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Research Note

Studies on heterosis in blackgram (*Vigna mungo* (L.) Hepper)

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Abstract

A field experiment was conducted with thirty hybrids of eleven parents (six lines and five testers in 'Line x Tester' mating design) along with a check variety 'MDU 1'. The aim is to estimate the magnitude of economic heterosis which is considered for exploitation of hybrid vigour for higher yield and early maturity. Negative heterosis for three traits *viz.*, plant height, days to 50 % flowering and days to maturity is desirable for early maturation of crop. Based on experimental results of this investigation four crosses *viz*., MDU 1/ VBN (Bg) 6, MDU 1/ PU 31, MDU 1/ Mash-114 and MDU 1/ Uttara had exhibited higher positive significant standard heterosis for eight yield and yield attributing traits in positive direction and negative heterosis for two traits *viz*., days to 50 % flowering and days to maturity. The presence of magnitude of standard heterosis was higher in these crosses for yield and yield attributes. Hence, exploitation of hybrid vigour could be done in these crosses and it might be helpful in the improvement of this crop.

Keywords

Standard heterosis, Single plant yield, Line x Tester and Selection index

Blackgram (2n=22) is an important short duration legume crop belonging to family *Fabaceae*, widely cultivated in Asia. The crop is utilized in several ways, as sources of protein, plant parts are used as fodder and green manure. It adapts well to various cropping systems owing to its ability to fix atmospheric nitrogen (N_2) in symbiosis with soil bacteria, rapid growth, and early maturity (Soren *et al*., 2012). Among the legumes blackgram is one of the narrow genetic base crop represents smaller variability in primary gene pool. Lack of newer varieties and genotypes adapted to local environment is among the factors affecting its production necessitating, the development of new varieties adapt to local condition. Heterosis has important implications for both in F_1 and for adopting transgressive segregates in F_2 generation (Bhagirath Ram *et al*., 2013). The presence of heterosis in food legumes had been reorted by Rama Kant and Srivastava, 2012. Little information about heterosis and gene action is available in blackgram. The exploitation of heterosis in blackgram has not been commercialized due to limited extent of out crossing (Singh, 2000). However, highly heterotic crosses can be used for development of high yielding pure line varieties in this self-pollinated crop. Therefore, objectives of the present study was to unravel the genetic information on heterosis and extent of heterosis for yield and its components in urdbean crosses for selection of promising genotypes in segregating generation.

Eleven diverse black gram genotypes adapted to various agro-climatic regions were crossed in Line x Tester fashion which comprised of six lines (L1-L6) *viz*., ADT 3, MDU 1, CO 6, LPG-752, ADT 5 and KUG 688 and five testers (T1-T6) *viz*., VBN (Bg) 4, VBN (Bg) 6, Mash-114, Uttara and PU-31 during *Kharif*, 2014 at Agricultural College and Research Institute, Madurai research farm to obtain thirty inter-varietal crosses. Field experimentation on heterosis analysis comprised of 30 F_1s along with eleven parents were grown in randomized block design with two replications during *Rabi*, 2015. The observations were recorded on five randomly selected competent plants from each row for 11 quantitative traits *viz*., plant height (cm), branches / plant, days to 50 per cent flowering, days to maturity, clusters / plant, pods / cluster, pods / plant, seeds / pod, pod length (cm). 100 seed weight and single plant yield. The mean data on above traits were used to compute mean heterosis, heterobeltiosis, standard heterosis (Hays *et al.* 1955) Variety 'MDU 1' was used as the standard parent as it is one of the best released variety in Tamil Nadu by using the formula suggested by Fonseca and Patterson, 1968.

Results pertaining to analysis of variance, heterosis over mid parent, better parent and check variety *i.e.* MDU1 and percent contribution of parents (lines and testers) were given in Table 1, 2, 3 and 4. Mean square due to genotypes shows significant variability for all traits suggested clearly that the parents inclusion in these studies have varied differently among themselves for various quantitative traits relates to yield and yield attributes. The extent of heterosis depends on the magnitude of non additive gene action and wide genetic diversity among parents (Bhagirath Ram *et al*., 2013).

Higher heterosis for plant height had an added advantage of increasing the number of branches and number of cluster/ plant by which it increases the yield. For plant height, highly significant positive heterosis over better parent was recorded for ADT 5/ VBN (Bg) 4 with 27.83 % followed by KUG 688/ Uttra and ADT 5/ Mash-114 with 25.11 and 23.94 % respectively. Whereas, highly significant positive standard heterosis was reported by LPG-752/ Mash-114, LPG-752/ PU 31 and LPG-752/ Uttra with 22.18, 21.77 and 21.36 % respectively. These results were in close agreement with report of Rama Kant and Srivastava, 2012. Nine crosses showed significant positive heterosis over mid parent for branches/ plant of which highly significant positive heterosis was recorded for KUG 688/ Mash-114 with 90.00 % followed by KUG 688/ VBN (Bg) 6 and KUG 688/ Uttara with 66.27 and 62.96 % respectively. Heterobeltiosis was also higher for the same three crosses *viz*., KUG 688/ Mash-114, KUG 688/ VBN (Bg) 6 and KUG 688/ Uttara with 80.95, 64.29 and 57.14 % respectively. While for heterosis over commercial check significant positive heterosis was recorded in ten crosses. Among which ‘KUG 688/ Mash-114 with 43.40 % followed by KUG 688/ VBN (Bg) 6 and MDU 1/ Mash-114 with 30.19 and 27.55 % respectively occupied the top position.

For number of branches / plant, significant positive heterosis was recorded in all three form of heterosis. Hence, it shows that this trait shows higher magnitude of dominance which are in conformity with earlier reports of Pandiyan *et al*., 2010 and Yashpal *et al*., 2015. Negative heterosis is desirable for days to 50 per cent flowering which attribute to early mature of hybrids and is the deciding factor on selection of short duration genotypes in different cross combinations. Negative significant heterosis over mid parent was recorded for five crosses of which, three crosses *viz*., ‘MDU 1/ VBN (Bg) 4, MDU 1/ Uttara and KUG 688 recorded highly negative heterosis per cent with -9.72, -9.59 and -7.80. Over better parent, six crosses showed negative significant heterosis of which ‘MDU 1/ VBN (Bg) 4, MDU 1/ Uttara and MDU/ PU 31 were recorded highly significant heterosis per cent with -13.33, -12.0 and -10.67 respectively. Negative significant heterosis over check variety was recorded for twenty one hybrids of which crosses ‘MDU 1/ Uttara, MDU 1/ VBN (Bg) 6 and LPG-752/ Mash-114 showed higher magnitude of negative heterosis with -32.00, -31.33 and -30.67% respectively. The above result is similar to the findings of Gupta (2005), indicating significantly negative standard heterosis for flowering. Negative heterosis for days to maturity is also useful in selection of earliness. Eight hybrids shows significant negative heterosis over mid parent of which crosses ‘MDU 1/ VBN (Bg) 4, MDU1/ Uttara and KUG 688/ Uttara’ were recorded highly significant negative heterosis per cent with -11.58, -10.88 and -9.29 % respectively. Of the ten crosses shows negative significant heterosis over better parent, highly significant values are observed for crosses ‘MDU 1/ VBN (Bg) 4, MDU1/ Uttara and MDU 1/ PU 31’ with -14.29, -13.61 and -10.88 % respectively. Higher heterosis over commercial check variety were observed for twenty hybrids of which crosses ‘LPG-752/ VBN (Bg) 4, LPG-752/ Mash-113 and MDU 1/ VBN (Bg) 6’ with -16.12, -15.20 and -13.70 % respectively. The result is similar to findings of Gupta, 2005, indicating significantly negative standard heterosis for flowering and days to maturity duration.

Positive significant heterosis over mid parent was recorded for 11 crosses for cluster per plant, of which ‘ADT 3/ VBN (Bg) 6’ with 41.08 % followed closely by ‘KUG 688/ VBN (Bg) 6 and ADT 5/ Mash-114’ with 36.36 and 32.23 % respectively ranked the top position. Seven crosses recorded significant positive heterobeltiosis for this trait, among them the crosses’ ADT 5/ VBN (Bg) 6’ with 39.34 % followed by ‘KUG 688/ VBN (Bg) 6 and ADT 5/ Mash-114’ with 35.25 and 30.08 % respectively. Highly significant positive standard heterosis was obtained in twelve crosses. Among them the crosses ‘ADT 3/ VBN (Bg) 6 with 53.15 % followed by ‘LPG-752/ Mash-114 and LPG-752/ Uttara’ each with 48.65 % were the toppers. The higher magnitude of heterosis for cluster/ plant over commercial check suggested that predominance of dominance for heterotic expression of these three hybrids. Because increase in number of cluster/ plant will contribute to increase in number of pods and then on yield. A similar finding on cluster/ plant was reported by Barad *et al.* (2008) and Thomas *et al.* (2008).

Fourteen hybrids were exhibited positive significant heterosis over mid parent for pods/ cluster, of which maximum values recorded for ’LPG-752/ Uttara’ with 43.69 % followed by ‘LPG-752/ Mash-114 and ADT 5/ VBN (Bg) 4 with 38.89 and 35.24 % respectively. Significant positive heterosis per cent over better were recorded for nine hybrids, whereas maximum significant positive values on heterosis per cent over better parent was observed for crosses’ADT 3/ Mash-114’ with 32.00 % followed by ‘ADT 3/ VBN (Bg) 6 and ADT 3/ VBN (Bg) 4’ with 28.30 and 26.00 % respectively. Heterosis per cent over standard check variety was higher in fourteen crosses of which highly positive significant values were exhibited by 'LPG-732/ Mash-114, LPG-732/ Uttara and LPG-732/ PU 31 with 44.23, 42.31 and 38.46 % respectively. The maximum number of crosses exhibited higher heterotic vigor over commercial variety for pods/ cluster. Moreover, the higher magnitude of heterosis over standard variety in desired direction exhibited presence of dominant gene action for better heterotic combination in the hybrids. The similar kinds of results were reported by Patil *et al*., 2012. Positive significant heterosis for pods/ plant is desirable for selection of high yielding genotypes from crosses. Heterosis over mid parent was higher in twelve crosses, however maximum positive significant value were observed in 'LPG-752/ Uttara' with 44.68 % followed closely by 'LPG-752/ Mash-114 and KUG 688/ VBN (Bg) 6' with 40.21and 34.07 % respectively. With respect to heterosis over better parent was observed in six crosses of which 'LPG-752/ Mash-114' recorded with 38.78 % closely followed by 'LPG-752/ Uttara and LPG-752/ PU 31' with 38.78 and 31.37 % respectively. Twelve hybrids exhibited significant positive heterosis over commercial check, of which maximum values were observed for 'LPG-752/ Mash-114' with 38.79 % closely followed by 'LPG-752/ Uttara and LPG-752/ PU 31' with 38.78 and 36.73 % respectively over standard check for pods/ plant. The result was akin with the findings of Bagade *et al*., 2002; Patil *et al*., 2012 in Indian bean. Pod length is one of the important yield attributing trait which decides the seed number and size.

Ten crosses exhibited significant positive heterosis over mid parent for pod length, of which the maximum values were observed in 'ADT 5/ Mash-114' with 30.38 % followed by 'CO 6/ Mash-114 and ADT 3/ VBN (Bg) 6' with 21.57 and 19.08 % respectively. Significant positive heterobeltiosis was observed in five crosses of which 'ADT 5/ Mash-114' with 28.85 % followed by 'CO 6/ Mash-114 and KUG 688/ Uttara' with 19.23 and 18.29 % respectively was recorded highly significant positive heterosis. Highly significant positive economic heterosis was exhibited by fourteen crosses for pod length, out of which 'ADT 3/ VBN (Bg) 6, ADT 5/ Mash-114 and MDU 1/ Mash-114' were reported maximum economic heterosis for pod with 28.75, 28.75 and 26.25 % respectively. Similar observation was made by Bagade *et al*., 2002 and Chikkadeviah *et al*. 1981 in Indian bean and Shashibhushan and Chaudhari, 2000 in cowpea. Significant positive relative heterosis was exhibited by eleven hybrids for seeds per pod of which ' MDU 1/ VBN (Bg) 6, MDU 1/ Mash-114, MDU 1/ Uttara and MDU 1/ PU 31 observed maximum value with 28.38, 27.69, 27.00 and 26.29 % respectively over mid parent for seeds/pod. Over better parent significant positive heterosis per cent was recorded for four hybrids *viz*., MDU 1/ VBN (Bg) 6, MDU 1/ Mash-114, MDU 1/ Uttara and MDU 1/ PU 31 with 26.27, 25.49, 25.34 and 25.29 % respectively. Likewise for over standard variety the maximum positively significant heterosis per cent was recorded for four crosses viz., MDU 1/ Uttara, MDU 1/ VBN (Bg) 6, MDU 1/ Mash-114 and MDU 1/ PU 31 with 23.43, 23.13, 24.17, 23.13 % respectively. The same crosses exhibited significant positive heterosis over mid parent, better parent and over commercial check. Hence it clearly shows that the parents has desirable variability for seeds/ pod as increase in number of seeds the yield could also be increase. Similar result was also reported by Shashibhushan and Chaudhari (2000) in cowpea; Patil *et al*. (2012) in lab lab bean.

Among the 30 crosses studied fifteen were exhibited significant positive heterosis for 100 seed weight over mid parent. Of which four crosses 'MDU 1/ Uttara, MAD 1/ VBN (Bg) 6, MDU 1/ PU 31 and MDU 1/ Mash-114' were observed with maximum values of heterosis over mid paren with 37.38, 36.67, 35.95 and 34.47 % respectively. Heterobeltiosis per cent was higher for ten crosses of which four crosses *viz*., MDU 1/ VBN (Bg) 6, MDU 1/ PU 31, MDU 1/ Mash-114 and MDU 1/ Uttara were recorded highly significant positive heterosis. While fifteen crosses exhibited higher standard heterosis out of which four crosses 'MDU 1/ VBN (Bg) 6 with 33.19 % followed closely by31.41 MDU 1/ Mash-114, MDU 1/ PU 31, and MDU 1/ Uttara with by31.41, 31.39 and 30.29 % respectively, recorded maximum significant positive heterosis percent. Out of 30 hybrids, seventeen were exhibited significant positive heterosis for seed yield per plant over mid parent out of these five crosses *viz*., MDU 1/ VBN (Bg) 6, MDU 1/ Mash-114, MDU 1/ PU 31, LPG-752/ Uttara and LPG-752/ VBN (Bg) 4 recorded highly significant positive heterosis per cent with 46.56, 43.75, 41.38, 38.46 and 37.09 respectively. Over better parent significant positive heterosis in desired direction for single plant yield was observed for twelve crosses.

Six crosses *viz*., 'MDU 1/ VBN (Bg) 6, MDU 1/ PU 31, LPG-752/ VBN (Bg) 4, MDU 1/ Mash-114, LPG-752/ Uttara and MDU 1/ Uttar recorded highly significant positive heterobeltiosis for single plant yield. While seventeen crosses exhibited highly significant positive heterosis over standard variety, out of which six crosses viz., 'MDU 1/ VBN (Bg) 6, MDU 1/ PU 31, MDU 1/ Mash-114, LPG-752/ Uttara, MDU 1/ Uttara, and LPG-752/ VBN (Bg) 4 exhibited maximum significant positive heterosis per cent with 42.31, 36.84, 33.42, 32.48, 31.70 and 31.70 % respectively over standard check 'MDU 1'. Estimation of heterosis for yield per plant had also been conducted by Reddy (1998), Neog and Talukdar (1999), Patel *et al.* (2009), Reddy *et al.* (2011) and Ram *et al.* (2013) who reported significant positive heterosis for yield per plant.

Based on overall observation of the results of this investigation the top four crosses *viz*., 'MDU 1/ VBN (Bg) 6, MDU 1/ PU 31, MDU 1/ Mash-114 and MDU 1/ Uttara had exhibited high positive significant standard heterosis for seed yield per plant and its yield attributing traits in positive direction and negative heterosis for two traits *viz*., Days to 50 % flowering and Days to maturity. These crosses recorded high standard heterosis of 42.31 %, 36.84 %, 33.42 %, and 31.70% respectively for seed yield per plant (g). The presence of magnitude of heterosis was higher in these crosses for yield and its attributes. Hence, exploitation of hybrid vigour could be done in these crosses and it might be helpful in the improvement of this crop.

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Table 1. Heterosis per cent for Plant height, Branches /plant, Days to 50% flowering and Days to maturity

Hybrids	Plant height (cm)			Branches /plant			Days to 50% flowering			Days to maturity		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
ADT 3 x VBN(Bg) 4	16.67 *	12.00	14.99	47.73 **	44.44 **	22.64 **	2.16	1.43	-5.33	1.43	0.00	-3.40
ADT 3 x VBN(Bg) 6	16.03 *	15.80 *	18.89 *	35.71 **	32.56 **	7.55	9.49 **	7.14 *	0.00	6.14 **	3.52	0.00
ADT 3 x Mash 114	8.64	5.60	8.42	30.86 **	23.26 *	-0.00	8.15 **	4.29	-2.67	7.69 **	3.52	0.00
ADT 3 x Uattra	3.40	2.60	0.00	34.15 **	27.91 **	3.77	-0.71	-1.41	-6.67 *	0.00	-1.41	-4.76 *
ADT 3 x PU - 31	11.74	6.60	9.45	31.76 **	30.23 **	5.66	-0.74	-4.29	-10.67 **	-6.62 **	-10.56 **	-13.61 **
MDU 1 x VBN(Bg) 4	2.22	-0.62	-0.62	-4.08	-11.32	-11.32	-9.72 **	-13.33 **	-13.33 **	-11.58**	-14.29 **	-12.29 **
MDU 1 x VBN(Bg) 6	0.51	-0.60	1.64	-6.38	-16.98 *	26.98 **	4.23	-1.33	-31.33**	-7.80 **	3.40	-13.70**
MDU 1 x Mash 114	10.74	9.03	9.03	7.69	-7.55	27.55**	2.86	-4.00	-24.00**	-5.04 *	-10.20 **	-10.20 **
MDU 1 x Uattra	6.78	1.85	1.85	0.00	-13.21	23.21**	-9.59 **	-12.00 **	-32.00 **	-10.88 **	-13.61 **	-13.61 **
MDU 1 x PU - 31	4.14	0.62	0.62	-17.89 *	-26.42 **	26.42 **	-4.29	-10.67 **	-20.67 **	-5.42 *	-10.88 **	-10.88 **
CO 6 x VBN(Bg) 4	2.97	0.41	-0.21	-10.42	-15.69	-18.87 *	0.00	0.00	8.00 **	0.72	0.00	-4.76 *
CO 6 x VBN(Bg) 6	-6.31	-7.63	-5.54	0.65	-9.22	-12.64	7.35 **	5.80	2.67	6.18 **	4.29	-0.68
CO 6 x Mash 114	3.14	1.86	1.23	-10.11	-21.57 *	-24.53 **	5.97 *	2.90	-5.33	5.54 *	2.14	-2.72
CO 6 x Uattra	-7.56	-11.57	-12.11	-4.44	-15.69	-18.87 *	-2.86	-4.23	-9.33 **	0.72	0.00	-4.76 *
CO 6 x PU - 31	-10.02	-12.81	-13.35	-9.68	-17.65 *	-20.75 *	10.45 **	7.25 *	-1.33	7.41 **	3.57	-1.36
LPG 752 x VBN(Bg) 4	-5.27	-7.99	-7.80	3.45	0.00	26.79**	3.65	2.90	-25.33**	-0.36	-0.72	-16.12 **
LPG 752 x VBN(Bg) 6	3.85	2.81	5.13	-6.02	-7.14	-16.42 **	2.22	1.47	-8.00 **	-0.73	-2.16	-7.48 **
LPG 752 x Mash 114	23.96 **	21.93 **	22.18 **	-0.00	- 4.76	24.53 **	0.75	-1.47	-30.67 **	-2.22	-5.04 *	-15.20 **
LPG 752 x Uattra	27.10 **	21.11 **	21.36 **	1.23	-2.38	-22.64 **	-6.47 *	-8.45 **	-13.33 **	-8.30 **	-8.63 **	-13.61 **
LPG 752 x PU – 31	25.90 **	21.52 **	21.77 **	16.67	16.67	-7.55	3.76	1.47	-8.00 **	1.12	-2.16	-7.48 **
ADT 5 x VBN(Bg) 4	29.94 **	27.83 **	20.74 **	3.45	0.00	-15.09	5.80 *	5.80	-2.67	2.16	1.43	-3.40
ADT 5 x VBN(Bg) 6	5.83	0.20	2.46	-1.20	-2.38	-22.64 **	7.35 **	5.80	-2.67	4.73 *	2.86	-2.04
ADT 5 x Mash 114	27.59 **	23.94 **	20.12 *	27.50	21.43 *	-3.77	2.99	0.00	-8.00 **	1.11	-2.14	-6.80 **
ADT 5 x Uattra	12.06	11.69	2.05	20.99 *	16.67	-7.55	-7.14 **	-8.45 **	-13.33 **	-8.63 **	-9.29 **	-13.61 **
ADT 5 x PU – 31	1.89	0.88	-5.95	4.76	4.76	-16.98 *	2.99	0.00	-8.00 **	2.22	-1.43	-6.12 **
KUG 688 x VBN(Bg) 4	8.24	5.65	-0.21	5.75	2.22	-13.21	3.60	2.86	-4.00	0.71	-0.70	-4.08
KUG 688 x VBN(Bg) 6	23.72 **	16.27 *	18.89 *	66.27 **	64.29 **	30.19 **	0.73	-1.43	-8.00 **	0.36	-2.11	-5.44 *
KUG 688 x Mash 114	23.30 **	18.86 *	15.20	90.00 **	80.95 **	43.40 **	-0.74	-4.29	-10.67 **	-1.10	-4.93 *	-8.16 **
KUG 688 x Uattra	25.68 **	25.11 **	13.55	62.96 **	57.14 **	24.53 **	-7.80 **	-8.45 **	-13.33 **	-9.29 **	-10.56 **	-13.61 **
KUG 688 x PU – 31	8.52	6.61	-0.62	2.38	2.38	-18.87 *	3.70	0.00	-6.67 *	3.68	-0.70	-4.08
SE	1.62	1.87	1.87	0.18	0.21	0.21	0.89	1.02	1.02	1.44	1.66	1.66

d_i = Relative heterosis; d_{ii} = Heterobeltiosis; d_{iii} = Standard heterosis

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Table 2. Heterosis per cent for Cluster / plant, Pods / cluster, Pods / plant and Pod length (cm)

Hybrids	Cluster / plant			Pods / cluster			Pods / plant			Pod length (cm)		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
ADT 3 x VBN(Bg) 4	29.31 **	26.05 *	35.14 **	9.90 **	26.00 **	11.15 *	10.00	1.85	12.24	2.82	2.25	13.75 *
ADT 3 x VBN(Bg) 6	41.08 **	39.34 **	53.15 **	2.04 **	28.30 **	10.77 **	26.53 **	14.81	26.53 *	19.08 **	17.05 **	28.75 **
ADT 3 x Mash 114	7.44	5.69	17.12	4.69 **	32.00 **	16.92 **	15.69	9.26	20.41	4.82	-1.14	8.75
ADT 3 x Uattra	24.48 **	22.95 *	35.14 **	9.03 **	20.00 *	15.38	13.13	3.70	14.29	13.61 *	9.09	20.00 **
ADT 3 x PU - 31	9.24	9.24	17.12	3.81 **	18.18 *	15.00 **	12.38	9.26	20.41	0.00	-6.00	17.50 **
MDU 1 x VBN(Bg) 4	-1.79	-2.65	-0.90	-3.03	-7.69	17.69*	-5.26	-8.16	28.16*	0.59	4.49	6.25
MDU 1 x VBN(Bg) 6	3.00	-1.64	8.11	26.86**	-3.77	28.92**	9.68	4.08	29.08**	1.82	-1.18	25.00**
MDU 1 x Mash 114	11.11	5.69	17.12	24.00**	9.62	29.62**	17.53	16.33	16.33*	7.59	6.25	26.25**
MDU 1 x Uattra	-22.75 *	-26.23 *	-18.92	23.26**	-13.46	23.46*	6.38	2.04	22.04*	0.62	-0.00	21.25*
MDU 1 x PU - 31	-13.04	-15.97	-9.91	27.76 *	-20.00 *	25.38**	2.00	0.00	24.08*	11.11 *	-20.00 **	20.00*
CO 6 x VBN(Bg) 4	11.11	7.44	17.12	3.85	-5.26	3.85	19.57 *	19.57	12.24	-2.44	-10.11	0.00
CO 6 x VBN(Bg) 6	-2.06	-2.46	7.21	1.82	-1.75	7.69	13.33	10.87	4.08	-0.00	-5.88	-0.00
CO 6 x Mash 114	-3.28	-4.07	6.31	-8.57	-15.79	-7.69	6.38	4.17	2.04	21.57 **	19.23 **	16.25 **
CO 6 x Uattra	5.35	4.92	15.32	16.00	1.75	11.54	7.69	6.52	0.00	5.13	1.23	2.50
CO 6 x PU - 31	6.67	5.79	15.32	-16.07 *	-17.54 *	-9.62	-3.09	-7.84	-4.08	-23.43 *	-33.00 **	-16.25 **
LPG 752 x VBN(Bg) 4	-5.93	-15.00	7.21	-6.54	-16.67 *	-3.85	5.26	2.04	2.04	-7.87	-7.87	2.50
LPG 752 x VBN(Bg) 6	14.50	7.14	35.14 **	4.42	-1.67	13.46	29.03 **	22.45 *	22.45 *	-4.60	-6.74	3.75
LPG 752 x Mash 114	25.48 **	17.86	48.65 **	38.89 **	25.00 **	44.23 **	40.21 **	38.78 **	38.79 **	1.80	-4.49	6.25
LPG 752 x Uattra	25.95 **	17.86	48.65 **	43.69 **	23.33 **	42.31 **	44.68 **	38.78 **	38.78 **	2.35	-2.25	8.75
LPG 752 x PU – 31	25.10 **	15.71	45.95 **	25.22 **	20.00 *	38.46 **	34.00 **	31.37 **	36.73 **	-7.94	-13.00 **	8.75
ADT 5 x VBN(Bg) 4	25.00 *	21.85 *	30.63 **	35.24 **	22.41 **	36.54 **	22.92 *	18.00	20.41	0.59	-4.49	6.25
ADT 5 x VBN(Bg) 6	5.39	4.10	14.41	8.11	3.45	15.38	10.64	4.00	6.12	12.73 *	9.41	16.25 **
ADT 5 x Mash 114	32.23 **	30.08 **	44.14 **	16.98 *	6.90	19.23 *	18.37 *	16.00	18.37	30.38 *	28.75 **	28.75 **
ADT 5 x Uattra	-0.41	-1.64	8.11	-4.95	-17.24 *	-7.69	-5.26	-10.00	-8.16	13.04 *	12.35 *	13.75 *
ADT 5 x PU – 31	2.52	2.52	9.91	2.65	-0.00	11.54	-8.91	-9.80	-6.12	-6.67	-16.00 **	5.00
KUG 688 x VBN(Bg) 4	7.30	4.17	12.61	8.57	-1.72	9.62	20.43 *	19.15	14.29	12.28 *	7.87	20.00 **
KUG 688 x VBN(Bg) 6	36.36 **	35.25 **	48.65 **	9.91	5.17	17.31	34.07 **	29.79 **	24.49 *	-1.80	-3.53	2.50
KUG 688 x Mash 114	19.34 *	17.89	30.63 **	13.21	3.45	15.38	28.42 **	27.08 *	24.49 *	11.25 *	8.54	11.25
KUG 688 x Uattra	30.58 **	29.51 **	42.34 **	10.89	-3.45	7.69	23.91 *	21.28	16.33	19.02 *	18.29 **	21.25 **
KUG 688 x PU – 31	-0.42	-0.83	7.21	-6.19	-8.62	1.92	8.16	3.92	8.16	-6.59	-15.00 **	6.25
SE	0.54	0.63	0.63	0.21	0.24	0.24	2.21	2.55	2.55	0.21	0.24	0.24

d_i = Relative heterosis; d_{ii} = Heterobeltiosis; d_{iii} = Standard heterosis

Table 3. Heterosis per cent for Seeds / plant, 100 seed weight and yield/ plant

Hybrids	Seeds / plant			100 seed weight (g)			Yield/ plant (g)		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
ADT 3 x VBN(Bg) 4	0.00	0.00	-7.14	9.20 **	5.95	12.66 **	9.94 **	6.82 *	13.25 **
ADT 3 x VBN(Bg) 6	20.00 *	15.38	7.14	15.53 **	10.71 **	17.72 **	16.67 **	11.36 **	18.07 **
ADT 3 x Mash 114	4.00	0.00	-7.14	-12.10 **	-17.86 **	-12.66 **	-11.52 **	-17.05 **	-12.05 **
ADT 3 x Uattra	16.67	7.69	0.00	0.00	-8.33 **	-2.53	2.47	-5.68	0.00
ADT 3 x PU - 31	3.70	0.00	0.00	0.00	-2.38	3.80	1.16	-1.14	4.82
MDU 1 x VBN(Bg) 4	-18.52 *	-21.43 *	-21.43 *	5.06	5.06	5.06	4.82	4.82	4.82
MDU 1 x VBN(Bg) 6	28.38**	26.27 *	23.43 *	36.67 **	35.19 **	33.19 **	46.56 **	44.46 **	42.31 **
MDU 1 x Mash 114	27.69**	25.49**	23.13**	34.47 **	32.13 **	31.41 **	43.75 **	36.64 **	33.42 **
MDU 1 x Uattra	27.00**	25.34**	24.17**	37.38 *	31.27**	30.29**	35.73**	33.00**	31.70**
MDU 1 x PU - 31	26.29**	25.29**	23.13**	35.95 **	33.50 **	31.39 **	41.38 **	38.90 **	36.84 **
CO 6 x VBN(Bg) 4	0.00	-7.69	-14.29	10.59 **	3.30	18.99 **	10.11 **	3.16	18.07 **
CO 6 x VBN(Bg) 6	-4.35	-8.33	-21.43 *	-13.10 **	-19.78 **	-7.59 *	-12.00 **	-18.95 **	-7.23 *
CO 6 x Mash 114	21.74 *	16.67	0.00	-13.41 **	-21.98 **	-10.13 **	-12.79 **	-21.05 **	-9.64 **
CO 6 x Uattra	18.18	18.18	-7.14	-0.62	-12.09 **	1.27	-1.78	-12.63 **	-0.00
CO 6 x PU - 31	-4.00	-14.29	-14.29	-18.13 **	-23.08 **	-11.39 **	-17.32 **	-22.11 **	-10.84 **
LPG 752 x VBN(Bg) 4	0.00	0.00	-7.14	-4.29	-7.14 *	-1.27	37.09**	36.82 **	31.20**
LPG 752 x VBN(Bg) 6	-4.00	-7.69	-14.29	5.59	1.19	7.59 *	5.95 *	1.14	7.23 *
LPG 752 x Mash 114	20.00 *	15.38	7.14	13.25 **	5.83	12.53 **	12.73 **	5.68	12.05 **
LPG 752 x Uattra	25.00 **	15.38	7.14	22.08 **	11.90 **	18.99 **	38.46 **	33.64 **	32.48 **
LPG 752 x PU – 31	11.11	7.14	7.14	2.44	0.00	6.33	4.65	2.27	8.43 **
ADT 5 x VBN(Bg) 4	-7.69	-7.69	-14.29	15.58 **	12.66 **	12.66 **	17.28 **	14.46 **	14.46 **
ADT 5 x VBN(Bg) 6	4.00	0.00	-7.14	28.95 **	27.27 **	24.05 **	29.56 **	28.75 **	24.10 **
ADT 5 x Mash 114	20.00 *	15.38	7.14	25.68 **	24.00 **	17.72 **	24.36 **	22.78 **	16.87 **
ADT 5 x Uattra	25.00 **	15.38	7.14	35.17 **	30.67 **	24.05 **	33.33 **	29.11 **	22.89 **
ADT 5 x PU – 31	3.70	0.00	0.00	8.39 **	5.00	6.33	7.98 **	4.76	6.02
KUG 688 x VBN(Bg) 4	25.00 **	15.38	7.14	-2.99	-7.95 **	2.53	-2.86	-7.61 **	2.41
KUG 688 x VBN(Bg) 6	4.35	0.00	-14.29	-3.03	-9.09 **	1.27	-2.33	-8.70 **	1.20
KUG 688 x Mash 114	13.04	8.33	-7.14	3.11	-5.68	5.06	2.96	-5.43	4.82
KUG 688 x Uattra	18.18	18.18	-7.14	8.86 **	-2.27	8.86 **	8.43 **	-2.17	8.43 **
KUG 688 x PU – 31	-4.00	-14.29	-14.29	-1.19	-5.68	5.06	-1.14	-5.43	4.82
SE	0.52	0.60	0.60	0.12	0.13	0.13	0.11	0.13	0.13

d_i = Relative heterosis; d_{ii} = Heterobeltiosis; d_{iii} = Standard heterosis