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Parental Selection, Combining Ability Effects and Gene Action for Yield and Earliness in Blackgram [*Vigna mungo* (L.) Hepper]

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ABSTRACT: Combining ability studies were carried out in blackgram comprising of six diverse parents and their 15 F_1 crosses generated through diallel mating design for twelve yield, yield attributing traits along with earliness. The results indicated that both additive and non-additive gene actions played a major role in the inheritance of the traits. Among the parents, TBG-104 and LBG-752 were found to be good general combiners for yield attributing characters, TU-40 was the best choice for earliness and these parents could be exploited for producing desirable recombinants in the segregating generations for yield and earliness. The crosses LBG-752 × TBG-104, LBG-752 × PU-31, LBG-752 × TU-40, TU-40 × TBG-104 and IPU-2-43 × TBG-104 were found to be the best combinations for improvement of yield as evident from their mean performances and *sca* effects. The crosses TU-40 × TBG-104 and IPU-2-43 × TBG-104 were the best combinations for early flowering. By and large, among all the crosses LBG-752 × TBG-104 was found to be the best cross for utilization in breeding programs aimed at developing high yielding short duration cultivars.

Keywords: Blackgram, combining ability, gene action, yield, yield components, earliness

INTRODUCTION

Pulses constitute an important component of the vegetarian diet in the Indian sub-continent and occupies a significant role in Indian farming since times immortal. Blackgram [*Vigna mungo* (L.) Hepper] (2n=22) is third widely grown pulse crops of India after chickpea and redgram. Blackgram accounts for 13 per cent of total pulse area and 10 per cent of total pulse production in India with an area of about 5.60 M ha, production of 3.06 M t and productivity of 546 kg ha^{-1} (Anonymous, 2018-19). Andhra Pradesh is one of the leading blackgram growing states of India with an area of 3.81 lakh hectares, production of 3.13 lakh tonnes and productivity of 821.5 kg ha^{-1} (Anonymous, 2018-19). Despite being the largest producer, India is also the largest importer and consumer of pulses in the world. The country has experienced progressive decline in per capita availability of pulses from 60.7 g day^{-1} in 1951 to 56.0 g day^{-1} in 2019-20 as against the WHO's recommendation of 80 g day^{-1}. This decline is mainly attributed to the steady marginalization of cultivation of pulse crops in the wake of the green revolution that poses a great risk to the country's nutritional security. This situation alarms a daunting need to break this bottleneck by developing high yielding varieties. In this bleak scenario of demand, supply and consumption imbalances, the pulse production needs to be boosted up in order to meet the requirements of increasing population. It can only be achieved by increasing area and productivity of pulses.

However, 87% of the area under blackgram is rainfed and as a result, crop often faces terminal moisture stress that causes yield losses up to 30%. Early flowering and maturity not only provide an escape mechanism to drought and terminal heat stresses but also makes the varieties to fit well in different ecological niches that brings additional area under blackgram cultivation. This highlights the need to develop high yielding and early maturing varieties of blackgram with wide adaptability which could be a major technological advancement for sustaining blackgram production.

Breeders often face the problem of designing the best criteria for selecting parents before initiating a hybridization program. The *per se* performance of genotypes is not always a good index of their nicking ability. Hence, there is a constant need to screen germplasm to isolate potential combining lines and desirable cross combinations. The combining ability determined through diallel analysis (Griffing, 1956) is a useful technique to assess the nicking ability of the parents, superior combinations and at the same time it elucidates the nature and magnitude of gene actions involved. The concept of combining ability analysis has significant practical implications in plant breeding as it allows the prediction of the relative efficiency of parents based on early generation performance besides enabling the study of comparative performance of lines in hybrid combinations, thus saving a lot of breeder's time and resources. In a self-pollinated crop like blackgram where pure line breeding is a thumb rule, crosses with high *sca* effects can be utilized to isolate desirable transgressive segregants which may result in an outstanding variety. Hence development of short duration and high yielding varieties that fit well into different cropping windows is highly essential for breaking the yield ceiling in blackgram.

Considering all these criteria the present investigation was aimed to identify best parents and crosses for yield, maturity and yield component traits in blackgram.

MATERIAL AND METHODS

The experimental material for this study consisted of six diverse blackgram genotypes *viz.*, LBG-752, TU-40, PU-31, IPU-2-43, TBG-104, GBG-1 and 15 F_1's derived by half diallel mating among these parents.

In the crossing block, parents were sown in two staggers with an interval of 10 days in between for continuous availability of pollen (28-07-2019 and 08-08-2019) during *kharif*, 2019. The hybridization process was carried out for about 50 days to obtain sufficient seed in each combination. The crossed seed of each combination was harvested separately and stored in paper bags. The six parents and their 15 F_1 crosses were sown in Randomized Block Design with two replications during *rabi*, 2019. Each entry was sown in 2 rows by dibbling the seeds in 3 m length, with a spacing of 30 cm between the rows and 10 cm within the row. Common crop management practices such as plant protection, weeding and irrigation were carried out to maintain good crop growth. The observations were recorded on five randomly tagged competitive plants from the centre of row in each genotype in each replication for all the yield and yield component traits such as plant height, number of primary branches per plant, number of clusters per plant, number of pods per plant, pod length, number of seeds per pod, seed yield per plant, 100 seed weight and harvest index, except days to 50% flowering and days to maturity which were recorded on per plot basis. The mean of these five plants were used for the statistical analysis. Analysis of data for general and specific combining ability was carried out following Griffing's (1956) Method II, Model I (fixed effect model). The statistical analysis was done using TNAU STAT software.

RESULTS AND DISCUSSION

A. Persual of mean performance

Analysis of variance: The analysis of variance carried out for twelve traits revealed highly significant (1%) differences among the experimental material (parents and F_1s) for the characters *viz.*, days to 50% flowering, days to maturity, plant height, number of primary branches per plant, number of clusters per plant, number of pods per plant, pod length, number of seeds per pod and seed yield per plant (Table 1). The traits *viz.*, number of pods per cluster, 100 seed weight and harvest index exhibited significant variation at 5%. These results justified the presence of considerable amount of genetic variation for all the traits examined in the experimental material.

Mean performance. The appraisal of the mean performance of genotypes is so crucial that decides the real field performance of genotypes. Hence, critical examination of *per se* performance is the main factor that decides the fate of breeding program. The mean performance of six parents and fifteen crosses pertaining to yield, yield attributing traits and earliness were furnished in the Table 2.

Table 1: Analysis of variance for yield, maturity and yield components in blackgram.

S. No.	Characters	Mean sum of squares		
		Replications (df:1)	Treatments (df:20)	Error (df:20)
1.	Days to 50 % flowering	0.214	5.474**	1.664
2.	Days to maturity	0.023	11.095**	4.724
3.	Plant height (cm)	9.562	28.135**	2.918
4.	No. of primary branches per plant	0.003	0.924**	0.081
5.	No. of clusters per plant	2.675	7.450**	1.689
6.	No. of pods per cluster	0.077	0.174*	0.061
7.	No. of pods per plant	6.403	103.143**	9.243
8.	Pod length (cm)	0.016	0.177**	0.054
9.	No. of seeds per pod	0.086	0.424**	0.079
10.	Seed yield per plant (g)	0.065	8.603**	0.640
11.	100 seed weight (g)	0.181	0.219*	0.075
12.	Harvest index (%)	0.222	19.600*	6.356

*Significant at 5% level; ** Significant at 1 % level

Table 2: Mean performance of six parents and 15 crosses for yield, maturity and yield components in blackgram.

S. No.	Parents	DF	DM	PH(cm)	NPB	NCP	NPC	NPP	PL(cm)	NSP	SYP(g)	100 SW (g)	HI (%)
1.	LBG-752	39.50	76.50	24.90	3.50	9.60	3.20	25.70	5.37	6.64	6.99	5.55	35.29
2.	TU-40	35.00	67.50	21.00	3.60	8.80	3.20	18.50	5.16	6.50	5.36	4.71	40.20
3.	PU-31	38.50	72.00	20.10	2.70	7.30	2.80	20.90	4.60	7.00	5.19	5.09	34.12
4.	IPU-2-43	37.50	70.50	21.18	3.90	10.90	3.20	28.60	4.42	6.90	7.81	4.67	40.73
5.	TBG-104	35.50	74.00	25.95	3.90	10.50	3.30	32.50	4.69	6.70	8.33	4.95	38.53
6.	GBG-1	37.50	76.00	27.45	2.20	9.40	3.30	23.20	5.05	6.00	5.11	4.92	35.22
	Mean of parents	37.25	72.75	23.43	3.30	9.42	3.17	24.90	4.88	6.62	6.47	4.98	37.35
	Max. value	39.50	76.50	27.45	3.90	10.90	3.30	32.50	5.37	7.00	8.33	5.55	40.73
	Min. value	35.00	67.50	20.10	2.20	7.30	2.80	18.50	4.42	6.00	5.11	4.67	34.12
	Crosses												
7.	LBG-752 × TU-40	35.50	74.50	25.48	3.90	13.00	3.30	43.30	4.84	6.95	10.75	5.06	42.63
8.	LBG-752 × PU-31	36.50	78.00	27.40	3.40	13.00	3.30	40.70	5.32	7.30	10.10	5.31	42.11
9.	LBG-752 × IPU-2-43	35.50	73.00	22.70	2.30	11.30	3.00	32.30	4.61	6.00	7.03	5.62	34.45
10.	LBG-752 × TBG-104	36.50	70.50	35.30	4.10	17.10	3.40	56.50	5.01	7.50	13.85	5.65	48.05
11.	LBG-752 × GBG-1	35.00	73.50	25.60	2.50	13.40	3.30	31.90	4.91	6.60	7.97	5.02	34.06
12.	TU-40 × PU-31	34.50	74.00	33.30	2.20	12.80	3.30	36.80	5.32	5.90	8.35	5.02	37.39
13.	TU-40 × IPU-2-43	34.00	73.50	22.60	4.00	10.30	3.80	27.80	5.23	6.50	7.90	4.56	42.94
14.	TU-40 × TBG-104	32.50	72.00	31.74	3.40	13.90	3.20	42.70	4.42	7.00	9.62	4.95	44.95
15.	TU-40 × GBG-1	33.50	72.00	23.40	2.60	12.50	3.50	33.40	5.38	6.30	7.36	5.44	42.57
16.	PU-31 × IPU-2-43	35.50	73.50	23.54	3.40	10.30	2.70	25.30	4.67	5.90	5.11	4.58	38.72
17.	PU-31 × TBG-104	36.50	72.50	25.22	2.90	10.00	3.80	28.90	4.57	6.50	6.78	4.69	41.11
18.	PU-31 × GBG-1	36.00	73.00	28.18	2.80	12.30	3.40	35.60	4.67	6.70	8.53	5.12	39.32
19.	IPU-2-43 × TBG-104	34.00	76.50	26.34	4.20	10.60	3.80	38.80	4.92	6.00	8.68	5.34	37.89
20.	IPU-2-43 × GBG-1	35.00	73.50	25.00	3.80	9.60	3.40	29.20	4.65	6.40	7.00	4.82	38.07
21.	TBG-104 × GBG-1	35.50	75.50	25.12	4.00	10.20	3.50	29.70	4.61	6.10	7.78	5.19	41.96
	Mean of crosses	35.07	73.70	26.73	3.30	12.02	3.38	35.53	4.88	6.51	8.45	5.09	40.41
	Max. value	36.50	78.00	35.30	4.20	17.10	3.80	56.50	5.38	7.50	13.85	5.65	48.05
	Min. value	32.50	70.50	22.60	2.20	9.60	2.70	25.30	4.42	5.90	5.11	4.56	34.06
	General mean	35.69	73.43	25.79	3.30	11.28	3.32	32.49	4.88	6.54	7.88	5.06	39.54
	C.D.	2.71	4.60	3.817	0.60	2.74	0.46	6.27	0.48	0.59	1.68	0.57	5.48
	SE(m)	0.91	1.55	1.29	0.20	0.92	0.16	2.11	0.16	0.20	0.56	0.19	1.85
	SE(d)	1.29	2.19	1.82	0.29	1.30	0.22	2.99	0.23	0.28	0.80	0.27	2.61
	C.V.	3.62	2.98	7.05	8.67	11.56	6.64	9.19	4.67	4.32	10.14	5.42	6.61

DF: Days to 50% flowering, DM: Days to maturity, PH: Plant height (cm), NPB: Number of primary branches per plant, NCP: Number of clusters per plant, NPC: Number of pods per cluster, NPP: Number of pods per plant, PL: Pod length (cm), NSP: Number of seeds per pod, SYP: Seed yield per plant (g), 100SW: 100 seed weight (g), HI: Harvest index (%).

Persual of the *per se* performance showed that among the six parents, TU-40 was the earliest to flower and reach maturity. Apart from these two traits TU-40 showed high mean performance for number of primary branches per plant, number of pods per cluster, pod length and harvest index. The next best parent was IPU-2-43 for maturity which also exhibited good *per se* performance for seven traits *viz.*, number of primary of primary branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, number of seeds per pod, seed yield per plant and harvest index. Hence, these parents and their cross combinations could be utilized to design early maturing, short duration blackgram varieties.

Among the six parents, LBG-752 exhibited high *per se* performance for nine yield contributing characters *i.e.*, plant height, number of primary branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length, number of seeds per pod, seed yield per plant and 100 seed weight. The next best genotype was TBG-104 excelling for eight yield attributing traits *i.e.*, plant height, number of primary branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, number of seeds per pod, seed yield per plant and harvest index, along with early flowering. Based on the *per se* performance for yield, yield attributing traits and earliness, the genotypes *viz.*, LBG 752, and TBG-140 for yield, TU-40 and IPU-2-43 for earliness were reckoned as best parents.

Among the crosses, TU-40 × TBG-104 was the earliest to flower followed by TU-40 × GBG-1, IPU-2-43 × TBG-104 TU-40 × IPU-2-43 and TU-40 × PU-31. Similarly, LBG-752 × TBG-104, TU-40 × TBG-104, TU-40 × GBG-1, PU-31 × TBG-104, LBG-752 × IPU-2-43 and PU-31 × GBG-1 were the crosses that were early to mature. The cross TU-40 × TBG-104 was early in both flowering and maturity. Apart from this, it exhibited high mean performance for seven traits *viz.*, plant height, number of primary branches per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, seed yield per plant and harvest index.

The F_1s derived from the cross LBG-752 × TBG-104 took minimum days to reach maturity and also exhibited high mean performance for ten yield and yield attributing traits *viz.*, plant height, number of primary branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length, number of seeds per pod, seed yield per plant, 100 seed weight and harvest index discerning it as the ideal cross for simultaneous improvement of yield and early maturity. In the same lane, the next best cross was LBG-752 × PU-31 which turned out to be a better performer for nine yield and yield attributing traits *viz.*, plant height, number of primary branches per plant, number of clusters per plant, number of pods per plant, pod length, number of seeds per pod, seed yield per plant, 100 seed weight and harvest index. Similarly, the next better performer was LBG-752 × TU-40 that showed better performance for six traits (number of primary branches per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, seed yield per plant and harvest index). The cross IPU-2-43 × TBG-104 exhibited superior performance for seven traits *viz.*, days to 50% flowering, number of primary branches per plant, number of pods per cluster, number of pods per plant, pod length, seed yield per plant and 100 seed weight. Hence, these crosses could be successfully utilized in blackgram breeding programs for the development of high yielding short duration varieties.

B. Combining ability studies

Selection of parents with high mean values may not serve the purpose of hybridization programs, as they necessarily be not able to transmit their superior traits to their progenies. Some combinations produce superior progenies on crossing with others, while certain others may not. The genotypes which perform well in combinations are of great importance to the plant breeder. This urges the need to evaluate the combining ability of parents and their resulting progeny. Hence, all the 15 F_1's along with their parents were subjected to combining ability analysis (Griffing, 1956).

Analysis of variance for combining ability. The analysis of variance for combining ability (Table 3) indicated that both *gca* (general combining ability) and *sca* (specific combining ability) mean squares were significant for all the characters studied. This suggested that both additive and non-additive gene effects were involved in the genetic control of seed yield and its attributes. Mean sum of squares due to *sca* for 100 seed weight was found to be non significant suggesting the predominance of additive gene effects involved in controlling this trait and there is no ample variation among the crosses for this trait. Therefore, the analysis of variance suggested the presence of wide variability for the respective traits among the parents and their F_1s evaluated except 100 seed weight among the crosses.

The ratio of *gca* to *sca* variances for twelve yield, yield attributes along with earliness were presented in Table 3. Variance estimates of *sca* were greater than *gca* and the ratio of $\sigma^2 sca$ / $\sigma^2 gca$ was less than unity for all the traits suggesting the predominant role of non-additive gene effects. Malhotra (1983), Singh *et al*. (1987), Dasgupta and Das (1991), Sharma and Pandey (1996), Santha and Veluswamy (1999), Dana and Dasgupta (2001), Vaithiyalingan *et al*. (2002), Singh and Singh (2005), Selvam and Elangaimannam (2010), Panigrahi *et al.* (2015), Bharathi *et al.* (2019) and Toppo *et al.* (2020) also observed greater values of *sca* variances than *gca* variances for most of the yield attributing traits.

Table 3: ANOVA for combining ability for yield, maturity and yield components in blackgram.

S. No.	Character	Mean sum of squares			$\sigma^2 gca$	$\sigma^2 sca$	$\sigma^2 gca/\sigma^2 sca$
		gca (df=5)	*sca* (df=15)	Error (df=20)			
1.	Days to 50 % flowering	5.42**	1.84*	0.83	0.57	1.01	0.57
2.	Days to maturity	7.06*	5.12*	2.40	0.58	2.72	0.21
3.	Plant height (cm)	14.96**	15.21**	1.65	1.66	13.56	0.12
4.	Number of primary branches per plant	0.86**	0.33**	0.04	0.10	0.29	0.36
5.	Number of clusters per plant	3.66**	4.99**	0.85	0.35	4.14	0.09
6.	Number of pods per cluster	0.08*	0.08**	0.02	0.01	0.06	0.11
7.	Number of pods per plant	77.52**	75.30**	4.45	9.13	70.84	0.13
8.	Pod length (cm)	0.17**	0.08*	0.03	0.02	0.05	0.33
9.	Number of seeds per pod	0.20**	0.22**	0.04	0.02	0.18	0.11
10.	Seed yield per plant (g)	5.74**	3.82**	0.32	0.68	3.50	0.19
11.	100 seed weight (g)	0.20**	0.08	0.04	0.02	0.04	0.49
12.	Harvest index (%)	16.03**	13.46**	3.41	1.58	10.04	0.16

*Significant at 5% level; ** Significant at 1 % level

General combining ability (*gca*) and specific combining ability (*sca*) effects. The *gca* effects of six parents and *sca* effects of 15 cross combinations for twelve yield, yield attributing traits were presented in the Table 4. Negative *gca* effect for days to 50 % flowering and days to maturity are desirable for development of early maturing genotypes, while positive *sca* effects are beneficial for all the other yield attributing traits.

On examination of *gca* effects of six parents utilized in the present work, LBG-752 with high and significant *gca* for number of clusters per plant, number of pods per plant, pod length, number of seeds per pod, seed yield per plant and 100 seed weight and TBG-104 with high and significant *gca* for plant height, number of primary branches per plant, number of pods per cluster, number of pods per plant, seed yield per plant and harvest index, can be declared as best general combiners for yield and yield attributing traits.

Similarly, TU-40 was the next best parent and the only line that exhibited negatively significant *gca* effects for both days to 50% flowering and days to maturity highlighting its potential use as a parent for breeding short duration varieties. Apart from maturity, it also exhibited positive significant *gca* effect for pod length and harvest index. Superior parents identified based on mean performance and *gca* effects were presented in the Table 5. Based on the mean performance and *gca* effects, TBG-104, LBG-752 and IPU-2-43 were the best parents for yield and yield attributing traits followed by TU-40 for earliness. Since *gca* effects are attributed to additive gene effects, the above mentioned parents have good potential for respective characters and might be used in crossing programmes to synthesize a dynamic population with most of the favorable genes accumulated.

Information on *gca* effect should be supplemented by *sca* effects and hybrid performances to predict the transgressive types possibly be available in segregating generations. Superior crosses identified based on mean performance and *sca* effects were presented in the Table 6. Therefore, considering the results of *gca*, *sca* and mean performance of crosses and parents, LBG-752 × TBG-104, LBG-752 × PU-31, LBG-752 × TU-40, TU-40 × TBG-104 and IPU-2-43 × TBG-104 were sorted to be the best crosses that may yield early maturing and high yielding segregants. The cross LBG-752 × TBG-104 evinced highest *sca* effect for seed yield per plant and also exhibited significant negative *sca* effect for days to maturity signifying that this combination could be the desirable choice for exercising single plant selection for simultaneous improvement of seed yield and early maturity.

Table 4: Estimates of general combining ability (*gca*) effects of parents and specific combining ability (*sca*) effects of crosses.

S. No.	Parents	DF	DM	PH(cm)	NPB	NCP	NPC	NPP	PL(cm)	NSP	SYP(g)	100 SW (g)	HI (%)
1.	LBG-752	1.02 **	1.06 *	0.72	0.01	1.01 **	0.07	3.58 **	0.16 **	0.22 **	1.06 **	0.29 **	-0.61
2.	TU-40	-1.23 **	-1.63 **	-0.25	0.02	0.15	0.03	-0.8	0.17 **	-0.02	-0.06	-0.12	1.76 **
3.	PU-31	0.77 *	0.13	-0.33	-0.37 **	-0.74 *	-0.14 *	-2.29 **	-0.05	0.06	-0.74 **	-0.06	-1.24
4.	IPU-2-43	-0.1	-0.38	-2.25 **	0.30 **	-0.63 *	-0.02	-2.10 **	-0.15 **	-0.15 *	-0.48 *	-0.14 *	-0.41
5.	TBG-104	-0.48	0.13	1.89 **	0.41 **	0.48	0.13 *	4.27 **	-0.15 **	0.09	1.02 **	0.04	1.78 **
6.	GBG-1	0.02	0.69	0.21	-0.38 **	-0.27	0.06	-2.65 **	0.02	-0.21 **	-0.79 **	0.00	-1.29 *
	S.E. $g_{(j)}$	0.29	0.49	0.41	0.06	0.29	0.05	0.68	0.05	0.06	0.18	0.06	0.59
	Crosses												
7.	LBG-752 × TU-40	0.02	1.63 *	-0.78	0.56 **	0.57	0.01	8.03 **	-0.37 **	0.21 *	1.87 **	-0.17	1.93 *
8.	LBG-752 × PU-31	-0.98 *	3.38 **	1.22 *	0.46 **	1.46 **	0.19 **	6.92 **	0.33 **	0.47 **	1.89 **	0.02	4.41 **
9.	LBG-752 × IPU-2-43	-1.11 **	-1.12	-1.56 **	-1.31 **	-0.36	-0.24 **	-1.67	-0.28 **	-0.61 **	-1.43 **	0.41 **	-4.07 **
10.	LBG-752 × TBG-104	0.27	-4.12 **	6.90 **	0.38 **	4.33 **	0.01	16.16 **	0.13	0.65 **	3.88 **	0.26 **	7.34 **
11.	LBG-752 × GBG-1	-1.73 **	-1.68 *	-1.12	-0.44 **	1.38 **	-0.01	-1.52	-0.15 *	0.05	-0.18	-0.33 **	-3.58 **
12.	TU-40 × PU-31	-0.73	2.07 **	8.09 **	-0.75 **	2.12 **	0.09	7.41 **	0.32 **	-0.69 **	1.27 **	0.15	-2.68 **
13.	TU-40 × IPU-2-43	-0.36	2.07 **	-0.69	0.38 **	-0.49	0.46 **	-1.78	0.33 **	0.12	0.56 *	-0.24 **	2.04 *
14.	TU-40 × TBG-104	-1.48 **	0.07	4.31 **	-0.34 **	1.99 **	-0.29 **	6.74 **	-0.47 **	0.39 **	0.78 **	-0.02	1.87 *
15.	TU-40 × GBG-1	-0.98 *	-0.49	-2.35 **	-0.35 **	1.34 **	0.09	4.37 **	0.31 **	-0.01	0.34	0.50 **	2.56 **
16.	PU-31 × IPU-2-43	-0.86 *	0.32	0.33	0.18	0.39	-0.46 **	-2.79 **	-0.01	-0.56 **	-1.55 **	-0.27 **	0.82
17.	PU-31 × TBG-104	0.52	-1.18	-2.12 **	-0.44 **	-1.02 *	0.49 **	-5.57 **	-0.1	-0.19 *	-1.38 **	-0.34 **	1.03
18.	PU-31 × GBG-1	-0.48	-1.24	2.51 **	0.25 **	2.03 **	0.16 *	8.06 **	-0.18 *	0.31 **	2.18 **	0.12	2.31 **
19.	IPU-2-43 × TBG-104	-1.11 **	3.32 **	0.91	0.19 *	-0.53	0.36 **	4.14 **	0.35 **	-0.48 **	0.25	0.39 **	-3.03 **
20.	IPU-2-43 × GBG-1	-0.61	-0.24	1.25 *	0.58 **	-0.78	0.04	1.47	-0.1	0.22 *	0.39	-0.09	0.23
21.	TBG-104 × GBG-1	0.27	1.26	-2.77 **	0.66 **	-1.29 **	-0.01	-4.41 **	-0.14	-0.32 **	-0.33	0.09	1.93 *
	S.E. $s_{(ii)}$	0.81	1.37	1.14	0.18	0.82	0.14	1.87	0.14	0.17	0.50	0.17	1.64
	S.E. $s_{(ij)}$	0.39	0.65	0.54	0.09	0.39	0.07	0.89	0.07	0.08	0.24	0.08	0.78

*Significant at 5% level; ** Significant at 1 % level

DF: Days to 50% flowering, DM: Days to maturity, PH: Plant height (cm), NPB: Number of primary branches per plant, NCP: Number of clusters per plant, NPC: Number of pods per cluster, NPP: Number of pods per plant, PL: Pod length (cm), NSP: Number of seeds per pod, SYP: Seed yield per plant (g), 100SW: 100 seed weight (g), HI: Harvest index (%)

Table 5: Desirable parents selected based on *gca* effects and mean performance for yield, maturity and yield components in blackgram.

S. No.	Character	Mean	*gca* effects	Mean and *gca* effects
1.	Days to 50 % flowering	TU-40, TBG-104, IPU-2-43, GBG-1	TU-40	TU-40
2.	Days to maturity	TU-40, IPU-2-43, PU-31	TU-40	TU-40
3.	Plant height (cm)	GBG-1, TBG-104, LBG-752	TBG-104	TBG-104
4.	Number of primary branches per plant	TBG-104, IPU-2-43, TU-40, LBG-752	TBG-104, IPU-2-43	TBG-104, IPU-2-43
5.	Number of clusters per plant	IPU-2-43, TBG-104, LBG-752	LBG-752	LBG-752
6.	Number of pods per cluster	GBG-1, TBG-104, IPU-2-43, TU-40, LBG-752	TBG-104	TBG-104
7.	Number of pods per plant	TBG-104, IPU-2-43, LBG-752	TBG-104, LBG-752	TBG-104, LBG-752
8.	Pod length (cm)	LBG-752, TU-40, GBG-1	LBG-752, TU-40	LBG-752,TU-40
9.	Number of seeds per pod	PU-31, IPU-2-43, TBG-104, LBG-752, TU-40	LBG-752	LBG-752
10.	Seed yield per plant (g)	TBG-104, IPU-2-43, LBG-752	LBG-752, TBG-104	LBG-752,TBG-104
11.	100 seed weight (g)	LBG-752, PU-31	LBG-752	LBG-752
12.	Harvest index (%)	IPU-2-43, TU-40, TBG-104	TBG-104, TU-40	TBG-104, TU-40

Table 6: Superior crosses identified based on mean performance and *sca* effects for yield, maturity and yield components in blackgram.

Character	Mean performance	*sca* effects	Mean performance and *sca* effects
Days to 50 % flowering	TU-40 × TBG-104 TU-40 × GBG-1 TU-40 × IPU-2-43 IPU-2-43 × TBG-104 TU-40 × PU-31	LBG-752 × GBG-1 TU-40 × TBG-104 LBG-752 × IPU-2-43 IPU-2-43 × TBG-104 LBG-752 × PU-31 TU-40 × GBG-1	TU-40 × TBG-104 TU-40 × GBG-1 IPU-2-43 × TBG-104
Days to maturity	LBG-752 × TBG-104 TU-40 × TBG-104 TU-40 × GBG-1 PU-31 × TBG-104 LBG-752 × IPU-2-43 PU-31 × GBG-1	LBG-752 × TBG-104 LBG-752 × GBG-1	LBG-752 × TBG-104
Plant height (cm)	LBG-752 × TBG-104 TU-40 × PU-31 TU-40 × TBG-104 PU-31 × GBG-1 LBG-752 × PU-31	TU-40 × PU-31 LBG-752 × TBG-104 TU-40 × TBG-104 PU-31 × GBG-1 IPU-2-43 × GBG-1	LBG-752 × TBG-104 TU-40 × PU-31 TU-40 × TBG-104 PU-31 × GBG-1
Number of primary branches per plant	IPU-2-43 × TBG-104 LBG-752 × TBG-104 TU-40 × IPU-2-43 TBG-104 × GBG-1	TBG-104 × GBG-1 IPU-2-43 × GBG-1 LBG-752 × TU-40 LBG-752 × PU-31	LBG-752 × TBG-104 TBG-104 × GBG-1 LBG-752 × TU-40

	LBG-752 × TU-40	LBG-752 × TBG-104	
Number of clusters per plant	LBG-752 × TBG-104 TU-40 × TBG-104 LBG-752 × GBG-1 LBG-752 × TU-40 LBG-752 × PU-31	LBG-752 × TBG-104 TU-40 × PU-31 PU-31 × GBG-1 TU-40 × TBG-104 LBG-752 × PU-31	LBG-752 × TBG-104 TU-40 × TBG-104 LBG-752 × PU-31
Number of pods per cluster	TU-40 × IPU-2-43 PU-31 × TBG-104 IPU-2-43 × TBG-104 TU-40 × GBG-1 TBG-104 × GBG-1	PU-31 × TBG-104 TU-40 × IPU-2-43 IPU-2-43 × TBG-104 LBG-752 × PU-31 PU-31 × GBG-1	TU-40 × IPU-2-43 PU-31 × TBG-104 IPU-2-43 × TBG-104
Number of pods per plant	LBG-752 × TBG-104 LBG-752 × TU-40 TU-40 × TBG-104 LBG-752 × PU-31 IPU-2-43 × TBG-104	LBG-752 × TBG-104 PU-31 × GBG-1 LBG-752 × TU-40 TU-40 × PU-31 LBG-752 × PU-31	LBG-752 × TBG-104 LBG-752 × TU-40 LBG-752 × PU-31
Pod length (cm)	TU-40 × GBG-1 LBG-752 × PU-31 TU-40 × PU-31 TU-40 × IPU-2-43 LBG-752 × TBG-104	IPU-2-43 × TBG-104 LBG-752 × PU-31 TU-40 × IPU-2-43 TU-40 × PU-31 TU-40 × GBG-1	TU-40 × GBG-1 LBG-752 × PU-31 TU-40 × PU-31 TU-40 × IPU-2-43
Number of seeds per pod	LBG-752 × TBG-104 LBG-752 × PU-31 TU-40 × TBG-104 LBG-752 × TU-40 PU-31 × GBG-1	LBG-752 × TBG-104 LBG-752 × PU-31 TU-40 × TBG-104 PU-31 × GBG-1 IPU-2-43 × GBG-1	LBG-752 × TBG-104 LBG-752 × PU-31 TU-40 × TBG-104 PU-31 × GBG-1
Seed yield per plant (g)	LBG-752 × TBG-104 LBG-752 × TU-40 LBG-752 × PU-31 TU-40 × TBG-104 IPU-2-43 × TBG-104	LBG-752 × TBG-104 PU-31 × GBG-1 LBG-752 × PU-31 LBG-752 × TU-40 TU-40 × PU-31	LBG-752 × TBG-104 LBG-752 × TU-40 LBG-752 × PU-31
100 seed weight (g)	LBG-752 × TBG-104 LBG-752 × IPU-2-43 TU-40 × GBG-1 IPU-2-43 × TBG-104 LBG-752 × PU-31	TU-40 × GBG-1 LBG-752 × IPU-2-43 IPU-2-43 × TBG-104 LBG-752 × TBG-104	LBG-752 × TBG-104 IPU-2-43 × TBG-104
Harvest inde × (%)	LBG-752 × TBG-104 TU-40 × TBG-104 TU-40 × IPU-2-43 LBG-752 × TU-40 TU-40 × GBG-1	LBG-752 × TBG-104 LBG-752 × PU-31 TU-40 × GBG-1 PU-31 × GBG-1 TU-40 × IPU-2-43	LBG-752 × TBG-104 TU-40 × IPU-2-43 TU-40 × GBG-1

CONCLUSION

Based on *per se* and *gca* effects it could be concluded that the parents *viz.*, TBG-104, LBG-752, TU-40 and IPU-2-43 were the best general combiners for yield and yield attributing traits. The parent TU-40 was the best general combiner for earliness. The crosses *viz.*, LBG-752 × TBG-104, LBG-752 × PU-31, LBG-752 × TU-40, TU-40 × TBG-104 and IPU-2-43 × TBG-104 were found superior and could be exploited in future breeding programmes to isolate desirable segregants for yield and maturity in black gram. While selecting early maturing lines, it is crucial to seek balance between maturity and yield, so that there is least compromise on yield. In this lane, the cross LBG-752 × TBG-104 could be considered as the best one that may throw early maturing and high yielding segregants. Breeding methods like modified recurrent selection or repeated crossing in segregating generations could be useful for the exploitation of additive and non additive gene actions in all the crosses.

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