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Heterosis in Soybean [*Glycine max* (L.) Merrill]

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ABSTRACT

Ninety soybean hybrids derived from a line × tester analysis along with their parents were evaluated at the Research Farm of Kisan (PG) College, Simbhaoli, to estimate heterosis over mid- and better-parent. Heterosis was positively significant for yield in 15 hybrids over better-parent and in 24 hybrids over mid-parent. Heterosis for yield was generally accompanied by heterosis for number of seeds/pod, number of pods/plant and pod length. For protein 16 and for oil 31 hybrids exhibited significant positive heterosis over better parent. In view of the availability of genetic male sterility, the study revealed good scope for commercial exploitation of heterosis for yield and oil contents in soybean.

Keywords: better parent, crosses, line x tester, mid parent, seed yield

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] has become the "miracle crop" of the 21st century. It is a triple beneficiary crop, which contains about 40% proteins, possessing high level of essential amino acids except methionine and cystine, 20% oil rich in poly unsaturated fatty acids specially omega-6 and omega-3 fatty acids, 6-7% total minerals, 5-6% crude fibre and 17-19% carbohydrates (Chauhan *et al.* 1988). Besides, it has good amount of iron, vitamin B-complex and isoflavones such as daidzein, genistein of glycitin. Presence of calcium and iron, makes it highly suitable for women who suffer from osteoporosis and anemia. The isoflavones of soybean have been found to possess health benefits, as they exhibited properties like cancer preventing, combating menopausal problem and helping to recover from diabeties (Chauhan *et al.* 2002).

At present, India ranks fifth with respect to soybean acreage and production in the globe. In the past three decades from 70's onwards, the crop exhibited a phenomenal growth (Paroda 1999). In India, the planted area under soybean in 2007-08 was 8.870 m ha which produced 9.460 mt of soybean with a productivity of 1067 kg/ha (ICAR Data Book 2007).

The heterosis or hybrid vigor can be defined as the superiority of individuals of the F_1 generation in relation to their parents (Fehr 1987). This phenomenon has been explored during the last 70 years. Heterosis can be considered as one of the most important contributions of the genetics to agriculture, with great reflexes in agricultural seed yield. Specifically in soybeans, for the commercial hybrids to turn reality, two requirements are pointed as fundamentals: presence of heterosis for seed yield, and an economical method for production of hybrid seed in wide scale (Paschal and Wilcox 1975). For a trait with high number of genes and with dominance effect it is easier to obtain a hybrid than a line with superior genotypes (Burton 1987). The most accepted hypotheses to explain heterosis involve dominance and the overdominance, besides epistatic effects.

For soybean improvement, breeding methods like intervarietal hybridization and inter-specific hybridization have promise to broaden the genetic base either through creation of variability or introgression of desirable genes from wild species (Bhatnagar and Karmakar 1995). The choice of the parents is an important step in hybridization program to create variation for selection of useful recombinants. In soybean [*Glycine max* (L.) Merrill], the scope for exploitation of hybrid vigour largely depends on the direction and magnitude of heterosis and ease with which hybrid seeds can be produced. Discovery of a male sterile, female fertile mutant by Brim and Young (1971) suggested the possibility of exploiting heterosis in soybean breeding.

Exploitation of heterosis through synthetics and ultimately hybrids could pay off improving yield potential and its components in soybean. Superiority of hybrids over the mid and better parents for seed yield was found to be associated with manifestations of heterotic effects in main yield components i.e., days to maturity, 100-seed weight seeds/plant, pods/plant, pod bearing nodes/plant, plant height, protein content and oil content. It is clearly stated from the literature that heterotic effects ranges from significantly positive to significantly negative for different traits and were very pronounced in F_1 of soybean especially crosses among widely divergent materials (Sabbouh *et al.* 1998; Maheshwari *et al.* 1999; Sood 1999; Guleria *et al.* 2000; Pandini *et al.* 2002; Wang *et al.* 2002; Patil *et al.* 2003; Bhosle *et al.* 2005).

Therefore, in the present investigation an attempt has been made to estimate heterosis for yield, protein, oil content and other related attributes.

MATERIALS AND METHODS

The present investigation aimed to gather information on the genetic basis of yield and its contributing traits in 30 diverse strains (BAUS-31, NRC-63, DS-200-1, NRC-64, Dsb-3-4, NRC-65, Him-80-1600, Ps-1364, Him-80-1601, Ps-1368, Js 97-51, Ps-1370, Js 97-52, RKs-15, Js (SH) 98-92, RKs-18, MACS-708, Rsc-4, MACS-746, Rsc-5, MACS-975, SL-688, MACS-128, TNAUS-7, MACS-68-1, VLS-60, MACS-86, Bragg, MACS-352 and PK 416) and 3 testers (Js 335, BLS-59 and Ds-2106) of soybean [*Glycine max* (L.) Merrill], which were procured from the National Bureau of Plant Genetic Resources, New Delhi, including most of the genotypes from an indigenous collection. The parents were considered as homozygous since the crop is highly self-pollinated. Thirty lines and three testers of soybean were planted in the crossing block at the Research Farm Kisan (PG) College during spring of 2007. All 90 possible crosses were made. In the next season F_1's

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were advanced to the F_2 generation.

All the 90 F_1 crosses along with 30 parents, 90 F_2s and 3 testers were planted in a randomized complete block design with three replications during spring of 2007-08. In each replication of the each 123 treatments were grown in 2 m long two row and the spacing was maintained at 40 × 10 for row to row and plant to plant, respectively. Within a row, seeds were hand dibbled to 10 cm apart. All the necessary agronomic package of practices was followed to raise a good crop. In the line x tester experiments, 10 randomly selected competitive plants from each of the parents, F_1's and F_2's were tagged for recording the observations on the following characters viz., days to 50% flowering, plant height (cm), duration of pod filling, number of fruiting nodes, number of branches/plant, number of pods/plant, pod length (cm), number of seeds/pod, biological yield/plant, grain yield/plant, number of nodules/plant, nodule weight (mg), harvest index, protein content (%) and oil content (%). Heterosis was calculated as percentage of deviation of the F_1 mean over mid parent (MP) and better parent (BP) in entire set of parents for the character in the experiments.

RESULTS

The manifestation of heterosis in percentage for different characters over mid-parent and better parent are given in **Tables 1** and **2** as computed in line x tester analysis. The details of results obtained for each character are described below.

Days to 50% flowering indicated negative heterosis over mid parent in 77 crosses (**Table 1**). Highest significant negative mid-parent heterosis was expressed by the crosses MACS-352 x BLS-59, (-23.37%), followed by MACS-352 x Ds-2106 (-23.19%) and Rsc-4 x Ds-2106 (-21.60%) while, over the better parent (**Table 2**) it was exhibited by MACS-352 x Js 335 (-26.67%) followed by MACS-352 x BLS-59 (-25.93%) and MACS-352 x Ds-2106 (-25.19%). For plant height 23 and 36 crosses showed positive heterosis over mid-parent and better parent, respectively. Highest significant positive heterosis was exhibited by the cross Ps-1364 x Js 335 (18.02%) over the mid parent. Highest significant positive heterobeltiosis for plant height was noted in the cross Bragg x Js 335 (31.03%). Similarly, for number of branches/plant, Bragg x Ds-2106 (33.33%) showed maximum positive significant heterosis over both mid and better parent.

Out of 90 crosses 16 showed positive heterosis over the mid-parent for number of fruiting nodes and maximum positive significant heterosis was observed in the cross MACS-975 x Js 335 (25.81%). Since early maturity is considered a desirable character, therefore, negative heterosis would be beneficial. The maximum negative heterosis for days to maturity over the mid-parent was found in BAUS-31 x Js 335 (-19.46%). For duration of pod filling the crosses namely BAUS-31 x Js 335 (-19. 64%), followed by Rsc-4 x Js 335 (-18.39%), MACS-708 x Js 335 (-17.04%), BAUS-31 x Js 335 (-16.22%) and Rsc-4 x BLS-59 (-15.91%) showed maximum significant negative heterobeltiosis; similarly, for the number of pods/plant and pod length the highest positive significant heterosis over the mid-parent and better parent was exhibited by Rsc-4 x BLS-59 (46.80%), MACS-975 x Js 335 (36.36%) and Js 97-52 x Ds-2106 (68.38%), and Rsc-4 x Js 335 (31.80%), respectively. For grain yield/plant, the highest estimate of relative heterosis over the mid-parent was exhibited by Rsc-4 x BLS-59 (75.61%) and over the better parent it was exhibited by Rsc-4 x BLS-59 (50.00%) followed by Bragg x Ds-2106 (39.13%), VLS-60 x Ds-2106 (34.78%), BAUS-31 x Ds-2106 (28. 89%) and MACS-352 x Js 335 (17.05%). Heterosis over the better parent for biological yield/plant was exhibited by the cross Rsc-4 x Js 335 (13.89%).

In case of nodule weight the maximum positively significant heterosis over the mid-and better parents was exhibited in the crosses RKs-18 x Js 335 (64.18%) and RKs-18 x Js 335 (100.00%), respectively. Protein content showed positive heterosis over the mid-parent in 36 crosses of which RKs-15 x Js 335 (8.54%) showed the maximum value, while highest significant positive heterobeltiosis for protein content was noted in NRC-65 x Js 335 (11.29%) followed by NRC-65 x BLS-59 (5.36%), NRC-63 x BLS-59 (4.83%), NRC-65 x Ds-2106 (4.09%) and NRC-63 x Ds-2106 (3.97%). Similarly, for oil content, highest relative heterosis was recorded in the cross Js(SH) 98-92 x BLS-59 (11.03%) followed by MACS-746 x Js 335 (10.16%), Js(SH) 98-92 x Js 335 (9.77%) and NRC-65 x BLS-59 (9.09%). Significant positive heterobeltiosis for oil content was noted with 25 crosses among which high estimates were expressed by MACS-746 x Js 335 (8.46%) followed by PK 416 x Ds-2106 (6.72%), NRC-65 x BLS-59 (6.15%) and MACS-975 x Js 335 (5.47%) and NRC-65 x BLS-59 (6.15%).

DISCUSSION

Soybean is a self-pollinated crop and the scope for exploitation of hybrid vigour depends on the direction and magnitude of heterosis involved. Heterosis will also have a direct effect on the breeding methodology to be used for varietal improvement. Weiss *et al.* (1947) and Weber *et al.* (1970) reported considerable work on hybrid vigour in soybean in Western countries. Limited information is available in soybean regarding the existence and level of heterosis for protein and oil content. Weber *et al.* (1970) evaluated heterotic performance of F_1 soybean hybrids and averaging over all hybrids studied, reported no statistically significant heterosis relative to the mid-parent values for protein or oil, and heterosis relative to the high-parent of -0.9% for protein and -1.5% (significant at $P<0.05$) to 0.14% for oil. Nelson and Bernard (1984) reported no statistically significant heterosis for protein or oil percentage, but observed little variation for the two traits among the parents investigated.

Yield is a complex character and highly influenced by environment. Grafius (1959) suggested that there might not be genes for yield per se but for the components. Therefore, it would be interesting to know the relationship between the heterosis for seed yield and its components. During the present investigation out of 11 hybrids with highly significant positive BP heterosis, none showed positive heterosis for the two yield components viz., pod length and seeds/pod. In three hybrids (RSC-4 × DS-2106, Bragg × JS-335 and Bragg × DS-2106), the manifestation of heterosis for yield was through number of pods/plant. This clearly shows that number of pods/plant, seeds/pod and pod length were primarily responsible for manifestation of heterosis for yield in soybean. Liua *et al.* (2005) reported that pod and seed number are the most important yield components of soybean. Bhosle *et al.* (2005) and Pandini *et al.* (2002) studied heterosis for soybean seed yield and yield components and suggested that pods/plant are suitable for indirect selection for high seed yield. Recently Alghamdi (2009) studied faba bean and reported highly significant mid- and better-parent heterosis for pods/plant and seeds/pod as 85.0-131.4, 54.2-73.7 and 54.4-127.2, 62.9-97.7, respectively. Dogney *et al.* (1998) reported positive and significant heterosis over better parent for seeds/pod and pods/plant. Similarly, Ponnusamy and Harer (1998) studied heterosis and combining ability in soybean and reported 91.3% mid-parent heterosis for pods/plant.

The mid and better-parent heterosis for grain yield/plant and plant height was mainly through the number of pods/plant. Paola *et al.* (2009a, 2009b), Burton and Brownie (2006), Wang *et al.* (2002) and Manjarrez-Snadoval *et al.* (1997) also reported mid and better-parent heterosis for yield and plant height.

For other characters like protein content, the crosses NRC-63 × DS-2106 and RKS-15 × JS-335 showed positive BP heterosis, for oil content, reaffirming the negative correlation between these two traits, however, one cross (NRC-65 × JS-335) which showed highest BP heterosis for protein content was positively associated with oil content. For rest of the characters the heterosis was variable with crosses and ranged negative to positive, which is in close agreement with the earlier reports of Sabbouh *et al*. (1998).

Table 1 Heterosis (%) over mid parent for yield and yield contributing characters in soybean.

Cross	Days to 50% flowering	Plant height (cm)	No. of branches / plant	No. of fruiting nodes	Duration of pod filling	No. of pods/ plant	Pod length	Seeds/ pod	Grain yield/ plant	Biological yield	No. of nodules/ plant	Harvest index	Nodules weight	Protein content	Oil content
BAUS-31 × JS-335	-8.85**	-12.23**	-3.23**	8.82**	-19.46**	15.45*	-22.37**	-6.67**	25.84**	-5.41	-6.67**	31.21**	18.18**	-3.29**	-11.89**
BAUS-31 × BLS-59	-11.39**	-12.23**	0.00	-22.67**	-7.19**	-12.11	-13.08**	6.67**	-11.11**	-28.33**	15.25**	23.00**	5.56**	-0.18	-0.89**
BAUS-31 × DS-2106	-15.48**	-1.99**	-11.76**	13.04**	-13.10**	9.73	-26.70**	-20.00**	33.33**	1.38	33.33**	28.85**	-1.37	0.36	-10.64**
DS-200-1 × JS-335	-15.97**	1.11**	3.45**	-14.71**	-10.64**	-9.50	8.29**	6.67**	6.52**	-12.04**	29.03**	20.41**	22.58**	-2.55**	-7.23**
DS-200-1 × BLS-59	-14.86**	-2.74**	-6.25**	-25.33**	2.21	-14.29*	-4.00**	-6.67**	-11.83**	-19.66**	-11.48**	7.85	14.71**	2.33**	-7.76**
DS-200-1 × DS-2106	-9.96**	4.66**	-6.25**	-18.84	-3.16	-16.30*	-3.38*	6.67**	-8.89**	-13.74**	-32.31**	4.87	33.33**	-2.78**	-12.76**
DSB-3-4 × JS-335	-1.30	-27.62**	0.00	1.27	-2.30	15.88*	-13.62**	-12.50**	18.37**	-32.55**	-13.85**	77.99**	22.08**	1.96**	2.01**
DSB-3-4 × BLS-59	-8.26**	-31.45**	-18.92**	-23.26**	-4.78**	-11.86	6.73**	0.00	-13.13**	-43.59**	56.25**	52.52**	15.66**	-1.84**	5.69**
DSB-3-4 × DS-2106	-13.11**	-17.94**	-8.11**	-5.00*	0.00	-3.77	-2.33	0.00	14.58**	-18.40**	-5.88**	33.56**	7.14**	-5.76**	-1.95**
Him-80-1600 × JS-335	-2.11**	-1.02**	17.24**	-15.94**	0.93	-15.74*	-14.16**	-17.65**	-10.34**	-3.41	-23.94**	-9.57	15.63**	0.45	0.79**
Him-80-1600 × BLS-59	-10.48**	-13.56**	0.00	-10.53**	0.49	-2.28	-11.31**	-5.88**	-13.64**	-13.00**	8.57**	-1.13	8.57**	-0.70	4.42**
Him-80-1600 × DS-2106	-12.80**	0.48	12.50**	-11.43**	1.44	-14.41*	-22.81**	-17.65**	-5.88*	6.00	-18.92**	-13.55	15.49**	-1.58**	0.77**
Him-80-1601 × JS-335	5.31**	-12.89**	-6.25**	-22.67**	1.88	-19.50**	4.39**	6.67**	-22.92**	-25.00**	19.30**	1.65	41.54**	-0.72	0.00
Him-80-1601 × BLS-59	0.42	-12.82**	-8.57**	-12.20**	3.90*	-11.48	-4.00**	-6.67**	-5.15	-26.50**	-7.14**	22.55**	12.68**	-6.97**	-4.56**
Him-80-1601 × DS-2106	-1.26	-19.81**	-8.57**	0.00	5.80**	1.21	9.18**	-6.67**	12.77**	-9.95**	6.67**	21.97**	16.67**	-6.76**	-8.73**
JS-97-51 × JS-335	3.64**	16.29**	0.00	1.41	-4.41**	7.96	10.14**	0.00	-7.69**	-11.00**	17.24**	1.71	17.65**	-13.63**	-1.23**
JS-97-51 × BLS-59	-0.43	19.77**	-3.03**	-35.90**	-8.22**	-24.02**	-2.97*	-12.50**	-39.13**	-18.35**	33.33**	-25.50**	-5.41**	-12.92**	5.00**
JS-97-51 × DS-2106	0.43	14.45**	-3.03**	-27.78**	-3.62*	-25.00**	-7.18**	-12.50**	-32.58**	-6.67	-11.48**	-29.04**	-6.67**	-9.93**	1.20**
JS-97-52 × JS-335	7.49**	1.86**	18.75**	-10.00**	-3.10	-0.40	1.96	6.67**	1.08	2.33	-2.94	-1.35	9.59**	0.93	1.19**
JS-97-52 × BLS-59	1.68*	1.44**	-14.29**	-26.44**	-2.29	-15.75*	6.53**	6.67**	-23.40**	-12.45**	-7.46**	-13.43	11.39**	-0.04	3.20**
JS-97-52 × DS-2106	3.33**	6.70**	-25.71**	-25.93**	-4.55**	-25.29**	68.38**	20.00**	-29.67**	-5.71	15.49**	-25.28**	2.50	-1.17*	-0.38**
Js(SH) 98-92 × JS-335	-5.13**	-7.21**	23.53**	15.94**	-2.52	27.68**	-14.68**	-12.50**	14.29**	-2.11	-3.23	15.17*	15.07**	2.08**	9.77**
Js(SH) 98-92 × BLS-59	-11.02**	-0.22	8.11**	-34.21**	1.19	-27.75**	-6.10**	0.00	-29.29**	-12.16**	24.59**	-19.67**	-3.80*	0.31	11.03**
Js(SH) 98-92 × DS-2106	-14.98**	0.45	-8.11**	-22.86**	-1.18	-24.35**	7.27**	12.50**	-27.08**	-12.07**	-16.92**	-16.83*	-15.00**	-1.52*	5.84**
MACS-708 × JS-335	-12.66**	11.56**	-11.11**	-18.92**	-16.67**	-18.49*	-6.53**	0.00	-32.67**	-13.16**	-14.29**	-22.25**	34.38**	5.60**	-0.41**
MACS-708 × BLS-59	-15.00**	-9.34**	-2.56**	-11.11**	-11.21**	23.65**	-1.03	-14.29**	-5.88*	-11.38**	-4.35*	3.04	8.57**	5.36**	1.65**
MACS-708 × DS-2106	-17.36**	-14.15**	-7.69**	-12.00**	-12.96**	-5.74	-6.47**	14.29**	-15.15**	-12.11**	-9.59**	-5.21	15.49**	4.02**	-5.14**
MACS-746 × JS-335	-0.41	2.73**	-6.25**	-19.10**	-6.07**	-11.49	-13.62**	-12.50**	-9.91**	-9.24*	13.85**	-1.50	44.44**	-0.27	10.16**
MACS-746 × BLS-59	-5.56**	-19.37**	-25.71**	-35.42**	-0.70	-28.43**	1.92	0.00	-30.36**	-25.84**	-6.25**	-7.32	23.08**	-2.76**	6.72**
MACS-746 × DS-2106	-7.87**	-24.48**	-8.57**	-37.78**	-1.62	-35.76**	-4.19**	-12.50**	-32.11**	-22.13**	17.65**	-12.43	6.33**	-6.64**	6.06**
MACS-975 × JS-335	7.76**	21.35**	9.09**	25.81**	-4.48**	40.85**	-12.11**	-6.67**	27.10**	13.54**	-9.86**	11.63	15.07**	-2.79**	6.30**
MACS-975 × BLS-59	5.35**	-15.37**	-16.67**	-13.04**	-0.47	-11.11	-11.93**	-6.67**	-33.33**	-34.41**	-25.71**	1.40	1.27	-8.78**	5.18**
MACS-975 × DS-2106	0.41	5.76**	5.56**	11.11**	-2.76	-1.37	-5.78**	6.67**	-20.00**	-17.86**	-8.11**	-2.42	-10.00**	-7.05**	-5.34**
MACS-128 × JS-335	5.39**	1.26**	21.43**	-7.69**	-3.75*	9.45	-14.69**	-20.00**	-9.89**	-11.93**	30.00**	1.23	38.46**	0.75	3.10**
MACS-128 × BLS-59	0.00	-2.74**	9.68**	-11.11**	-1.14	8.82	-5.83**	-6.67**	-4.35	-10.17**	11.86**	6.06	12.68**	0.22	1.18**
MACS-128 × DS-2106	-2.36**	-20.57**	-9.68**	-21.21**	0.23	-20.77**	-7.04**	-6.67**	-25.84**	-27.70**	-4.76*	1.95	0.00	-0.30	0.75**
MACS-68-1 × JS-335	0.00	-4.79**	6.25**	-1.37	-10.56**	14.29	-3.26*	-12.50**	-9.28**	-19.63**	-21.13**	11.57	18.42**	0.09	2.70**
MACS-68-1 × BLS-59	-5.53**	-13.13**	-8.57**	-20.00**	-11.42**	-10.37	-7.62**	-12.50**	-28.57**	-34.48**	0.00	8.06	-4.88*	0.80	2.34**
MACS-68-1 × DS-2106	-7.17**	5.51**	2.86**	-5.41**	-14.09**	-4.10	-14.29**	-12.50**	-3.16	-8.13*	-35.14**	3.85	-8.43**	-4.31**	-3.37**
MACS-86 × JS-335	0.42	-2.37**	-3.45**	-5.08**	-3.20	2.08	0.97	6.67**	-22.35**	-14.04**	-7.25**	-10.30	6.06**	-4.61**	-13.12**
MACS-86 × BLS-59	-1.61*	-4.54**	6.25**	-27.27**	2.84	-14.87*	3.48**	6.67**	-32.56**	-24.39**	11.76**	-11.75	16.67**	-5.69**	-7.34**
MACS-86 × DS-2106	-4.00**	-8.93**	0.00	-3.33	-0.47	3.03	2.88*	-6.67**	-8.43**	-11.21**	-11.11**	0.09	15.07**	-10.37**	-8.30**
MACS-352 × JS-335	-20.80**	-2.06**	-6.25**	0.00	-9.43**	11.89	-5.66**	0.00	20.88**	-3.20	19.35**	25.81**	16.36**	2.98**	-3.70**
MACS-352 × BLS-59	-23.37**	-6.76**	8.57**	-11.11**	-8.83**	8.70	-6.28**	-12.50**	-8.70**	-13.08**	4.92*	4.91	11.48**	-0.35	1.67**
MACS-352 × DS-2106	-23.19**	5.31**	-20.00**	-20.00**	-9.69**	-14.16*	-7.48**	0.00	-14.61**	-5.61	1.54	-9.98	22.58**	0.69	-4.38**
NRC-63 × JS-335	0.86	15.90**	13.33**	-20.59**	-6.37**	-14.16*	-7.92**	-6.67**	-28.89**	-12.26**	16.13**	-17.79*	20.69**	5.16**	4.92**
NRC-63 × BLS-59	-2.06**	17.96**	-3.03**	-25.33**	-3.42*	-11.71	-13.71**	-6.67**	-23.08**	-5.22	27.87**	-19.01**	21.88**	5.88**	4.56**
NRC-63 × DS-2106	-5.31**	20.91**	-3.03**	-21.74**	-2.48	-18.22*	-13.73**	-20.00**	-25.00**	-2.42	10.77**	-21.09**	16.92**	4.46**	3.17**
NRC-64 × JS-335	-5.36**	24.58**	-11.11**	-21.05**	-8.92**	-20.49**	-6.73**	-5.88**	-13.68**	-2.80	5.71*	-11.82	-25.00**	2.13**	4.38**
NRC-64 × BLS-59	-9.79**	8.27**	-2.56**	-22.89**	-6.41**	-6.07	-2.75*	-5.88**	-6.25*	-6.90	10.14**	-1.05	11.43**	1.75**	4.03**
NRC-64 × DS-2106	-9.70**	-1.04**	-23.08**	-22.08**	-8.71**	-20.80**	-1.33	-17.65**	-24.73**	-12.92**	-4.11	-14.06*	-29.58**	2.52**	3.47**
NRC-65 × JS-335	-4.27**	-15.09**	-12.50**	-24.64**	2.35*	21.89**	4.76**	-6.67**	-43.12**	-37.50**	-6.85**	-8.70	13.43**	12.10**	6.25**
NRC-65 × BLS-59	-6.94**	-11.11**	14.29**	-5.26**	5.37**	0.00	18.05**	20.00**	-10.91**	-18.60**	5.56*	10.10	-9.59**	7.54**	9.09**
NRC-65 × DS-2106	-6.88**	1.20**	-14.29**	0.00	5.31**	-14.64*	-5.66**	6.67**	-32.71**	-19.15**	-13.16**	-17.82*	-2.70	6.79**	4.55**
Ps-1364 × JS-335	18.02**	-7.65**	-5.88**	-1.49	19.52**	-6.91	-14.02**	-12.50**	-19.57**	-25.23**	-6.33**	7.14	16.13**	-6.34**	2.38**
Ps-1364 × BLS-59	12.45**	-6.14**	-2.70**	-13.51**	23.31**	-7.27	4.31**	0.00	-9.68**	-17.24**	-7.69**	7.43	-11.76**	-8.40**	3.61**
Ps-1364 × DS-2106	11.49**	-4.08**	-24.32**	-23.53**	23.08**	-23.77**	-3.70**	-12.50**	-37.78**	-26.32**	-9.76**	-15.62*	18.84**	-9.69**	0.77**
Ps-1368 × JS-335	-1.71*	-12.47**	-9.09**	-26.03**	7.80**	-16.43*	0.00	-6.67**	-21.95**	-32.04**	50.00**	26.53**	-1.30	-1.26*	-13.04**
Ps-1368 × BLS-59	-4.49**	-19.14**	-5.56**	-32.50**	11.06**	-15.74*	1.46	6.67**	-18.07**	-16.07**	45.76**	-2.36	-8.43**	-3.65**	-9.80**
Ps-1368 × DS-2106	-8.50**	8.19**	-16.67**	-37.84**	6.08**	-19.63**	-3.77**	-6.67**	-17.50**	1.49	17.46**	-11.75	-7.14**	-4.87**	-16.28**
Ps-1370 × JS-335	0.43	-3.24**	-5.56**	-14.67**	0.00	-4.68	-23.08**	-12.50**	-4.17	-16.16**	10.77**	10.59	-1.49	-3.73**	-6.28**
Ps-1370 × BLS-59	-1.64*	-15.38**	-17.95**	-19.51**	1.87	0.84	0.93	0.00	-9.28**	-32.79**	9.38**	33.98**	15.07**	-0.84	-8.47**
Ps-1370 × DS-2106	-4.07**	-24.59**	-12.82**	-18.42**	1.85	-10.37	-14.80**	-12.50**	-6.38*	-16.96**	11.76**	11.52	-5.41**	-0.31	-14.17**
RKs-15 × JS-335	12.00**	2.80**	15.15**	14.29**	13.62**	14.55*	-2.39	-6.67**	13.95**	-18.97**	-7.69**	39.71**	18.18**	8.54**	-1.65**
RKs-15 × BLS-59	6.78**	-10.45**	-22.22**	-29.87**	19.02**	-10.19	0.00	-6.67**	-5.75*	-8.80*	15.63**	4.80	5.56**	3.32**	-0.42**
RKs-15 × DS-2106	7.56**	-2.64**	-5.56**	-4.23*	17.39**	10.50	-9.95**	-6.67**	21.43**	-6.61	5.88**	29.96**	15.07**	3.57**	-7.20**
RKs-18 × JS-335	-7.17**	10.67**	5.88**	-12.33**	-10.09**	-36.56**	9.86**	20.00**	-19.59**	-5.63	-11.11**	-13.80*	13.28**	0.00	1.99**
RKs-18 × BLS-59	-9.68**	-4.50**	-18.92**	-20.00**	-8.57**	-16.52*	1.92	6.67**	-10.20**	-14.06**	9.68**	6.10	64.18**	-1.08	4.03**
RKs-18 × DS-2106	-11.20**	-14.69**	-29.73**	-8.11**	-7.55**	-31.33**	-7.91**	6.67**	-13.68**	-10.62**	42.42**	-0.73	61.76**	-7.45**	-0.39**
Rsc-4 × JS-335	-17.30**	-1.03**	13.33**	1.59	-17.83**	-12.00	4.11**	0.00	11.11**	17.14**	-21.13**	-2.55	1.69	-1.52*	4.72**

Table 1 (Cont.)

Cross	Days to 50% flowering	Plant height (cm)	No. of branches / plant	No. of fruiting nodes	Duration of pod filling	No. of pods/ plant	Pod length	Seeds/ pod	Grain yield/ plant	Biological yield	No. of nodules/ plant	Harvest index	Nodules weight	Protein content	Oil content
Rsc-4 × BLS-59	-16.13**	-2.55**	-9.09**	17.14**	-13.35**	46.80**	-8.41**	-12.50**	75.61**	-9.65**	-20.00**	10.15	26.15**	-3.96**	1.20**
Rsc-4 × DS-2106	-21.60**	13.94**	-3.03**	-12.50**	-12.76**	-2.91	-12.22**	-12.50**	13.92**	2.44	-18.92**	10.96	27.27**	-3.12**	0.76**
Rsc-5 × JS-335	-3.03**	15.32**	0.00	18.64**	6.05**	15.22*	-2.78*	6.67**	-3.70	6.22	5.26*	-8.42	40.54**	3.34**	-2.88**
Rsc-5 × BLS-59	-6.61**	0.00	-20.00**	-9.09**	8.70**	2.67	3.32*	-6.67**	24.39**	-24.23**	-1.33	68.27**	32.50**	1.80**	-4.17**
Rsc-5 × DS-2106	-4.92**	-8.03**	-2.86**	-16.67**	7.66**	-11.58	-5.50**	6.67**	-6.33*	-0.98	-8.86**	-4.84	30.86**	2.93**	-6.77**
SL-688 × JS-335	6.72**	12.89**	11.76**	-1.54	17.18**	-12.92	-14.43**	-20.00**	-1.20	13.21**	20.00**	-9.89	8.82**	4.08**	5.10**
SL-688 × BLS-59	1.20	14.22**	-18.92**	-8.33**	23.23**	0.00	-3.06*	-6.67**	14.29**	-1.74	21.74**	15.92*	-10.81**	4.46**	4.76**
SL-688 × DS-2106	6.77**	6.76**	-13.51**	-3.03	21.55**	1.40	1.48	-6.67**	23.46**	0.48	6.85**	27.23**	-25.33**	2.00**	-1.14**
TNAUS-7 × JS-335	3.42**	-12.44**	3.23**	-10.14**	-6.28**	13.64	9.52**	12.50**	10.11**	-3.60	-1.33	15.88*	-12.50**	0.63	-2.42**
TNAUS-7 × BLS-59	-0.41	-11.96**	0.00	-2.63	-2.79	30.04**	3.41*	12.50**	8.89**	-5.00	0.00	20.50**	-25.71**	-1.60**	2.04**
TNAUS-7 × DS-2106	2.02**	-2.80**	-17.65**	-11.43**	-3.23	-18.58*	2.83*	-12.50**	19.54**	-0.46	-2.56	20.17**	-21.13**	-0.97	-2.34**
VLS-60 × JS-335	4.20**	0.00	3.45**	15.94**	-2.69	14.95*	10.48**	33.33**	3.23	-5.83	51.61**	10.55	23.53**	-3.39**	-0.40**
VLS-60 × BLS-59	-2.81**	-1.15**	0.00	-5.26**	3.26	0.46	-5.37**	-6.67**	-2.13	1.24	34.43**	-1.58	59.46**	-3.35**	0.00
VLS-60 × DS-2106	-1.99**	1.44**	6.25**	8.57**	1.84	14.55*	3.77**	6.67**	36.26**	10.09**	-1.54	24.66**	25.33**	-6.48**	-1.96**
Bragg × JS-335	-3.67**	31.79**	13.33**	21.21**	-8.40**	30.77**	-1.87	6.67**	13.98**	12.38**	1.54	3.12	55.26**	3.32**	-1.59**
Bragg × BLS-59	-9.37**	22.48**	3.03**	1.37	-5.65**	11.85	-1.44	-6.67**	14.89**	7.89*	12.50**	5.94	29.27**	1.21*	-1.20**
Bragg × DS-2106	-13.18**	25.27**	33.33**	16.42**	-2.59	29.91**	5.56**	-6.67**	40.66**	5.37	23.53**	35.19**	34.94**	2.19**	-3.08**
PK-416 × JS-335	-9.47**	30.36**	-15.15**	-23.29**	5.48**	-32.77**	-9.43**	0.00	-17.17**	-1.37	17.14**	-15.88*	1.59	-5.20**	4.28**
PK-416 × BLS-59	-10.24**	20.95**	-5.56**	-12.50**	0.00	-13.69	1.45	-12.50**	-8.00**	-2.11	13.04**	-4.53	-24.64**	-7.80**	3.94**
PK-416 × DS-2106	-11.72**	-12.21**	-5.56**	5.41**	0.00	-4.92	4.67**	0.00	11.34**	0.00	-20.55**	10.99	2.86	-8.20**	7.92**
SEm±	).715	).390	l.014	l.931	l.667	7.230	l.310	).393	2.810	3.579	2.197	5.850	l.889	).585	).103

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Table 2 Heterosis (%) over better parent for yield and yield contributing characters in soybean.

Cross	Days to 50% flowering	Plant height (cm)	No. of branches / plant	No. of fruiting nodes	Duration of pod filling	No. of pods/ plant	Pod length	Seeds/ pod	Grain yield/ plant	Biological yield	No. of nodules/ plant	Harvest index	Nodules weight	Protein content	Oil content
BAUS-31 × JS-335	-10.43**	-18.32**	-11.76**	5.71*	-19.64**	15.45	-22.73**	-12.50**	19.15**	-7.89	-20.00**	21.15**	11.43**	-4.52**	-20.63**
BAUS-31 × BLS-59	-16.67**	-14.88**	0.00	-30.95**	-10.71**	-13.27	-15.45**	0.00	-16.67**	-31.75**	0.00	21.17**	2.70	-2.73**	-9.76**
BAUS-31 × DS-2106	-21.09**	-2.48**	-11.76**	8.33**	-15.62**	6.90	-27.03**	-25.00**	28.89**	-3.51	10.53**	18.80*	-5.26*	-2.70**	-21.64**
DS-200-1 × JS-335	-18.70**	-2.15**	0.00	-17.14**	-15.25**	-9.91	1.83	0.00	4.26	-12.04**	14.29**	17.79*	22.58**	-6.87**	-13.49**
DS-200-1 × BLS-59	-15.87**	-9.30**	-11.76**	-33.33**	0.48	-15.04	-7.69**	-12.50**	-14.58**	-25.40**	-20.59**	3.11	5.41*	-3.43**	-13.01**
DS-200-1 × DS-2106	-11.72**	1.00**	-11.76**	-22.22**	-5.69**	-18.10*	-9.91**	0.00	-8.89**	-15.74**	-42.11**	2.44	21.05**	-8.70**	-20.90**
DSB-3-4 × JS-335	-1.72*	-38.21**	-15.00**	-9.09**	-4.93*	9.76	-15.60**	-12.50**	13.73**	-41.50**	-20.00**	59.85**	2.17	0.44	0.79**
DSB-3-4 × BLS-59	-11.90**	-35.77**	-25.00**	-25.00**	-5.69**	-15.45	6.73**	0.00	-15.69**	-47.62**	47.06**	45.84**	4.35*	-2.02**	5.69**
DSB-3-4 × DS-2106	-17.19**	-25.61**	-15.00**	-13.64**	0.00	-6.50	-5.41**	0.00	7.84*	-30.61**	-15.79**	19.79*	-2.17	-6.09**	-5.97**
Him-80-1600 × JS-335	-4.92**	-11.36**	13.33**	-17.14**	-3.14	-17.27*	-17.09**	-22.22**	-17.02**	-8.33*	-25.00**	-11.98	12.12**	-0.71	0.79**
Him-80-1600 × BLS-59	-11.90**	-14.55**	-5.88**	-19.05**	0.00	-5.31	-16.24**	-11.11**	-20.83**	-23.02**	5.56*	-5.00	2.70	-0.88	3.17**
Him-80-1600 × DS-2106	-14.84**	-4.09**	5.88**	-13.89**	0.00	-18.10*	-24.79**	-22.22**	-11.11**	2.91	-21.05**	-15.98*	7.89**	-2.26**	-2.24**
Him-80-1601 × JS-335	3.48**	-21.03**	-16.67**	-27.50**	-2.69	-25.95**	-1.83	0.00	-24.49**	-25.00**	-2.86	-0.29	35.29**	-0.99	-3.17**
Him-80-1601 × BLS-59	-5.56**	-13.02**	-11.11**	-14.29**	2.90	-17.56*	-7.69**	-12.50**	-6.12	-31.75**	-23.53**	12.70	8.11**	-8.44**	-6.50**
Him-80-1601 × DS-2106	-7.81**	-22.43**	-11.11**	-5.00*	3.79	-4.58	1.80	-12.50**	8.16*	-12.04**	-15.79**	19.82*	10.53**	-8.70**	-14.18**
JS-97-51 × JS-335	-0.87	4.60**	-6.25**	0.00	-6.06**	5.17	4.59**	0.00	-10.64**	-17.59**	-2.86	-2.78	8.11**	-13.98**	-4.76**
JS-97-51 × BLS-59	-8.73**	-1.40**	-5.88**	-40.48**	-12.99**	-25.00**	-5.77**	-12.50**	-41.67**	-29.37**	11.76**	-33.12**	-5.41*	-13.72**	2.44**
JS-97-51 × DS-2106	-8.59**	-3.00**	-5.88**	-27.78**	-7.79**	-25.00**	-12.61**	-12.50**	-33.33**	-11.65**	-28.95**	-32.08**	-7.89**	-11.23**	-5.22**
JS-97-52 × JS-335	6.09**	-5.42**	5.56**	-20.00**	-4.37*	-11.35	-4.59**	0.00	0.00	1.85	-5.71*	-2.29	-4.76*	-1.21	0.79**
JS-97-52 × BLS-59	-3.97**	-1.40**	-16.67**	-28.89**	-6.99**	-24.11**	1.92	0.00	-25.00**	-19.05**	-8.82**	-18.21*	4.76*	-0.87	1.57**
JS-97-52 × DS-2106	-3.13**	5.91**	-27.78**	-33.33**	-8.30**	-31.91**	63.63**	12.50**	-30.43**	-7.48	7.89**	-26.10**	-2.38	-1.47*	-2.99**
Js(SH) 98-92 × JS-335	-6.72**	-20.25**	5.00**	14.29**	-4.48*	25.44**	-14.68**	-12.50**	9.80**	-10.08*	-14.29**	9.24	0.00	0.17	4.29**
Js(SH) 98-92 × BLS-59	-13.49**	-5.79**	0.00	-40.48**	-0.47	-28.07**	-8.26**	0.00	-31.37**	-13.18**	11.76**	-20.77**	-9.52**	-0.26	4.29**
Js(SH) 98-92 × DS-2106	-17.97**	-8.26**	-15.00**	-25.00**	-1.87	-25.00**	6.31**	12.50**	-31.37**	-20.93**	-28.95**	-21.23**	-19.05**	-1.57*	3.57**
MACS-708 × JS-335	-13.04**	-0.89**	-27.27**	-23.08**	-17.04**	-24.22**	-14.68**	-12.50**	-37.04**	-17.50**	-14.29**	-23.54**	30.30**	-1.79**	-3.17**
MACS-708 × BLS-59	-19.05**	-11.16**	-13.64**	-14.29**	-14.03**	16.41	-7.69**	-25.00**	-11.11**	-13.49**	-5.71*	-5.02	2.70	-0.78	0.00
MACS-708 × DS-2106	-21.88**	-18.75**	-18.18**	-15.38**	-14.93**	-10.16	-15.32**	0.00	-22.22**	-18.33**	-13.16**	-6.64	7.89**	-1.55*	-10.45**
MACS-746 × JS-335	-4.76**	-9.61**	-16.67**	-33.33**	-6.28**	-29.57**	-15.60**	-12.50**	-21.88**	-19.86**	5.71*	-3.24	26.83**	-0.36	8.46**
MACS-746 × BLS-59	-5.56**	-21.83**	-27.78**	-42.59**	-4.05*	-42.47**	1.92	0.00	-39.06**	-29.79**	-11.76**	-14.65	17.07**	-3.96**	3.85**
MACS-746 × DS-2106	-8.59**	-29.26**	-11.11**	-48.15**	-4.05*	-47.85**	-7.21**	-12.50**	-42.19**	-32.62**	5.26*	-13.84	2.44	-8.27**	4.48**
MACS-975 × JS-335	6.84**	18.68**	-5.26**	11.43**	-4.48*	36.36**	-14.04**	-12.50**	13.33**	7.44	-11.11**	4.83	0.00	-3.31**	5.47**
MACS-975 × BLS-59	1.59	-21.86**	-21.05**	-28.57**	-4.04*	-15.04	-15.79**	-12.50**	-40.00**	-35.71**	-27.78**	-10.46	-4.76*	-9.50**	3.12**
MACS-975 × DS-2106	-3.91**	1.00**	0.00	-2.78	-5.38**	-6.90	-7.02**	0.00	-30.00**	-23.97**	-10.53**	-8.24	-14.29**	-8.27**	-7.46**
MACS-128 × JS-335	0.79	-9.87**	21.43**	-14.29**	-5.22**	0.00	-17.43**	-25.00**	-12.77**	-12.73**	11.43**	-2.98	32.35**	-1.05	0.76**
MACS-128 × BLS-59	0.00	-4.48**	0.00	-23.81**	-6.09**	-1.77	-6.73**	-12.50**	-8.33*	-15.87**	-2.94	3.50	8.11*	-0.26	-2.27**
MACS-128 × DS-2106	-3.13**	-24.66**	-17.65**	-27.78**	-3.91*	-29.31**	-10.81**	-12.50**	-26.67**	-30.00**	-21.05**	-2.44	-5.26*	-0.35	0.00
MACS-68-1 × JS-335	-2.61**	-6.63**	-5.56**	-5.26*	-10.76**	6.25	-4.59**	-12.50**	-12.00**	-20.37**	-22.22**	7.50	0.00	-0.80	0.00
MACS-68-1 × BLS-59	-11.90**	-20.00**	-11.11**	-23.81**	-14.41**	-15.63	-8.49**	-12.50**	-30.00**	-39.68**	-2.78	-2.26	-13.33**	0.35	-1.50**
MACS-68-1 × DS-2106	-14.06**	0.50	0.00	-7.89**	-16.22**	-8.59	-16.22**	-12.50**	-8.00*	-9.43*	-36.84**	0.21	-15.56**	-5.22**	-3.73**
MACS-86 × JS-335	-2.46**	-16.94**	-6.67**	-20.00**	-4.93*	-10.91	-4.59**	0.00	-29.79**	-18.33**	-8.57**	-22.90**	0.00	-6.28**	-23.81**
MACS-86 × BLS-59	-3.17**	-10.89**	0.00	-42.86**	0.93	-26.55**	0.00	0.00	-39.58**	-26.19**	11.76**	-19.51*	13.51**	-6.10**	-17.89**
MACS-86 × DS-2106	-6.25**	-17.74**	-5.88**	-19.44**	-1.40	-12.07	-3.60*	-12.50**	-15.56**	-17.50**	-15.79**	-14.08	10.53**	-10.44**	-21.64**
MACS-352 × JS-335	-26.67**	-11.21**	-16.67**	-5.13**	-11.66**	8.55	-8.26**	0.00	17.02**	-4.50	5.71*	19.62*	3.23	0.00	-7.14**
MACS-352 × BLS-59	-25.93**	-6.98**	5.56**	-14.29**	-9.91**	6.84	-6.73**	-12.50**	-12.50**	-18.25**	-5.88*	3.22	-8.11**	-1.96**	-0.81**
MACS-352 × DS-2106	-25.19**	1.87**	-22.22**	-23.08**	-9.91**	-14.53	-10.81**	0.00	-15.56**	-9.01*	-13.16**	-14.54	0.00	-0.43	-10.45**
NRC-63 × JS-335	0.00	9.14**	6.25**	-22.86**	-8.19**	-14.55	-14.68**	-12.50**	-31.91**	-13.89**	2.86	-20.99**	12.90**	2.76**	1.59**
NRC-63 × BLS-59	-5.56**	13.02**	-5.88**	-33.33**	-8.62**	-13.27	-18.27**	-12.50***	-27.08**	-13.49**	14.71**	-21.19**	5.41*	4.83**	2.44**
NRC-63 × DS-2106	-9.38**	20.00**	-5.88**	-25.00**	-6.90**	-20.69*	-20.72**	-25.00**	-26.67**	-2.88	-5.26*	-24.28**	0.00	3.97**	-2.99**
NRC-64 × JS-335	-7.83**	21.20**	-27.27**	-26.83**	-10.76**	-27.61**	-8.77**	-11.11**	-14.58**	-3.70	5.71*	-12.77	-27.27**	0.17	3.97**
NRC-64 × BLS-59	-15.87**	0.47	-13.64**	-23.81**	-7.94**	-13.43	-7.02**	-11.11**	-6.25	-14.29**	8.57**	-8.29	5.41*	1.13	3.20**
NRC-64 × DS-2106	-16.41**	-5.00**	-31.82**	-26.83**	-9.35**	-26.12**	-2.63	-22.22**	-27.08**	-14.15**	-7.89**	-14.86	-34.21**	2.43**	0.00
NRC-65 × JS-335	-5.88**	-23.50**	-22.22**	-25.71**	-2.24	15.45	0.92	-12.50**	-50.00**	-43.18**	-10.53**	-11.70	5.56*	11.29**	4.62**
NRC-65 × BLS-59	-9.52**	-11.52**	11.11**	-14.29**	4.35*	-4.07	16.35**	12.50**	-20.97**	-20.45**	0.00	-0.07	-10.81**	5.36**	6.15**
NRC-65 × DS-2106	-10.16**	-2.76**	-16.67**	-2.78	3.32	-17.07*	-9.91**	0.00	-41.94**	-28.03**	-13.16**	-20.40*	-5.26*	4.09**	2.99**
Ps-1364 × JS-335	13.91**	-11.98**	-20.00**	-5.71*	11.21**	-8.18	-15.60**	-12.50**	-21.28**	-25.93**	-15.91**	4.81	16.13**	-6.59**	2.38**
Ps-1364 × BLS-59	3.97**	-11.16**	-10.00**	-23.81**	18.84**	-9.73	3.81*	0.00	-12.50**	-23.81**	-18.18**	2.71	-18.92**	-9.85**	2.38**
Ps-1364 × DS-2106	2.34**	-6.00**	-30.00**	-27.78**	17.54**	-26.72**	-6.31**	-12.50**	-37.78**	-27.36**	-15.91**	-17.58	7.89**	-11.58**	-2.24**
Ps-1368 × JS-335	-3.36**	-18.72**	-21.05**	-28.95**	2.24	-19.09*	-3.67*	-12.50**	-31.91**	-35.19**	28.57**	14.50	-17.39**	-1.35*	-28.57**
Ps-1368 × BLS-59	-7.14**	-21.40**	-10.53**	-35.71**	9.18**	-19.47*	0.00	0.00	-29.17**	-25.40**	26.47**	-5.86	-17.39**	-4.84**	-25.20**
Ps-1368 × DS-2106	-11.72**	7.39**	-21.05**	-39.47**	3.32	-24.14**	-8.11**	-12.50**	-26.67**	-0.97	-2.63	-20.24*	-15.22**	-6.53**	-32.84**
Ps-1370 × JS-335	-0.85	-14.54**	-22.73**	-20.00**	-0.45	-10.40	-24.11**	-12.50**	-6.12	-20.66**	2.86	6.41	-8.33**	-4.12**	-11.11**
Ps-1370 × BLS-59	-4.76**	-17.62**	-27.27**	-21.43**	-1.36	-4.00	-2.68	0.00	-10.20**	-34.13**	2.94	30.22**	13.51**	-1.76*	-12.20**
Ps-1370 × DS-2106	-7.81**	-29.07**	-22.73**	-22.50**	-0.45	-13.60	-15.18**	-12.50**	-10.20**	-23.14**	0.00	7.15	-7.89**	-1.74*	-20.90**
RKs-15 × JS-335	9.57**	-13.39**	0.00	14.29**	8.52**	10.91	-6.42**	-12.50**	4.26	-24.19**	-14.29**	19.92*	11.43**	7.95**	-5.56**
RKs-15 × BLS-59	0.00	-17.32**	-26.32**	-35.71**	17.87**	-14.16	-1.92	-12.50**	-14.58**	-9.52*	8.82**	-4.55	2.70	1.41*	-3.25**
RKs-15 × DS-2106	0.00	-12.99**	-10.53**	-5.56*	15.17**	4.31	-14.41**	-12.50**	13.33**	-14.52**	-5.26*	11.42	10.53**	1.13	-13.43**
RKs-18 × JS-335	-9.84**	-2.62**	-10.00**	-15.79**	-12.11**	-38.46**	7.34**	12.50**	-22.00**	-11.38**	-20.00**	-18.47*	100.00**	-1.26	1.59**
RKs-18 × BLS-59	-11.11**	-7.42**	-25.00**	-23.81**	-9.86**	-17.95*	1.92	0.00	-12.00**	-15.08**	0.00	4.97	48.65**	-3.61**	3.20**
RKs-18 × DS-2106	-13.28**	-20.09**	-35.00**	-10.53**	-7.98**	-31.62**	-10.81**	0.00	-18.00**	-17.89**	23.68**	-6.24	44.74**	-10.27**	-3.73**
Rsc-4 × JS-335	-19.67**	-10.65**	6.25**	-8.57**	-18.39**	-20.00*	3.64*	0.00	-4.26	13.89**	-22.22**	-15.27	-3.23	-3.61**	3.91**

Table 2 (Cont.)

Cross	Days to 50% flowering	Plant height (cm)	No. of branches / plant	No. of fruiting nodes	Duration of pod filling	No. of pods/ plant	Pod length	Seeds/ pod	Grain yield/ plant	Biological yield	No. of nodules/ plant	Harvest index	Nodules weight	Protein content	Oil content
Rsc-4 × BLS-59	-17.46**	-2.78**	-11.76**	-2.38	-15.91**	31.86**	-10.91**	-12.50**	50.00**	-18.25**	-22.22**	92.21**	10.81**	-7.21**	-0.78**
Rsc-4 × DS-2106	-23.44**	9.72**	-5.88**	-22.22**	-14.55**	-13.79	-12.61**	-12.50**	0.00	1.94	-21.05**	-3.65	10.53**	-6.88**	-1.49**
Rsc-5 × JS-335	-3.45**	5.21**	-11.11**	0.00	2.24	-3.64	-3.67*	0.00	-17.02**	2.78	-2.44	-19.92*	20.93**	1.93**	-6.35**
Rsc-5 × BLS-59	-10.32**	-0.93**	-22.22**	-28.57**	8.70**	-15.04	1.87	-12.50**	6.25	-31.75**	-9.76**	56.34**	23.26**	1.76*	-6.50**
Rsc-5 × DS-2106	-9.38**	-10.43**	-5.56**	-30.56**	6.64**	-27.59**	-7.21**	0.00	-17.78**	-1.94	-12.20**	-16.89*	23.26**	2.44**	-12.69**
SL-688 × JS-335	3.25**	2.34**	-5.00**	-8.57**	11.66**	-17.27*	-21.10**	-25.00**	-12.77**	11.11**	20.00**	-19.31*	0.00	2.18**	3.88**
SL-688 × BLS-59	0.00	13.95**	-25.00**	-21.43**	21.74**	-6.19	-8.65**	-12.50**	0.00	-10.32*	20.00**	10.50	-10.81**	3.92**	2.33**
SL-688 × DS-2106	4.69**	3.27**	-20.00**	-11.11**	18.96**	-6.03	-7.21**	-12.50**	11.11**	0.00	2.63	13.77	-26.32**	2.00**	-2.99**
TNAUS-7 × JS-335	1.68*	-22.81**	-5.88**	-11.43**	-6.28**	13.64	5.50**	12.50**	4.26	-6.14	-7.50**	6.41	-15.15**	0.09	-3.97**
TNAUS-7 × BLS-59	-3.17**	-14.47**	0.00	-11.90**	-6.28**	28.32**	1.92	12.50**	2.08	-9.52*	-7.50**	18.02*	-29.73**	-2.37**	1.63**
TNAUS-7 × DS-2106	-1.56	-8.77**	-17.65**	-13.89**	-5.83**	-20.69**	-1.80	-12.50**	15.56**	-5.26	-5.00	10.20	-26.32**	-2.26**	-6.72**
VLS-60 × JS-335	0.81	-10.09**	0.00	14.29**	-2.69	11.82	6.42**	25.00**	2.13	-8.70*	34.29**	5.57	13.51**	-4.88**	-2.38**
VLS-60 × BLS-59	-3.97**	-1.83**	-5.88**	-14.29**	-0.45	-3.54	-6.73**	-12.50**	-4.17	-3.17	20.59**	-3.61	59.46**	-6.07**	-0.81**
VLS-60 × DS-2106	-3.91**	-2.75**	0.00	5.56*	-0.90	8.62	-0.90	0.00	34.78**	4.35	-15.79**	18.87*	23.68**	-9.57**	-6.72**
Bragg × JS-335	-9.23**	31.03**	6.25**	14.29**	-13.83**	23.64**	-3.67*	0.00	12.77**	9.26*	-5.71**	1.63	31.11**	2.62**	-1.59**
Bragg × BLS-59	-10.77**	10.23**	0.00	-11.90**	-14.23**	4.42	-1.90	-12.50**	12.50**	-2.38	5.88**	-2.15	17.78**	-0.79	-2.38**
Bragg × DS-2106	-13.85**	16.50**	29.41**	8.33**	-10.67**	19.83*	2.70	-12.50**	39.13**	4.85	10.53**	33.43**	24.44**	-0.35	-5.97**
PK-416 × JS-335	-14.06**	25.86**	-26.32**	-26.32**	3.59	-37.50**	-11.93**	0.00	-21.15**	-2.70	17.14**	-18.53*	0.00	-5.24**	2.29**
PK-416 × BLS-59	-10.94**	6.05**	-10.53**	-16.67**	-1.86	-18.75*	0.96	-12.50**	-11.54**	-7.94	11.43**	-13.23	-29.73**	-9.06**	0.76**
PK-416 × DS-2106	-11.72**	-11.50**	-10.53**	2.63	-0.93	-9.38	0.90	0.00	3.85	-3.60	-23.68**	7.65	-5.26*	-9.92**	6.72**
SEm±	0.826	0.338	1.172	2.230	1.924	8.358	1.513	0.454	3.245	4.132	2.537	7.910	2.182	0.676	0.119