	-4.27*	0.00	50.93**	44.63**	66.89**
LBG-904 × MASH-114	-1.60	-3.15	-4.65*	5.31**	1.71	6.25**	-15.64**	-26.78**	-15.50**

Crosses	Number of clusters per plant			Number of pods per plant			Pod length (cm)		
	MH	HB	SH	MH	HB	SH	MH	HB	SH
LBG-752 × PU-31	6.98	-8.00	-11.54	5.88*	4.13	5.88	-1.74	-3.42	-19.86**
LBG-752 × IC-436762	2.44	-8.70	-19.23**	3.70	0.00	5.88	-0.83	-4.00	-14.89**
LBG-752 × LBG-787	18.18**	0.00	0.00	3.59	-2.99	9.24**	3.90	2.56	-14.89**
LBG-752 × MASH-114	46.34**	30.43**	15.38*	10.66**	6.30*	13.45**	-2.93	-4.92	-17.73**
TBG-104 × PU-31	-6.38	-12.00	-15.38*	-7.00*	-7.38*	-5.04	-4.24	-8.13	-19.86**
TBG-104 × IC-436762	2.22	0.00	-11.54	0.00	-1.59	4.20	-16.13**	-16.80**	-26.24**
TBG-104 × LBG-787	-8.33	-15.38*	-15.38*	0.78	-3.73	8.40**	-7.17	-10.57*	-21.99**
TBG-104 × MASH-114	2.22	0.00	-11.54	3.61	1.57	8.40**	-3.67	-4.07	-16.31**
GBG-1 × PU-31	-10.64	-16.00*	-19.23**	-0.42	-2.48	-0.84	-0.83	-6.30	-15.60**
GBG-1 × IC-436762	15.56*	13.04	0.00	9.92**	5.56	11.76**	-9.52*	-10.24*	-19.15**
GBG-1 × LBG-787	4.17	-3.85	-3.85	12.80**	5.22	18.49**	-6.22	-11.02*	-19.86**
GBG-1 × MASH-114	-2.22	-4.35	-15.38*	2.06	-2.36	4.20	-10.84**	-12.60**	-21.28**
VBN-8 × PU-31	12.00*	12.00	7.69	7.76**	6.45*	10.92**	3.00	0.00	-14.89**
VBN-8 × IC-436762	-8.33	-12.00	-15.38*	3.20	2.38	8.40**	-2.04	-4.00	-14.89**
VBN-8 × LBG-787	1.96	0.00	0.00	0.00	-3.73	8.40**	-2.56	-5.00	-19.15**
VBN-8 × MASH-114	12.50*	8.00	3.85	5.18*	3.94	10.92**	-4.96	-5.74	-18.44**
TU-68 × PU-31	-9.80	-11.54	-11.54	2.02	0.00	5.88	5.17	2.52	-13.48**
TU-68 × IC-436762	-6.12	-11.54	-11.54	5.56*	5.56	11.76**	-2.46	-4.80	-15.60**
TU-68 × LBG-787	-11.54*	-11.54	-11.54	-2.31	-5.22	6.72*	-1.29	-3.36	-18.44**
TU-68 × MASH-114	-14.29*	-19.23**	-19.23**	1.19	0.79	7.56*	17.01**	15.57**	0.00

LBG-904 × PU-31	0.00	-8.00	-11.54	6.67*	5.79	7.56*	-0.44	-1.72	-19.15**
LBG-904 × IC-436762	18.18**	13.04	0.00	8.57**	5.56	11.76**	6.22	2.40	-9.22*
LBG-904 × LBG-787	-6.38	-15.38*	-15.38*	8.30**	2.24	15.13**	16.52**	15.52**	-4.96
LBG-904 × MASH-114	9.09	4.35	-7.69	2.44	-0.79	5.88	-1.68	-4.10	-17.02**

Crosses	Number of seeds per pod			100 seed weight (g)			Biological yield (g)		
	MH	HB	SH	MH	HB	SH	MH	HB	SH
LBG-752 × PU-31	21.43	6.25	6.25	3.79	2.24	9.60*	-18.35**	-26.14**	-21.76**
LBG-752 × IC-436762	-3.23	-6.25	-6.25	26.27**	14.62**	19.20**	-2.35	-5.73**	-13.19**
LBG-752 × LBG-787	-6.25	-6.25	-6.25	-18.94**	-20.15**	-14.40**	-10.11**	-21.35**	-10.11**
LBG-752 × MASH-114	-17.24	-25.00	-25.00	-6.28	-13.85**	-10.40*	-16.37**	-28.90**	-12.97**
TBG-104 × PU-31	12.00	7.69	-12.50	-4.80	-5.84	3.20	-0.12	-11.20**	-5.93**
TBG-104 × IC-436762	14.29	6.67	0.00	12.76**	0.00	9.60*	46.10**	38.42**	27.47**
TBG-104 × LBG-787	-3.45	-12.50	-12.50	-13.65**	-14.60**	-6.40	-15.75**	-27.50**	-17.14**
TBG-104 × MASH-114	0.00	0.00	-18.75	-0.81	-10.95*	-2.40	-2.79	-18.67**	-0.44
GBG-1 × PU-31	-3.45	-17.65	-12.50	3.50	-0.75	6.40	-13.30**	-24.27**	-19.78**
GBG-1 × IC-436762	-25.00*	-29.41*	-25.00	10.92*	3.25	1.60	-5.78**	-12.41**	-19.34**
GBG-1 × LBG-787	-27.27*	-29.41*	-25.00	-18.29**	-21.64**	-16.00**	-13.18**	-26.54**	-16.04**
GBG-1 × MASH-114	-13.33	-23.53	-18.75	-5.17	-10.57*	-12.00*	-11.67**	-27.29**	-10.99**
VBN-8 × PU-31	16.67	16.67	-12.50	8.88*	5.22	12.80**	32.20**	12.45**	19.12**
VBN-8 × IC-436762	-18.52	-26.67	-31.25*	28.14**	18.40**	18.40**	3.30	-6.68**	-14.07**
VBN-8 × LBG-787	-28.57*	-37.50**	-37.50**	-16.60**	-19.40**	-13.60**	-10.72**	-26.35**	-15.82**
VBN-8 × MASH-114	20.00	15.38	-6.25	13.68**	6.40	6.40	-7.93**	-26.03**	-9.45**
TU-68 × PU-31	11.11	0.00	-6.25	-20.82**	-27.61**	-22.40**	-5.32**	-11.41**	-6.15**
TU-68 × IC-436762	-26.67*	-26.67	-31.25*	19.82**	17.12**	4.00	-4.17**	-4.29*	-11.65**
TU-68 × LBG-787	-9.68	-12.50	-12.50	9.39*	0.00	7.20	-21.49**	-29.04**	-18.90**
TU-68 × MASH-114	-7.14	-13.33	-18.75	-0.91	-1.80	-12.80**	-18.12**	-28.19**	-12.09**
LBG-904 × PU-31	-28.57*	-37.50**	-37.50**	8.47	-4.48	2.40	-12.27**	-14.73**	-9.67**
LBG-904 × IC-436762	-22.58	-25.00	-25.00	26.92**	24.53**	5.60	0.23	-3.74*	-3.74*
LBG-904 × LBG-787	-18.75	-18.75	-18.75	27.12**	11.94**	20.00**	-6.26**	-12.12**	0.44
LBG-904 × MASH-114	10.34	0.00	0.00	-12.80*	-15.60**	-26.40**	-4.94**	-13.64**	5.71**

Crosses	Harvest index (%)			Seed yield per plant (g)		
	MH	HB	SH	MH	HB	SH
LBG-752 × PU-31	13.31**	4.99	9.08**	-6.72**	-9.13**	-15.19**
LBG-752 × IC-436762	5.24*	-7.84**	-4.25	3.24	-6.69**	-17.41**
LBG-752 × LBG-787	-5.81*	-15.41**	-12.11**	-13.82**	-16.21**	-21.48**
LBG-752 × MASH-114	3.58	-11.35**	-7.90**	-10.79**	-11.52**	-20.37**
TBG-104 × PU-31	-4.69*	-14.54**	-4.52	-3.41	-4.37*	-10.74**
TBG-104 × IC-436762	9.33**	-7.13**	3.75	60.91**	43.32**	31.11**
TBG-104 × LBG-787	-0.50	-13.42**	-3.27	-14.00**	-15.02**	-20.37**
TBG-104 × MASH-114	-22.57**	-35.66**	-28.12**	-21.63**	-22.27**	-28.89**
GBG-1 × PU-31	6.99**	-3.86	6.90*	-5.74**	-8.73**	-14.81**
GBG-1 × IC-436762	-1.34	-16.03**	-6.64*	-5.83**	-14.41**	-25.19**
GBG-1 × LBG-787	-15.28**	-26.12**	-17.86**	-24.34**	-26.88**	-31.48**
GBG-1 × MASH-114	-12.18**	-26.88**	-18.70**	-19.00**	-20.16**	-28.15**
VBN-8 × PU-31	-36.59**	-39.57**	-40.88**	-15.44**	-25.00**	-30.00**
VBN-8 × IC-436762	66.17**	49.40**	46.16**	73.71**	72.82**	24.81**
VBN-8 × LBG-787	31.96**	21.77**	19.12**	20.09**	6.32**	-0.37
VBN-8 × MASH-114	15.98**	1.83	-0.38	10.50**	-0.41	-10.37**
TU-68 × PU-31	-19.03**	-22.47**	-24.89**	-23.17**	-25.00**	-30.00**
TU-68 × IC-436762	1.76	-8.12**	-10.98**	-2.54	-12.08**	-21.85**
TU-68 × LBG-787	14.17**	5.83*	2.52	-9.53**	-11.86**	-17.41**
TU-68 × MASH-114	-7.70**	-18.62**	-21.16**	-22.98**	-23.46**	-31.11**
LBG-904 × PU-31	33.21**	25.06**	26.31**	17.02**	12.92**	13.33**
LBG-904 × IC-436762	5.09*	-6.83*	-5.90*	4.74*	-10.33**	-10.00**
LBG-904 × LBG-787	47.44**	34.10**	35.43**	39.31**	34.69**	35.19**
LBG-904 × MASH-114	-13.36**	-24.96**	-24.21**	-16.34**	-20.66**	-20.37**

MH: Mid parent Heterosis, **HB**: Heterobeltiosis, **SH**: Standard Heterosis

Conclusion

Additive as well as non-additive gene effects are of paramount importance in governing yield and its components with predominance of non-additive gene action for most of the yield traits. In this context, pedigree method of selection would be effective when the trait is governed by both additive and non-additive components. Population improvement methods like reciprocal recurrent selection may allow to accumulate the fixable & non-fixable effects to the most effective method. 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. Estimation of GCA effects revealed that the lines, LBG-904 and TBG-104 and the tester IC-436762 had high positive significance for seed yield/plant which were considered as good general combiners and can be used to develop pure line varieties. Estimation of SCA effects revealed that the crosses LBG-904 X LBG-787, VBN-8 X MASH-114, VBN-8 X IC-436762, TU-68 X LBG-787, TU-68 X MASH-114 and TBG-104 X IC-436762 were found to be best specific combiners for seed yield/plant. The crosses could be used in future breeding programs. The crosses VBN-8 X IC-436762, LBG-904 X LBG-787 and TBG-104 X IC-436762 not only recorded significant SCA effects but also exhibited positive significance for all three types of heterosis (Mid parent heterosis, Heterobeltiosis, Standard heterosis).

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