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Research Article

Heterosis and combining ability studies in blackgram (*Vigna mungo* L. Hepper) under alfisols of SAT region, India

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Abstract
Forty two F_1 hybrids of blackgram were produced in line x tester mode with fourteen lines and three testers. The F_1 hybrids along with parental lines were raised during *kharif, rabi* and *summer* 2013-14 to assess the heterosis and combining ability for seed yield and yield attributes over different environments. The pooled ANOVA revealed significant variability for seed yield, number of branches, pods, clusters, 100 seed weight, fodder biomass and harvest index due to crosses, environment, environment × crosses, while significant variability for environment × line × tester effect for all characters except for number of branches. Among 42 hybrids, three hybrids tested IC 587753 × PU-19, IC 436720 × PU-19, IC 436652 × LBG-20 exhibited significant and positive heterosis over mid, better and standard parent for seed yield, as well as significant specific combining ability. Hence these hybrids of this important pulse crop can be used for seed yield improvement through recurrent selection. Two lines *viz.,* IC 587753 and IC 519805 identified as good general combiners for seed yield and can serve as parental lines in crop improvement programs.

Key words
Line × tester, seed yield, yield attributes, gca, sca, heterosis, black gram and SAT

Introduction

Pulses are important food crops as they have higher protein content (20-36%) compared with major cereals (Gowda *et al*., 2014) especially to fulfill human nutritional requirement. The world population is projected to grow from the current ~7.3 billion to ~8.9 billion by 2050. Therefore, increasing food production and attaining nutritional security is a challenge. The 68th UN General Assembly declared year 2016 as the International Year of Pulses (IYP) to create public awareness of the nutritional benefits of pulses as part of sustainable food production.

Among pulses, blackgram or urd bean is an important pulse crop of the tropics and semi arid tropics (SAT) and has been identified as a potential crop in many countries (Girish *et al*., 2012). It is an important pulse crop of India and is mainly cultivated as a source of dietary protein because of its high protein content which is of about 25% in seeds (Haytowitz and Mathews, 1986). Being a legume crop it can potentially fix about 80% of its own nitrogen needs through biological nitrogen fixation and in addition can contribute to the yield of subsequent crops. The yield of this crop is stagnated over two decades and significant seasonal as well as year to year variation in yield was recorded due to non-availability of high yielding and stable performing cultivars. In order to increase the production and productivity of black gram it is essential to develop a high yielding pure line variety by selection from the segregating generations of superior crosses involving superior parents.

Materials and methods

Fourteen black gram genotypes representing different agro-climatic zones of erstwhile Andhra Pradesh were obtained from NBPGR Regional Centre, Hyderabad and was used as lines *viz.,* IC587753, IC436720, IC436519, IC343947, IC519805, IC343952, IC587752, IC587751, IC282009, IC436753, IC436610, IC436665, IC398971 and IC281987 while three released national varieties were used as testers *viz.*, PU-19, LBG-20 and T-9 (Table 1). With fourteen lines and three testers, 42 crosses were attempted and resultant F_1s along with parental lines were sown during *Kharif, Rabi* and *Summer* in 2013-14 in randomized complete block design (RCBD) with three replications at Hayathnagar Research Farm, CRIDA, Hyderabad. Each row of 1m length consists of 10 plants with a spacing of 10cm between the plants and 30cm between two rows was maintained. Recommended package of practices was followed to raise crop. Data were recorded on yield and its attributes. The seed yield and yield attributes data over seasons were analyzed for line × tester analysis, as proposed by Kempthorne (1957). Heterosis over mid parent, better parent and standard parent were estimated as per standard procedure suggested by Wynne *et al.* (1970).

Results and discussion

The analysis of variance for combining ability revealed that the variability for seed yield, number of branches, pods, clusters, 100 seed weight, fodder biomass and harvest index were significant due to crosses, environment, environment × crosses, while significant variability for environment × line × tester effect for all characters except number of branches.

The variability for all these characters except number of branches was also significant due to interaction between lines and tester (Table 2). This indicates that the presence of sufficient genetic diversity in the material, hence it is possible to select superior genotypes with high yield.

The significant gca for seed yield was observed in two lines *viz.*, IC 587753 (2.71), IC 519805 (0.74) while none of the testers showed positive and significant gca. IC 587753 also showed significant positive gca for yield attributes *viz.*, number of branches, pods, clusters and harvest index (Table 3). Number of lines and tester also showed significant gca effect for one or the other yield attributes. Positive and significant sca for seed yield was exhibited by nine crosses *viz.*, IC 587753 × PU-19, IC 436720 × PU-19, IC 436519 × T-9, IC 587752 × T-9, IC 587751 × LBG-20, IC 282009 × PU-19, IC 436610 × T-9, IC 281987 × PU-19, IC 436652 × LBG-20 (Table 4). In addition these crosses have showed positive and significant sca for other yield contributing traits. For number of pods positive and significant sca was exhibited by IC 436720 × PU-19, IC 436519 × T-9, IC 587751 × LBG-20 and IC 436610 × T-9, while for clusters positive and significant sca was showed by IC 587753 × PU-19, IC 436720 × PU-19, IC 282009 × PU-19 and IC 436652 × LBG-20. Similar results were reported by Chakraborty *et al.* (2010) in black gram; Swamy and Reddy (2003) in mungbean; Gadekar and Dodiya (2013) in chickpea.

The range of heterosis varied from -16.25 (IC 436610 × PU-19) to 49.21% (IC 587753 × PU-19) over mid parent, from -19.02 (IC 436610 × PU-19) to 40.84% (IC 587753 ×PU-19) over better parent and from 3.51 (IC 436610 × PU-19) to 80.01% (IC 587753 × PU-19) over standard check (T-9). Positive and significant heterosis was exhibited by 20 F_1 hybrids over mid parent, fourteen hybrids over better parent and 40 hybrids over standard parent (Table 5). Significant and positive heterosis over mid, better and standard parent was exhibited by fourteen hybrids and among them 5 crosses viz., IC 587753 × PU-19 (17.17g/pl), IC 587753 × LBG-20 (15.97g/pl), IC 436720 × PU-19 (15.71g/pl), IC 281987 × PU-19 (14.87g/pl) and IC 436652 × LBG-20 (14.55g/pl) were best performers for seed yield. Similar results were reported in blackgram by other research groups (Thangavel 2010; Anbu Selvam and Elangaimannan 2010; Karande *et al.*, 2013; Bhagirath Ram *et al.*, 2013). The results revealed that the three out of 42 hybrids *viz.*, IC 587753 × PU-19, IC 436720 × PU-19, IC 436652 × LBG-20 gave high seed yield and significant heterosis over mid, better and standard parent. Bhagirath Ram *et al.* (2013) reported similar results in blackgram; Gadekar and Dodiya (2013) in chickpea. Number of crosses also exhibited significant positive sca for various yield attributes. In general a hybrid having significant heterosis over mid, better and standard parents as well as showed significant sca with high yield is considered as most promising hybrid for development of high yield pure line varieties through recurrent selection in segregating generation in self pollinated crop like blackgram.

Conclusion

The hybrids IC 587753 × PU-19, IC 436720 × PU-19, IC 436652 × LBG-20 were considered promising for yield improvement in blackgram as they showed significant heterosis as well as significant sca for seed yield and yield attributes. Two identified lines IC 587753 and IC 519805 were the potential genotypes to use in hybridization program of blackgram.

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Table 1. List of parental genotypes used in the present study with their source of collection

S.No	IC No.	Source
Lines		
1	IC 587753	Vishakhapatnam
2	IC 436720	Adilabad
3	IC 436519	Rangareddy
4	IC 343947	Eastgodavari
5	IC 519805	Srikakulam
6	IC 343952	Eastgodavari
7	IC587752	Khammam
8	IC587751	Rangareddy
9	IC 282009	Medak
10	IC 436753	Adilabad
11	IC 436610	Medak
12	IC 398971	Prakasam
13	IC 281987	Adilabad
14	IC 436652	Nizamabad
Testers		
15	PU-19	Released
16	LBG-20	Released
17	T-9	Released

Table 2. Analysis of variance of parents and hybrids for seed yield pooled over seasons in black gram

Source of Variations	df	Seed yield /plant	Branches /plant	Pods/pl	Clusters /plant	100 seed weight	Fodder biomass	HI
Replication	2	2.08	1.16	8.47	4.03	0.47*	5.95	96.81
Environments	2	171.08**	54.37**	2007.22**	527.26**	8.61**	117.61**	2551.92**
Rep × Env.	4	19.26**	2.14*	195.45**	22.65**	0.08	6.41	55.16
Crosses	41	19.94**	1.09*	227.69**	21.03**	0.39**	19.3**	214.42**
Line effect	13	28.57	0.92	304.6	27.44	0.51	48.83**	327.58
Tester effect	2	1.42	4.18*	417.18	68.57*	0.48	19.23*	121.13
Line × Tester effect	26	17.05**	0.93	174.66**	14.17**	0.33**	4.53*	165.02**
Env × Crosses	82	13.04**	1.02**	138.71**	16.17**	0.41**	8.06**	131.63**
Env × Line effect	26	13.84	1.46**	178.7	16.26	0.31	11.66**	102.77
Env × Tester effect	4	60.17**	3.69**	182.07	8.97	2.42**	33.68**	388.63*
Env × L × T effect	52	9.01**	0.59	115.37**	16.68**	0.31**	4.29*	126.29**
Error	246	2.52	0.65	24.78	2.97	0.1	2.7	49.06

*, ** Significant at 5 and 1 per cent level, respectively

Table 3. General combining ability of lines and testers for seed yield pooled over seasons in blackgram

Lines	Seed yield	Branches/pl	Pods/pl	Clusters/pl	100 seed weight	Fodder biomass	HI
IC 587753	2.71**	0.34*	8.26**	2.61**	0.06	-0.14	6.13**
IC 436720	0.40	-0.03	0.13	-0.56	0.17**	-0.35	1.62
IC 436519	0.12	0.27	-1.94*	-0.24	0.06	0.05	0.50
IC 343947	0.57	0.10	1.50	0.33	-0.08	-0.30	4.05**
IC 519805	0.74*	0.12	0.94	-0.47	0.14*	-0.56	3.40*
IC 343967	-1.22**	-0.18	-2.63**	-1.02**	-0.18**	-1.11**	-1.45
IC 587752	-0.35	0.16	2.15*	0.50	-0.27**	-1.18**	1.49
IC 587751	-0.93**	-0.06	-3.96**	-0.13	-0.09	-0.93**	-0.09
IC 282009	-0.42	-0.27	-2.06*	-0.91**	0.15*	0.49	-3.77**
IC 436753	-0.59	-0.23	-2.65**	-0.74*	0.20**	-0.30	-0.47
IC 436610	-1.45**	-0.21	-4.81**	-1.28**	-0.04	-0.17	-3.05*
IC 398971	0.11	-0.03	2.46*	0.89**	-0.09	4.37**	-7.70**
IC 281987	0.44	-0.01	1.74	0.70*	-0.05	0.04	0.63
IC 436652	-0.14	0.03	0.87	0.33	0.00	0.12	-1.29
PU-19	0.12	0.04	0.81	0.12	-0.07*	0.09	-1.12
LBG-20	-0.06	0.16*	1.28**	0.67**	0.01	-0.43**	0.43
T-9	-0.06	-0.20**	-2.08**	-0.79**	0.05	0.34*	0.69
CD 95% GCA (Testers)	**0.28**	**0.14**	**0.87**	**0.30**	**0.06**	**0.29**	**1.23**
***SE* (Testers)**	***0.14***	***0.07***	***0.44***	***0.15***	***0.03***	***0.15***	***0.62***
CD 95% GCA (Lines)	**0.60**	**0.31**	**1.89**	**0.65**	**0.12**	**0.62**	**2.66**
***SE* (Lines)**	***0.31***	***1.16***	***0.96***	***0.33***	***0.06***	***0.32***	***1.35***

*, ** Significant at 5 and 1 per cent level, respectively

Table 4. Specific combining ability estimates for seed yield and yield attributes in blackgram-Pooled over seasons

S.No.	Crosses	Seed yield	Branches/pl	Pods/pl	Clusters/pl	100 seed weight	Fodder biomass	HI
1	IC 587753 × PU-19	1.42**	0.33	3.10	1.14*	0.07	1.13*	1.59
2	IC 587753 × LBG-20	0.40	-0.23	1.02	0.15	0.02	-0.65	-0.04
3	IC 587753 × T-9	-1.82**	-0.10	-4.12*	-1.28*	-0.09	-0.48	-1.55
4	IC 436720 × PU-19	2.27**	0.64*	7.01**	1.64**	0.08	0.06	4.86*
5	IC 436720 × LBG-20	-1.14*	-0.53	-1.96	-0.47	0.03	0.17	-2.61
6	IC 436720 × T-9	-1.13*	-0.12	-5.05**	-1.17*	-0.11	-0.23	-2.25
7	IC 436519 × PU-19	-0.24	0.18	1.36	0.54	-0.04	-0.28	2.18
8	IC 436519 × LBG-20	-1.04*	0.01	-5.11**	-1.17*	0.04	0.36	-2.21
9	IC 436519 × T-9	1.29*	-0.19	3.75*	0.62	0.00	-0.08	0.04
10	IC 343947 × PU-19	-0.07	0.18	2.03	0.64	-0.11	-0.05	1.33
11	IC 343947 × LBG-20	-0.91	-0.10	-0.22	-1.13	-0.06	-0.78	-3.86
12	IC 343947 × T-9	0.97	-0.08	-1.81	0.49	0.17	0.82	2.53
13	IC 519805 × PU-19	0.39	0.05	1.64	0.66	0.03	0.32	0.05
14	IC 519805 × LBG-20	-0.08	0.16	-4.89**	-0.50	0.34**	-0.71	0.60
15	IC 519805 × T-9	-0.31	-0.21	3.25	-0.15	-0.36**	0.38	-0.65
16	IC 343967 × PU-19	-0.50	0.12	-5.62**	-0.96	-0.07	-0.31	-1.40
17	IC 343967 × LBG-20	-0.22	-0.27	0.24	-0.39	0.00	-0.15	-1.19
18	IC 343967 × T-9	0.72	0.14	5.38**	1.35*	0.07	0.46	2.58
19	IC587752 × PU-19	-1.60**	0.12	-6.79**	-0.86	0.01	-0.52	-3.57
20	IC 587752 × LBG-20	0.36	0.12	5.35**	0.87	-0.21	-0.47	3.60
21	IC 587752 × T-9	1.24*	-0.24	1.44	-0.01	0.19	0.99	-0.03
22	IC 587751 × PU-19	-0.25	-0.21	1.16	0.27	-0.25*	0.49	-2.98
23	IC 587751 × LBG-20	1.75**	0.12	3.41*	1.00	0.22*	0.38	6.80**
24	IC 587751 × T-9	-1.50**	0.09	-4.56**	-1.26*	0.03	-0.87	-3.83
25	IC 282009 × PU-19	1.35*	-0.17	3.14	1.60**	0.03	-0.27	8.66**
26	IC 282009 × LBG-20	-0.66	-0.12	-1.83	-1.39*	0.00	0.33	-4.52
27	IC 282009 × T-9	-0.69	0.29	-1.31	-0.21	-0.04	-0.06	-4.14
28	IC 436753 × PU-19	-0.79	-0.38	-0.60	-0.79	-0.09	-0.43	-2.27
29	IC 436753 × LBG-20	-0.05	0.12	-2.30	0.44	0.10	-0.23	0.15
30	IC 436753 × T-9	0.84	0.26	2.90	0.35	-0.01	0.65	2.12
31	IC 436610 × PU-19	-1.71**	-0.67*	-5.49**	-1.97**	0.09	-0.47	-4.79*
32	IC 436610 × LBG-20	0.32	0.38	-0.91	0.98	0.07	0.17	2.09
33	IC 436610 × T-9	1.39**	0.29	6.40**	0.99	-0.15	0.30	2.70
34	IC 398971 × PU-19	0.06	0.09	0.56	-0.86	0.03	-0.22	1.08
35	IC 398971 × LBG-20	-0.75	-0.03	1.93	-0.63	-0.38**	1.29*	-3.60
36	IC 398971 × T-9	0.69	-0.06	-2.49	1.49**	0.35**	-1.07	2.52
37	IC 281987 × PU-19	1.39**	-0.10	0.73	-0.46	0.26*	-0.39	3.14
38	IC 281987 × LBG-20	0.17	0.40	2.37	0.16	-0.15	0.53	-1.57
39	IC 281987 × T-9	-1.56**	-0.30	-3.10	0.29	-0.11	-0.14	-1.58
40	IC 436652 × PU-19	-1.72**	-0.19	-2.23	-0.58	-0.04	0.94	-7.90**
41	IC 436652 × LBG-20	1.84**	-0.03	2.91	2.09**	-0.02	-0.26	6.35**
42	IC 436652 × T-9	-0.12	0.22	-0.68	-1.51**	0.06	-0.68	1.54
	CD 95% SCA	**1.04**	**0.53**	**3.27**	**1.13**	**0.22**	**1.08**	**4.60**
	SE	***0.53***	***0.27***	***1.66***	***0.57***	***0.11***	***0.55***	***2.33***

*, ** Significant at 5 and 1 per cent level, respectively

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Table 5. Mean values for seed yield of F_1s in 42 crosses of blackgram pooled over seasons and heterosis over mid, better and standard parental values

Crosses	Seed yield (g/pl)	Heterosis (%)		
		MP	BP	SP
IC 587753 × PU-19	17.17	49.21 **	40.84 **	80.01 **
IC 587753 × LBG-20	15.97	34.52 **	23.57 **	67.47 **
IC 587753 × T-9	13.74	34.98 **	26.97 **	44.07 **
IC 436720 × PU-19	15.71	26.59 **	24.41 **	64.68 **
IC 436720 × LBG-20	12.12	-5.13	-6.23	27.08 **
IC 436720 × T-9	12.13	9.41	-3.97	27.12 **
IC 436519 × PU-19	12.92	3.72	1.60	35.40 **
IC 436519 × LBG-20	11.93	-6.92	-7.70	25.09 **
IC 436519 × T-9	14.25	28.12 **	12.13 *	49.44 **
IC 343947 × PU-19	13.54	17.23 **	11.05	41.93 **
IC 343947 × LBG-20	12.52	5.06	-3.15	31.25 **
IC 343947 × T-9	14.39	40.79 **	31.97 **	50.88 **
IC 519805 × PU-19	14.17	25.06 **	16.23 **	48.56 **
IC 519805 × LBG-20	13.52	15.53 **	4.55	41.69 **
IC 519805 × T-9	13.29	32.82 **	26.91 **	39.30 **
IC 343967 × PU-19	11.32	-8.02	-8.86	18.66 *
IC 343967 × LBG-20	11.42	-9.87	-11.65 *	19.74 *
IC 343967 × T-9	12.35	12.50 *	-0.55	29.48 **
IC587752 × PU-19	11.09	-6.80	-9.07	16.23 *
IC 587752 × LBG-20	12.87	4.92	-0.47	34.89 **
IC 587752 × T-9	13.73	29.92 **	18.38 **	43.96 **
IC 587751 × PU-19	11.85	-0.68	-2.79	24.25 **
IC 587751 × LBG-20	13.68	11.19 *	5.80	43.39 **
IC 587751 × T-9	10.42	-1.79	-10.77	9.21
IC 282009 × PU-19	13.97	15.26 **	14.62 *	46.50 **
IC 282009 × LBG-20	11.78	-5.70	-8.88	23.49 **
IC 282009 × T-9	11.74	8.74	-2.61	23.09 **
IC 436753 × PU-19	11.66	0.19	-4.37	22.24 **
IC 436753 × LBG-20	12.22	1.77	-5.48	28.10 **
IC 436753 × T-9	13.10	27.05 **	18.19 **	37.34 **
IC 436610 × PU-19	9.87	-16.25 **	-19.02 **	3.51
IC 436610 × LBG-20	11.72	-3.56	-9.31	22.91 **
IC 436610 × T-9	12.79	22.23 **	12.32	34.06 **
IC 398971 × PU-19	13.20	2.70	-2.34	38.42 **
IC 398971 × LBG-20	12.21	-7.64	-9.66	28.04 **
IC 398971 × T-9	13.65	18.35 **	0.93	43.05 **
IC 281987 × PU-19	14.87	24.94 **	21.97 **	55.9 **
IC 281987 × LBG-20	13.47	9.78	4.20	41.22 **
IC 281987 × T-9	11.74	10.97	1.06	23.04 **
IC 436652 × PU-19	11.18	2.86	-8.32	17.18 *
IC 436652 × LBG-20	14.55	29.55 **	12.58 *	52.58 **
IC 436652 × T-9	12.59	31.92 **	31.89 **	31.94 **
S.E.		***0.65***	***0.75***	***0.75***
CD 95%		***1.28***	***1.78***	***1.78***
CD99%		***1.68***	***1.94***	***1.94***

*, ** Significant at 5 and 1 per cent level, respectively; MP-Mid parent, BP- Better parent, SP- Standard parent