HETEROSIS AND COMBINING ABILITY IN BLACK GRAM

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THOUGH hybrid vigour has been reported in many pulse crops by various workers (Solomon *et al.*, 1957 in pigeon pea; Ramanujam, Rohewal and Singh, 1964 in Bengal gram; Singh and Jain, 1970 in green gram; Singh and Singh, 1970 in pea; Singh and Jain, 1971 in lentil), yet development of hybrid varieties in these self-pollinated crops does not seem to be economically feasible. This aspect needs to be fully explored. In such crops development of pure lines from hybrid material is common practice. Choice of the parental lines for hybridization poses a serious problem. Line × tester analysis appears to be a useful tool for screening the lines with speed and reasonable confidence. Using this technique, heterosis and combining ability have been reported here in black gram (*Phaseolus mungo* L.).

MATERIALS AND METHODS

Two outstanding varieties, viz., Mash 1–1 and L. 64, were used as male parents and testers. These testers were crossed with nine female parents, viz., T. 27, T. 65, BR. 61, BR. 68, L. 46, L. 35–5, L. 47, L. 26–59 and P. 1–68. Twenty-nine entries consisting of two tester lines, 9 female parents and eighteen F_1 hybrids were grown in a randomized block design with three replications at Punjab Agricultural University, Ludhiana during rainy season of 1969. Each net plot included a single row of 2·25 m. accommodating 10 plants at 22·5 cm. apart. Rows were spaced 45 cm. apart. Non-experimental material were planted all round the plots to avoid border effect. Observations were recorded on five competitive plants for six characters including, grain yield, pod number, cluster number, branch number, 100-seed weight and pod length.

Statistical analysis was done on the mean values of five plants per entry. Heterosis was determined as percentage increase in F_1 hybrids over mid-parent and better parent. The method outlined by Kempthrone (1957) for covariance of half sibs and full sibs was used for obtaining estimates of general and specific combining ability effects and variances.

RESULTS AND DISCUSSION

HETEROSIS

The mean performance of better parent, mid-parent and F_1 hybrids for yield, cluster number, pod number, branch number, 100-grain weight and pod length are presented in Table 1. The hybrid vigour in F_1 generations over mid-parent and better parent are given in Table 2. In the same table hybrid vigour in F_1's for grain yield over best variety, Mash 1–1 is also given. It is noted from this table that overall heterosis over the mid-parent was present for yield, cluster number, pod number and branch number, but overall negative vigour was

TABLE

Mean performance of mid-parent, better

Cross	Grain yield (gm.)			Pod number		
	$\bar{P}$	BP	F_1	$\bar{P}$	BP	F_1
L 46 × L 64	25·8	32·8	38·8	123	135	167
L 35–5 × L 64	32·2	32·8	30·0	134	135	234
L 47 × L 64	31·8	32·8	37·9	128	135	142
L 26–59 × L 64	33·2	33·5	44·1	146	156	223
T 27 × L 64	33·8	34·8	66·8	151	168	214
T 65 × L 64	31·6	32·8	72·5	141	147	284
BR 61 × L 64	28·6	32·8	33·6	125	135	152
BR 68 × L 64	39·2	45·5	98·7	191	246	367
P I–68 × L 64	29·9	32·8	54·4	139	142	239
L 46 × Mash 1–1	35·7	52·5	50·9	186	261	212
L 35–5 × Mash 1–1	41·1	52·5	42·1	197	261	140
L 47 × Mash 1–1	38·1	52·5	37·9	191	261	156
L 26–59 × Mash 1–1	43·0	52·5	37·0	209	261	176
T 27 × Mash 1–1	43·6	52·5	79·9	215	261	283
T 65 × Mash 1–1	41·4	52·5	37·9	204	261	185
BR 61 × Mash 1–1	38·4	52·5	26·9	188	261	195
BR 68 × Mash 1–1	49·0	52·5	23·5	254	261	240
P 1–68 × Mash 1–1	39·8	52·5	86·5	202	261	392
C.D. *at* 5%	21·4			90·9		
C.D. at 1%	28·5			121·0		

observed for seed size and pod length. The relative range of heterosis in F_1 hybrids for grain yield over mid-parent was from – 52 to 152 per cent with an average of 37%.

Fifty six per cent. hybrids excelled the better parent in yield. The relative range of hybrid vigour was from –55·2 to 121·0 with average of 14·9%. Six hybrids superceded their better parents by significant margin. When F_1 hybrids were compared from their respective tester parent, viz., Mash 1–1 and L 64, it was observed that over all heterosis of –4·8 and 64·3 % respectively was obtained. This shows that the parent L 64 combined better than Mash 1–1. It would be of interest to compare the performance of hybrids with best variety of the area. It was observed that six crosses exceeded the best variety. Three hybrids, namely T 27×Mash 1–1, P 1–68×Mash 1–1 and BR 68×L 64, exceeded the best variety and the better parent by significant margin.

Heterosis in hybrids over better parent was observed for cluster number and pod number, while overall negative heterosis was noted for 100-grain weight and pod length. In case of branch number, half the crosses exhibited

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parent and F_1 hybrid for different characters

Cluster number			Branch number			100-seed weight (gm)			Pod length (cm)		
$\bar{P}$	BP	F_1	$\bar{P}$	BP	F_1	$\bar{P}$	BP	F_1	$\bar{P}$	BP	F_1
45	56	89	6·7	7·4	7·7	4·48	4·63	4·65	5·3	5·4	5·2
59	61	110	7·1	7·4	8·8	4·55	5·63	5·82	4·9	5·1	4·5
58	60	81	7·4	7·4	8·4	4·38	4·63	4·40	5·2	5·2	4·8
60	64	108	7·0	7·4	6·8	4·37	4·63	4·28	5·0	5·1	4·1
55	56	97	6·9	7·4	7·1	4·43	4·63	4·36	5·0	5·9	5·2
56	56	102	6·9	7·4	6·3	4·61	4·63	3·74	5·2	5·3	5·2
43	56	50	6·7	7·4	5·5	4·40	4·63	4·35	4·9	5·0	4·6
100	100	151	8·2	9·1	5·5	4·20	4·63	3·50	4·9	5·1	4·8
54	56	97	7·2	7·4	9·7	4·23	4·63	3·92	5·1	5·1	4·7
67	100	94	6·5	7·0	7·9	4·37	4·40	4·32	5·0	5·4	5·0
81	100	56	6·9	7·0	6·5	4·43	4·46	4·80	4·7	4·7	6·0
80	100	62	7·2	7·4	8·1	4·26	4·40	4·14	4·9	5·2	5·0
82	100	83	6·8	7·0	6·3	4·20	4·40	4·37	4·8	4·9	5·4
76	100	117	7·0	7·0	7·8	4·30	4·40	3·95	4·8	4·9	5·3
78	100	87	6·7	7·0	7·3	4·49	4·59	4·41	6·0	6·7	5·1
64	100	49	6·5	7·0	5·5	4·29	4·40	4·30	4·9	5·0	4·6
100	100	89	8·0	9·1	8·5	3·98	4·40	3·77	4·7	4·7	5·4
76	100	136	7·0	7·0	9·0	4·12	4·40	4·23	4·9	5·1	4·4
31·1			0·1			0·6			0·7		
41·5			0·2			0·9			1·0		

positive heterosis and remaining crosses showed negative heterosis. It was interesting to note similarity in expression of heterosis in yield and two of its components, namely cluster number and pod number. As regards other characters the manifestation of heterosis in yield was not necessarily associated. Singh *et al.* (1971) reported that pod number and cluster number are the most important yield components in black-gram. Thus it is obvious that increase in grain yield in F_1 hybrids is the result of increase in the yield components. Ramanujam, Rohewal and Singh (1964) also arrived at similar conclusion in Bengal gram.

Singh (1971) has extensively reviewed the literature on heterosis in pulse crops and its possible use in varietal improvement programme. He has ruled out the possibility of making use of F_1 or advanced generations to develop hybrid varieties for the present. He has demonstrated, taking example of green-gram, that it was possible to develop high yielding pure lines from those F_1 hybrids which had shown hybrid vigour over better parent and best variety of the area. All those crosses showing no heterosis over better parents got rejected

TABLE

Expression of heterosis in F_1 over

Cross	Grain yield			Pod number	
	$\bar{P}$	BP	Check	$\bar{P}$	BP
L 46 × L 64	50·1	18·3	–35·3	36·0	23·9
L 35–5 × L 64	–7·0	–8·5	–75·0	75·0	73·1
L 47 × L 64	19·4	15·7	–38·5	10·8	5·2
L 26–59 × L 64	33·1	31·6	–19·0	53·0	42·7
T 27 × L 64	97·6	92·0	21·4	59·2	27·6
T 65 × L 64	129·3	121·0	38·1	101·2	93·0
BR 61 × L 64	17·4	2·4	–56·3	21·8	12·6
BR 68 × L 64	152·0	116·7	46·8	92·7	49·2
P I–68 × L 64	81·5	65·8	3·6	72·8	68·5
L 46 × Mash 1–1	42·6	–3·0	–2·9	13·9	–18·9
L 35–5 × Mash 1–1	2·5	–19·8	–23·3	–28·7	–46·3
L 47 × Mash 1–1	–0·6	–27·8	–38·5	–18·5	–40·3
L 26–59 × Mash 1–1	–14·0	–29·5	–41·9	–18·6	–32·7
T 27 × Mash 1–1	83·2	52·3	34·3	31·9	8·3
T 65 × Mash 1–1	–8·5	–27·8	–38·5	–9·6	–29·3
BR 61 × Mash 1–1	–30·1	–48·8	–95·2	3·6	–25·5
BR 68 × Mash 1–1	–52·0	–55·2	–123·4	–5·4	–8·2
PI 68 × Mash 1–1	117·3	64·8	39·3	94·2	49·9
Overall heterosis	37·0	14·9		28·2	6·7

in early segregating generations. He has emphasized that this approach may be adopted in pulse crops for getting quick success. On this basis, it is suggested that those crosses which have shown heterosis over the best variety and better parents in black-gram may be further exploited in breeding programme for development of high yielding pure lines. Similar results have been reported by Smith (1952) in tobacco and Powers (1952) and Williams (1959) in tomato. These workers have also suggested that it is possible to develop pure line varieties which perform better than or as well as hybrids.

COMBINING ABILITY

The analysis of variance for six characters (Table 3) revealed that tester (male) differences were significant only for pod length, whereas reverse was true for lines (female). The line × tester interaction was significant for yield, pod number and cluster number.

The estimates of general combining ability effects are given in Table 4. G.c.a. effects for all these characters except pod length was not determined in respect of testers. As regards g.c.a. effects of female parents two lines, viz., T 27 and P 1-68, had significant g.c.a. value for grain yield. The lowest g.c.a. value

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mid-parent and better parent (%)

Cluster number		Branch number		100-seed weight		Pod length	
$\bar{P}$	BP	$\bar{P}$	BP	$\bar{P}$	BP	$\bar{P}$	BP
96·3	58·0	15·0	3·9	3·8	0·4	–1·3	–3·9
87·5	80·3	22·6	18·6	27·9	25·7	–8·6	–12·3
40·2	36·3	14·1	13·8	0·5	–5·0	–6·2	–6·7
78·5	67·4	–2·6	–7·5	–2·1	–7·7	–18·6	–20·5
78·0	72·2	2·8	–3·9	–1·6	–5·8	3·0	–12·5
83·3	81·7	–7·9	–14·4	–18·9	–19·2	–0·4	–2·3
18·4	–10·7	–25·2	–32·3	–1·1	–6·1	–16·5	–17·2
50·4	50·2	–32·8	–39·4	–16·7	–24·4	–2·7	–6·8
78·5	72·2	34·6	31·3	–7·3	–15·3	–8·8	–9·0
40·4	–5·7	21·5	12·8	–1·2	–1·8	–1·2	–8·0
–30·0	–43·7	–6·3	–6·6	8·4	7·6	27·7	27·5
–22·8	–38·3	13·1	9·6	–2·8	–5·9	1·2	–3·7
1·0	–17·0	–7·0	–9·5	4·1	–0·7	13·0	10·7
53·7	17·3	16·7	12·2	–8·1	–10·2	11·3	8·8
12·0	–13·0	9·6	4·7	–1·8	–3·9	–15·2	–23·8
–23·8	–51·0	–15·0	–21·0	0·2	–2·3	–9·8	–13·8
13·2	–11·7	6·5	–6·0	–5·3	–14·3	14·5	14·5
78·6	36·0	28·0	28·0	2·7	–3·9	–6·0	–9·3
36·8	13·0	4·7	–0·9	–0·1	–5·2	–1·7	–5·6

TABLE 3

Analysis of variance

Source	d.f.	Mean sum of square					
		Yield	Pod no.	Cluster no.	Branch no.	100-seed wt.	Pod length
Male	1	162·12	109·17	8·00	0·14	0·03	0·67**
Female	8	489·64**	6691·27**	976·14**	2·64**	0·41**	0·09
Male × Female	8	506·84**	4281·15*	618·94**	1·04	0·12	0·02
Error	34	65·86	1443·94	165·08	0·78	0·07	0·06

*Significant at 5 per cent level; **Significant at 1 per cent level.

TABLE 4

General combining ability effects

		Grain yield	Pod no.	Cluster no.	Branch no.	100-seed wt.	Pod length
MALES	L 64	—	—	—	—	—	−0·19
(Tester)	Mash 1–1	—	—	—	—	—	0·19
	S.E. ($\hat{g}_i$) ±	—	—	—	—	—	0·01
FEMALES	L 46	−15·13	−32·50	−0·48	0·42	0·19	—
(*line*)	L 35–5	−13·91	−35·17	−8·98	0·28	1·02	—
	L 47	−12·05	−73·17	−20·65	0·94	−0·03	—
	L 26–59	−9·39	−22·83	3·19	−0·78	0·03	—
	T 27	23·38	26·34	15·02	0·10	−0·14	—
	T 65	5·22	12·00	2·52	−0·54	−0·22	—
	BR 61	−19·74	−49·33	−42·48	−2·09	0·03	—
	BR 68	11·14	81·33	27·52	−0·33	−0·66	—
	P I–68	20·46	93·33	24·35	2·00	−0·22	—
S.E. ($\hat{g}_i$) ±		5·74	26·81	9·09	0·06	0·02	—

was expressed by BR 61. Similar trend was noticed for cluster number and pod number. For branch number, P 1-68 had the maximum g.c.a. effects and BR 61 had the minimum. In case of 100-seed weight L 35–5 had the highest and BR 68 had the lowest g.c.a. effects.

The estimates of s.c.a. effects are given in Table 5 for grain yield, cluster number and pod number. The s.c.a. effects for crosses between BR 68 × L 64, P 1-68 × Mash 1-1, T27 × Mash 1-1 and T 65 × L 64 were significantly high, while for four crosses it was significantly low for grain yield. It was noteworthy that the crosses which had significant s.c.a. effects for yield also had significant s.c.a. effects for cluster number and pod number, although there were slight differences in magnitude and ranking. Singh and Dhaliwal (1970) for grain yield and Dhaliwal and Singh (1970) for cluster number and pod number have also reported significant s.c.a. effect for these characters. The present study revealed that for grain yield, cluster number and pod number, the genetic variability is not predominantly additive as gene interactions were highly significant (Table 3). In the present study two lines, viz., T 27 and P 1-68, had significant g.c.a. effect for yield, pod number and cluster number. It is suggested that these lines could be chosen as one of the parents in hybrid breeding programme. In case of choice of tester it is difficult to arrive at any definite conclusion because the g.c.a. effects for yield was non-significant. The significant line × tester effect for yield, cluster number and pod number in this study indicated that the different testers produce markedly different combining ability effects. This was expected because different lines and testers were grouped in different clusters

TABLE 5

Specific combining ability effects

Character	Male	Female L 46	L 35–5	L 47	L26–59	T 27	T 65	Br 61	Br 68	P I–68
Grain yield	L 64	–10·14	–14·51	–7·52	–2·63	3·61	18·38	–8·03	41·64	–7·34
	Mash 1–1	4·97	0·59	–4·53	–6·77	19·76	–13·17	–11·70	–30·50	27·79
Pod number	L 64	–39·82	27·86	–44·82	10·68	–22·57	54·27	–46·74	102·93	–30·73
	Mash 1–1	7·31	–64·52	–28·35	–33·52	48·90	42·26	–2·60	–21·60	124·07
Cluster number	L 64	–2·58	22·67	–0·16	14·26	–2·32	9·25	–20·25	–16·91	–6·99
	Mash 1–1	2·09	–31·66	–20·48	–11·08	17·34	–6·74	–22·24	44·43	31·35

S.E. ($\hat{S}ij$) Grain yield $\pm$ 1·91; S.E. ($\hat{S}ij$) Pod number $\pm$ 8·96; S.E. ($\hat{S}ig$) Cluster number $\pm$ 3·03 by Mahalnobis's D^2-statistic(Malhotra and Singh, 1971). This as well as other similar studies reveal that line×tester cross analysis seems useful for screening the lines.

SUMMARY

Heterosis and combining ability were studied in line×tester crosses for six characters in black-gram. Heterosis was observed over mid-parent for grain, yield cluster number, pod number and branch number. Fifty-six and 33% of the hybrids excelled the better parent and standard check respectively. Three hybrids were significantly better than both better parent and standard check. Heterosis in yield seems to be reflected through heterosis in cluster and pod number. Superiority of one tester over the other could not be established. It was visualized that two lines, viz., T 27 and P 1-68 and a few crosses may prove useful in future breeding programmes.

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