



Heterosis and combining ability in blackgram (*Vigna mungo*) under different environments

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ABSTRACT

A diallel set of 10 parents and their 45 f_1 and 45 f_2 hybrids were analyzed to estimate the magnitude of heterosis and to understand the nature and magnitude of gene action under different environments for seed yield and its component characters of blackgram [*Vigna mungo* (L.) Hepper]. As the genotype \times environment interaction was significant for all the traits, hence the combining ability was carried out for each environment separately. The combining ability analysis revealed that the GCA and SCA variances were significant for all the characters in each of the three environments indicating the importance of both additive and non-additive genetic control of all the characters under study. Some parents having consistent desirable GCA estimates for some characters in most of the environments were UH 84-14 for days to 50 per cent flowering, harvest index (HI) and seed yield/plant; GU 1 and RBU 38 for harvest index (HI) and seed yield/plant; VBN 3 and VBN 4 for pod weight and seed yield/plant. Overall crosses based on high *per se* performance, high SCA effects, high heterobeltiosis and high standard heterosis only for seed yield per plant were VBN 3 \times UH 84-14 and RBU 38 \times UH 84-14 in E_1 and NUL 7 \times UH 84-14, IU 8-6 \times UH 84-14 and IU 8-6 \times VBN 4 in E_3 . As the environmental effect on the expression of the character was very high, different crosses emerged in different environments for seed yield/plant. Thus, these crosses can be included in the breeding programme for improvement in yield in specific environment.

Key words: Blackgram, Combining ability, Heterosis, Seed yield, Yield components

Food legumes are a vital source of protein, especially for the poor, who often cannot afford animal products. These crops contain high amounts of protein, macro- and micronutrients (Ca, P, K, Fe, and Zn), vitamins (niacin, vitamin A, ascorbic acid, inositol), fiber and carbohydrate for balance nutrition. They are rich in lysine, an essential amino acid which is found only at low levels in cereal protein (Solh Mahmoud 2009). Blackgram [*Vigna mungo* (L.) Hepper] is an important, protein rich food legume crop of Indian sub-continent. It is mostly grown in Madhya Pradesh, Maharashtra, Tamil Nadu, Uttar Pradesh, Rajasthan and Gujarat during *khariif* and Andhra Pradesh and West Bengal in *rabi*. Diallel analysis is one of the precise techniques to identify parents as well as the best cross combinations in the immediate generation after making the crosses. The nature of inheritance of quantitative traits aids in adopting proper selection method in breeding programme. Heterosis has

important implications for both in F_1 and for adopting transgressive segregates in F_2 generation. Genetic information regarding heterosis provides a clue for selecting the most suitable parents for hybridization. The presence of heterosis in food legumes has been demonstrated by Singh *et al.* (1975), and Shinde and Deshmukh (1989). The presence of heterosis can only be utilized in pulse crops for the development of high yielding pure line varieties (Singh 1971). Little information about heterosis and gene action is available in blackgram. The present study was carried out to estimate the extent of heterosis and nature of gene action in a 10-parental diallel for utilization of existing genetic variability to develop blackgram variety with improved grain yield character.

MATERIALS AND METHODS

Ten genetically diverse varieties of blackgram namely; GU 1, RBU 38, IPU 99-1, IU 8-6, NUL 7, Ludhiana U 201, VBN 3, VBN 4, UH 84-14 and NIC 17556, selected on the basis of high protein content, low protein content, high yielding, low yielding were crossed in diallel fashion (excluding reciprocals) during *khariif* 2006. Few F_1 seeds were planted to develop sufficient quantity of F_2 seed during

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Table 1 General combining ability (GCA) effects for seed yield and its component characters of 10 blackgram genotypes

Parent	Days to 50 % flowering			Number of effective branches/plant			Pod weight (g)			Harvest index (%)			Seed yield/plant (g)		
	GCA effects			GCA effects			GCA effects			GCA effects			GCA effects		
	E ₁	E ₂	E ₃	E ₁	E ₂	E ₃	E ₁	E ₂	E ₃	E ₁	E ₂	E ₃	E ₁	E ₂	E ₃
GU 1 (P ₁)	-0.60	-1.28	-0.56	0.35	0.11	1.12**	-0.11	0.41	-1.91**	3.16*	0.67	1.11	-0.073	0.37**	-0.89**
RBU 38 (P ₂)	1.29	1.75	1.10	1.68**	-0.19	0.54	0.04	-0.52	-0.70*	-1.48	-0.81	-0.91	-0.14	-0.05	-0.26**
IPU 99-1 (P ₃)	0.85	0.86	0.63	-1.42**	-0.17	-0.81**	-0.28	-0.79**	-1.01**	2.43	2.03	-0.65	-0.13	-0.17**	-0.87**
IU 8-6 (P ₄)	-0.10	0.61	0.80	-1.28*	-1.00**	0.54	0.88**	-0.13	1.34**	-0.64	-0.28	0.78	0.29	-0.18**	1.06**
NUL 7 (P ₅)	-0.82	-0.18	-1.03	-0.01	0.75**	0.96**	-0.14	-0.04	0.62	-0.59	-0.39	-1.00	-0.34	0.05	0.15*
Ludhiana U 201 (P ₆)	0.76	-0.02	0.49	-0.20	-0.94	-1.59**	-0.06	-0.70*	1.45**	-4.04**	0.72	2.35**	0.20	-0.18**	0.27**
VBN 3 (P ₇)	-0.10	-0.16	-0.50	0.48	-0.61**	0.04	0.25	1.33**	0.91**	1.07	-0.64	-2.17**	0.55*	0.14**	0.35**
VBN 4 (P ₈)	-1.32	-1.10	-1.20	-0.53	-0.44**	-0.12	-0.67*	-0.19	-0.89**	-0.34	-0.36	-4.22**	-0.73**	-0.29**	-0.44**
UH 84-14 (P ₉)	-1.93*	-2.02*	-1.03	1.07*	0.86**	0.21	0.57	0.13	0.88*	-0.36	-1.05	3.08**	0.64*	0.03	1.01**
NIC 17556 (P ₁₀)	1.98*	1.47	1.30	-0.12	1.30**	-0.90**	-0.44	0.49	-0.68*	0.80	0.13	1.63*	-0.26	0.29*	-0.38**
Var (g ₁)	0.911	1.00	1.06	0.50	0.15	0.30	0.33	0.28	0.34	1.33	1.06	0.73	0.260	0.037	0.07
Var (g ₁ g ₂)	1.359	1.49	1.58	0.75	0.53	0.45	0.50	0.42	0.50	1.98	1.58	1.098	0.388	0.056	0.11

* and ** significant at 5 and 1 per cent level of significance, respectively.

summer 2007. Ten parents, 45 F₁ and 45 F₂ crosses were evaluated following randomized block design with three replications at three locations [E₁: Sardarkrushinagar, E₂: Aseda and E₃: Khedbrahma] during *kharif* 2007. At each location, in each replication, each of the homogeneous generations, i.e. parents, and F₁ were sown in a plot of single row of five metre length spaced in a plot of three rows of five metre length spaced 25 cm apart. 10 cm distance between plant to plant was maintained in each plot. Non experimental rows were planted all around the experimental material to avoid any possible border effects. Observations were recorded on five random plants in parents and F₁'s in each replication for days to 50 % flowering, number of effective branches/plant, pod weight (g), harvest index (%) and seed yield/plant (g). The mean values were used for the analysis of variance. Data were first subjected to the usual analysis followed for a randomized block design for individual environment as suggested by Panse and Sukhatme (1967).

Griffing's (1956) method II for diallel analysis was used and estimated of general combining ability (GCA) and specific combining ability (SCA) effects were obtained. The relative importance of GCA and SCA was calculated by the ratio $2\sigma^2g/(2\sigma^2g + \sigma^2s)$ given by Baker (1978) for fixed effect model, where σ^2g is the estimate of GCA component and σ^2s that of the SCA component.

RESULTS AND DISCUSSION

Heterobeltiosis is useful in deciding the direction and prospects of future improvement programme and also find out the specific improvement programme, which might be more promising than the conventional breeding programme. The extent of heterosis depends on the magnitude of non-additive gene action and wide genetic diversity among parents. However, there are reports that in self-pollinated crops, crosses with high heterosis associated with high magnitude of additive \times additive gene effects give better segregants (Gupta *et al.* 1989). Mackey (1976) described that superiority of hybrid over better parent may be either due to dominance or epistasis or over dominance or combined effects of two or more of these phenomenon. In the present investigation the parent vs. crosses component of variance was significant for most of the characters in different environments as well as over environments, indicating presence of sufficient heterosis. The maximum value of heterosis over mid-parent was highest for seed yield/plant (-54.49 to 158.56) followed by pod weight (-27.86 to 101.92), number of effective branches/plant (-17.71 to 90.27) and harvest index (1.05 to 73.54); and low for days to 50 per cent flowering (-22.12 to 16.42) in all the environments (Table 2). Maximum desirable heterosis over better parent (heterobeltiosis) was 93.43 (NUL 7 \times UH 84-14 in E₃) for seed yield/plant followed by 76.21 (RBU 38 \times NUL 7 in E₁) for number of effective branches/plant, 49.04 (IU 8-6 \times UH 84-14 in E₃) for pod weight, 24.68 (IPU 99-1 \times UH 84-14 in E₃) for harvest index and 9.38

Table 2 Heterosis (%) for seed yield and component characters in blackgram hybrids

Character	Crosses	Mid-parent heterosis	High/Low	Environment	Crosses	Hetero-beltiosis	Environment
Days to 50 % flowering	×	22.12 to 16.42	Low	×	GU 1 × NUL 7	9.38	E ₃
Number of effective branches/plant	×	-17.71 to 90.27	High	×	IU 8-6 × UH 84-14	49.04	E ₃
Pod weight (g)	×	-27.86 to 101.92	High	×	RBU-38 × NUL 7	76.21	E ₁
Harvest index (%)	×	1.05 to 73.54	High	×	IPU 99-1 × UH 84-14	24.68	E ₃
Seed yield/plant (g)	×	-54.49 to 158.56	High	×	NUL 7 × UH 84-14	93.43	E ₁

(GU 1 × NUL 7 in E₃) for days to 50 per cent flowering. Among these crosses GU 1 × Ludhiana U 201, IU 8-6 × Ludhiana U 201 and IU 8-6 × UH 84-14 came out to be the promising crosses for some other important yield component characters in most of the environments. These crosses were considered promising for their use for yield improvement because of having high heterotic effect for seed yield. Similar results in varying environments for different characters were also reported by Singh and Singh (1974), Naidu and Satyanarayan (1993), Khattak *et al.* (2000), Sekhawat (2002), Venkatraman *et al.* (2007), Barad *et al.* (2008) and Thomas *et al.* (2008).

As the genotype × environment interaction was significant for all the traits, hence the combining ability was carried out for each environment separately. The combining ability analysis revealed that the GCA and SCA variances were significant for all the characters in each of the three environments indicating the importance of both additive and non-additive genetic control of all the characters under study. Nature and magnitude of combining ability effects help in identifying superior parents and their utilization in further breeding programme and the parents were classified as good, average and poor combiners for five characters. None of the parents was good general combiner for all the characters. Some parents having consistent desirable GCA estimates for some characters in most of the environments were UH 84-14 for days to 50 per cent flowering, harvest index and seed yield/plant; GU 1 and RBU 38 for harvest index and seed yield/plant; VBN 3 and VBN 4 for pod weight and seed yield/plant; NUL 7 for number of effective branches/plant and Ludhiana U 201 for pod weight and harvest index. In general, it was observed that top parents on the basis of high *per se* performance also had high general combining ability effects. Since GCA effects are attributed to additive and additive × additive gene effects, the above mentioned parents for GCA effects have good potential for respective characters and may be used in a multiple crossing programme to synthesize a dynamic population with most of the favourable genes accumulated (Griffing 1956). None of the cross combinations showed significant SCA effects for all the traits in all the environments. However, cross combinations with significant and high SCA effects in all the three

environments for at least two characters were IU 8-6 × VBN 4. While, crosses which expressed significantly high SCA effects in two environments for at least two characters were RBU 38 × NUL 7, VBN 3 × UH 84-14. Cross combination with significant and high SCA effects in two environment for at least one character was IU 8-6 × Ludhiana U 201. These crosses could be of immense potential in blackgram improvement programme. The result obtained in the present study are in confirmity with the earlier findings of Dhaliwal and Singh (1970), Dana and Dasgupta (2001), Singh and Dikshit (2003), Singh and Singh (2005), Venkatraman *et al.* (2007), Barad *et al.* (2008) and Thomas *et al.* (2008). Overall crosses based on high *per se* performance, high SCA effects, high heterobeltiosis and high standard heterosis only for seed yield/plant were VBN 3 × UH 84-14 and RBU 38 × UH 84-14 in E₁ and NUL 7 × UH 84-14, IU 8-6 × UH 84-14 and IU 8-6 × VBN 4 in E₃. As the environmental effect on the expression of the character was very high, different crosses emerged in different environments for seed yield/plant. Thus, these crosses can be included in the breeding programme for improvement in yield in specific environment.

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Table 3 Top three parents and three crosses based on *per se* performance, combining ability, heterobeltiosis and standard heterosis under different environments for seed yield and associated characters

Env. Parents	<i>Per se</i> performance					
	F ₁	F ₂	GCA	SCA	Heterobeltiosis	Standard heterosis
<i>Character : Days to 50 per cent flowering</i>						
E ₁	VBN 4 NUL 7 UH 84-14	IU 8-6 × NUL 7 GU 1 × UH 84-14 VBN 3 × VBN 4	UH 84-14	IU 8-6 × NUL 7	IU 8-6 × NUL 7 GU 1 × UH 84-14 VBN 3 × VBN 4	IU 8-6 × NUL 7 GU 1 × UH 84-14 VBN 3 × VBN 4
E ₂	NUL 7 VBN 4 UH 84-14	GU 1 × UH 84-14 IU 8-6 × Ludhiana U 201 GU 1 × Ludhiana U 201	UH 84-14	IU 8-6 × Ludhiana U 201 GU 1 × UH 84-14	GU 1 × UH 84-14 IU 8-6 × Ludhiana U 201 GU 1 × Ludhiana U 201	GU 1 × UH 84-14 IU 8-6 × Ludhiana U 201 GU 1 × Ludhiana U 201
E ₃	RBU 38 VBN 4 NUL 7	GU 1 × Ludhiana U 201 GU 1 × UH 84-14 IU 8-6 × NUL 7		GU 1 × Ludhiana U 201 IU 8-6 × NUL 7	GU 1 × Ludhiana U 201 GU 1 × UH 84-14 IU 8-6 × NUL 7	GU 1 × UH 84-14 IU 8-6 × NUL 7 GU 1 × Ludhiana U 201
<i>Character : Number of effective branches/plant</i>						
E ₁	IPU 99-1 IU 8-6 NIC 17556	IU 8-6 × VBN 4 GU 1 × RBU 38 GU 1 × IPU-99-1	RBU 38 UH 84-14	RBU 38 × NUL 7 VBN 3 × NIC 7556 GU 1 × UH 84-14	RBU 38 × NUL 7 GU 1 × UH 84-14 VBN 3 × UH 84-14	RBU 38 × NUL 7 GU 1 × UH 84-14 VBN-3 × UH-84-14
E ₂	IU-8-6 VBN 4 UH 84-14	GU 1 × IU 8-6 GU 1 × Ludhiana U 201 RBU 38 × Ludhiana U 201	NIC 17556 UH 84-14 NUL-7	IPU 99-1 × VBN 3 UH 84-14 × NIC 7556 IU-8-6 × UH 84-14	UH-84-14 × NUL 7 IPU 99-1 × VBN 3 NUL 7 × NIC 7556	UH 84-14 × NIC 17556 IPU 99-1 × VBN 3 GU 1 × UH 84-14
E ₃	IPU 99-1 Ludhiana U 201 NIC 17556	VBN 4 × UH 84-14 RBU 38 × UH 84-14 IPU 99-1 × IU 8-6	GU 1 NUL 7 Ludhiana U 201 × VBN-3	RBU 38 × NUL 7 IU 8-6 × UH 84-14 IPU 99-1 × VBN-4	RBU 38 × NUL 7 IU 8-6 × UH 84-14 IPU 99-1 × VBN 4	IU 8-6 × UH 84-14 GU 1 × RBU 38 IPU 99-1 × VBN 4
<i>Character : Pod weight</i>						
E ₁	IU 8-6 IPU 99-1 RBU 38	VBN 3 × UH 84-14 RBU 38 × UH 84-14 RBU 38 × VBN 3	IU 8-6	VBN 3 × UH 84-14 RBU 38 × UH 84-14 NUL 7 × NIC 7556	VBN 3 × UH 84-14 RBU 38 × UH 84-14 RBU 38 × VBN 3	VBN 3 × UH 84-14 RBU 38 × UH 84-14 IU 8-6 × UH 84-14
E ₂	NUL 7 VBN 3 Ludhiana U 201	UH 84-14 × NIC 17556 VBN 3 × UH 84-14 VBN 3 × NIC 17556	VBN 3	UH 84-14 × IC-17556 IPU 99-1 × NUL-7 RBU 38 × IPU 99-1	UH 84-14 × NIC 17556 VBN 3 × UH 84-14 RBU 38 × IPU 99-1	UH 84-14 × NIC 17556 VBN 3 × UH 84-14 VBN 3 × NIC 17556
E ₃	VBN 3	IU 8-6 × UH 84-14	Ludhiana U 201	IU 8-6 × UH 84-14	IU 8-6 × UH 84-14	IU 8-6 × UH 84-14

(Contd.)

Table 3 (Concluded)

Env. Parents	<i>Per se</i> performance					Standard heterosis
	F ₁	F ₂	GCA	SCA	Heterobeltiosis	
Ludhiana U 201	NUL 7 × VBN 3	IU 8-6 × UH 84-14	IU 8-6	NUL 7 × VBN 3	NUL 7 × VBN 3	NUL 7 × VBN 3
IPU 99-1	NUL 7 × UH 84-14	IU 8-6 × NUL 7	UH 84-14	IPU 99-1 × NIC 17556	NUL 7 × UH 84-14	NUL 7 × UH 84-14
<i>Character : Harvest index (%)</i>						
E ₁ VBN 3	GU 1 × IPU 99-1	GU 1 × RBU 38	GU 1	GU 1 × IPU 99-1	GU 1 × IPU 99-1	GU 1 × IPU 99-1
NUL 7	GU 1 × IU 8-6	GU 1 × IPU 99-1	GU 1	GU 1 × IU 8-6	GU 1 × VBN 4	GU 1 × IU 8-6
VBN 4	VBN 3 × NIC 17556	GU 1 × VBN 4	GU 1 × VBN 4	VBN 3 × NIC 7556	VBN 3 × NIC 17556	VBN 3 × NIC 17556
E ₂ GU 1	IPU 99-1 × IU 8-6	IPU 99-1 × NUL 7	IPU 99-1 × NUL 7	NUL 7 × VBN 4	NUL 7 × VBN 4	IPU 99-1 × UH 84-14
IPU 99-1	UH 94-14 × NIC 7556	RBU 38 × VBN 4	RBU 38 × VBN 4	IU 8-6 × VBN 4	IU 8-6 × VBN 4	GU 1 × IU 8-6
Ludhiana U 201	IU 8-6 × VBN 4	IU 8-6 × VBN 4	IU 8-6 × VBN 4	IU 8-6 × VBN 4	IU 8-6 × VBN 4	UH 84-14 × NIC 17556
E ₃ UH 84-14	IPU 99-1 × UH 84-14	IPU 99-1 × UH 84-14	UH 84-14	NUL 7 × Ludhiana U 201	IPU 99-1 × UH 84-14	IPU 99-1 × UH 84-14
NIC 17556	NUL 7 × Ludhiana U 201	RBU 38 × IPU 99-1	Ludhiana U 201	IPU 99-1 × UH 84-14	NUL 7 × Ludhiana U 201	NUL 7 × Ludhiana U 201
VBN 3	UH 84-14 × NIC 17556	UH 84-14 × NIC 17556	NIC 17556	GU 1 × IU 8-6	UH 84-14 × NIC 17556	UH 84-14 × NIC 17556
<i>Character : Seed yield/plant (g)</i>						
E ₁ VBN 3	VBN 3 × UH 84-14	IU 8-6 × Ludhiana U 201	UH 84-14	VBN 3 × UH 84-14	VBN 3 × UH 84-14	VBN 3 × UH 84-14
UH 84-14	RBU 38 × UH 84-14	IPU 99-1 × IU 8-6	VBN 3	RBU × UH 84-14	RBU 38 × UH 84-14	RBU 38 × UH 84-14
IU 8-6	GU 1 × Ludhiana U 201	GU 1 × UH 84-14	GU 1 × UH 84-14	IPU 99-1 × VBN 4	GU 1 × Ludhiana U 201	GU 1 × Ludhiana U 201
E ₂ NUL 7	UH 84-14 × NIC 17556	RBU 38 × NIC 7559	GU 1	IU 8-6 × VBN 4	IU 8-6 × UH 84-14	RBU 38 × UH 84-14
RBU 38	VBN 3 × UH 84-14	RBU 38 × UH 84-14	NIC 17556	UH 84-14 × NIC 17556	GU 1 × Ludhiana U 201	Ludhiana U 201 × NIC 17556
Ludhiana U 201	IU 8-6 × VBN 4	UH 84-14 × NIC 17556	VBN 3	VBN 3 × UH 84-14	IU 8-6 × Ludhiana U 201	IPU 99-1 × NUL 7
E ₃ VBN 3	NUL 7 × UH 84-14	IU 8-6 × UH 84-14	IU 8-6	NUL 7 × UH 84-14	NUL 7 × UH 84-14	NUL 7 × UH 84-14
UH 84-14	IU 8-6 × UH 84-14	IU 8-6 × NUL 7	UH 84-14	IU 8-6 × UH 84-14	IU 8-6 × UH 84-14	IU 8-6 × UH 84-14
NIC 17556	IU 8-6 × VBN 4	GU 1 × IU 8-6	VBN 3	IU 8-6 × VBN 4	IU 8-6 × VBN 4	IU 8-6 × VBN 4

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