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HETEROSIS IN SOYBEAN (*GLYCINE MAX* (L.) MERRILL)

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ABSTRACT

Twenty one soybean hybrids derived from a seven-parent half-diallel set along with their parents were evaluated to estimate heterosis. Heterosis was significant positive for yield in 16 hybrids over midparent and in 9 hybrids over better parent. Heterosis for yield was generally accompanied by heterosis for yield components. For protein, five and for oil one hybrid exhibited significant positive heterosis over midparent. In view of the availability of genetic male sterility, the study revealed good scope for commercial exploitation of heterosis for yield and protein contents in soybean.

Key words: Soybean, *Glycine max*, heterosis.

In a highly self-pollinated crop like soybean (*Glycine max* (L.) Merrill), the scope for exploitation of hybrid vigor 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 [1] suggested the possibility of exploiting heterosis in soybean breeding.

Further, the extent of heterosis will have direct effect on breeding methodology in the varietal improvement programme. Therefore, in the present investigation an attempt has been made to estimate heterosis for yield, protein, oil content and other related attributes in 21 hybrids of a seven parent half diallel set.

MATERIALS AND METHODS

Seven soybean lines, Bragg, Hardee, Monetta, KHSb-2, Local Black Soybean (LBS), DS-74-62 and SL-96, were crossed in all possible combinations excluding reciprocals to make a diallel set. The 21 hybrids along with seven parents were grown in randomized complete

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block design using three replications. Each entry was grown in a single-row plot. The observations were recorded on ten random plants in each entry for 10 quantitative traits of economic value. Protein content was estimated based on total nitrogen content of seeds by micro-Kjeldahl method [2] by multiplying percentage N by 6.25. Oil content was estimated by the nuclear magnetic resonance (NMR) technique.

Heterosis was calculated as percentage of deviation of the F_1 mean over midparent (MP), better parent (BP) in each cross, and the best parent (BeP) in the entire set of parents for the character in the experiment.

RESULTS AND DISCUSSION

The MP, BP and BeP heterosis either alone or in combination were significant for all the characters (Table 1). The number of hybrids with significant BP heterosis was four for days to flowering and maturity (earliness), five for plant height, four for number of primary branches, ten for pods per plant, three for seeds per pod, five for 100-seed weight, nine for grain yield, three for protein, and none for oil content. The BP heterosis (%) ranged from – 19.3 to 31.2 for days to flowering, – 5.5 to 8.0 for days to maturity, – 57.5 to 40.2 for plant height, – 39.8 to 69.1 for primary branches, – 43.7 to 110.1 for number of pods, – 14.8 to 16.7 for seeds per pod, – 45.5 to 21.7 for 100-seed weight, – 43.6 to 121.9 for grain yield, – 10.8 to 12.2 for protein content, and – 14.2 to 11.3 for oil content.

The four early maturing hybrids with significant negative BP heterosis for flowering time involved DS-74-62 (late) and SL-96 (medium) crossed with medium Hardee (medium) and KHSb-2 (late) parents. Among the hybrids taller than their respective better parents, the one with highest heterosis (40.2%) resulted by crossing two dwarf parents (Monetta and SL-96). Another hybrid, KHSb-2 x LBS, involving two tall parents surpassed the tallest parent in the experiment by 30.3%, indicating dispersion of genes for plant height.

Eight hybrids had better branching than the midparental value, whereas only four, viz. Bragg x Hardee (35.3%), Bragg x Monetta (17.8%), Hardee x SL-96 (17.5%) and Monetta x SL-96 (69.1%) showed their superiority over better parents. The parents of these hybrids had 3.6 (Monetta) to 4.7 (Bragg and Hardee) branches per plant, and the hybrid Monetta x SL-96 had 6.8 branches per plant compared to 7.5 in the best parent KHSb-2. Of the ten hybrids with BP heterosis for pods per plant, only three exhibited significant superiority over the best parent (LBS) which was involved in two of these crosses (with KHSb-2 and DS-74-62). Another hybrid of interest was KHSb-2 x DS-74-62.

Three hybrids of SL-96 with Hardee (16.7%), LBS (12.0%) and DS- 74-62 (9.1%) had more seeds per pod than their better parents and one of them (Hardee x SL-96) was even superior

Table 1. Percentage heterosis for different characters in soybean hybrids

Hybrid	Days to flower			Days to maturity			Plant height			Primary branches			Pods per plant		
	MP	BP	BeP	MP	BP	BeP	MP	BP	BeP	MP	BP	BeP	MP	BP	BeP
Bragg x Hardee	0.004	12.86**	18.45**	1.9*	3.6**	10.0**	-4.02	-4.8	-53.9**	35.4**	35.4**	-15.3**	86.3**	54.5**	-4.4
Bragg x Monetta	8.34**	9.44**	12.38**	1.2	4.3**	4.3**	7.32*	-8.6*	-55.7**	33.8**	17.8**	-26.4**	86.6	79.0**	-24.1**
Bragg x KHSb-2	-11.20**	8.67**	14.06**	-7.5**	-0.8	4.3**	-39.4**	-48.5**	-64.3**	-25.9**	-39.8**	-39.8**	-18.1**	-42.2	-44.1**
Bragg x LBS	3.60*	18.15**	24.02**	1.3	2.2*	6.6**	0.23	-25.6**	-25.6**	-7.2	-15.2*	-35.9**	12.6**	-20.8**	20.8**
Bragg x DS-74-62	-11.35**	3.30	8.42**	-2.3**	2.7**	9.0**	-5.37	-18.1**	-45.8**	-5.1	-19.5**	-27.7**	26.8**	-7.2	-18.2**
Bragg x SL-96	15.39	18.25**	18.25**	3.4**	4.6**	11.0**	16.53	-26.9**	-64.6**	-16.7**	-22.3**	-51.4**	13.4**	8.0*	-56.0**
Hardee x Monetta	-3.10	10.69**	13.69**	-4.3**	0.4	0.4	1.25	-13.1**	-58.6**	14.5	0.7	-37.0**	34.7**	8.1*	-33.2**
Hardee x KHSb-2	-6.59**	0.49	32.59**	-3.7**	1.6	11.5**	-9.69**	-11.3**	-47.2**	23.5**	0.4	0.4	31.9**	8.2**	4.5
Hardee x LBS	-20.00**	-19.25**	6.54*	5.3**	8.0**	12.6**	-29.4**	-47.9**	-47.9**	-17.7**	-24.8	-43.1	-30.4**	-43.7**	-43.7**
Hardee x DS-74-62	-17.92**	-15.52**	11.64**	-7.9**	-4.8**	4.4**	-21.45**	-32.5**	-55.3**	-0.8	-15.8**	-24.4**	8.8**	-7.3*	-18.5**
Hardee x SL-96	-7.54**	7.37**	7.37**	-6.3**	-5.5**	2.0*	20.6**	6.5*	-49.2**	26.2**	17.5**	-26.4**	-0.01	-20.6**	-50.8**
Monetta x KHSb-2	5.83**	31.19**	34.75**	-6.0**	4.2**	4.2**	-6.69	-30.4**	-51.8**	5.5	-22.2**	-22.2**	43.0**	-0.8	-4.2
Monetta x LBS	-15.43**	-2.37	0.28	0.9	3.0**	3.0**	-36.6**	-57.5**	-57.5**	18.9**	-3.2	-26.8**	8.7*	-25.3**	-26.3**
Monetta x DS-74-62	0.76	18.87**	22.09**	-3.1**	5.2**	5.2**	-6.0*	-28.8**	-52.9**	17.5**	-10.1	-19.3**	33.1**	-5.2	-16.6**
Monetta x SL-96	8.21**	9.68**	9.68**	-3.6**	0.3	0.3	12.8**	9.2*	-60.2**	80.0**	69.1**	-8.6	112.4**	110.1**	-21.4**
KHSb-2 x LBS	-3.21	3.04	38.53**	-5.5**	2.4**	6.8**	54.3**	30.3**	30.3**	15.7*	1.6	1.6	62.3**	59.5**	59.5**
KHSb-2 x DS-74-62	-9.86**	-5.89**	31.41**	-3.6**	-1.7*	15.0**	8.8**	6.4*	-26.3**	7.3	1.9	1.9	43.1**	36.7**	32.0**
KHSb-2 x SL-96	-9.10**	14.52**	14.52**	-8.5*	-2.6**	5.1**	-3.58	-26.4**	-49.0**	4.3	-19.7**	-19.7**	-7.7*	-36.3**	-38.5**
LBS x DS-74-62	-7.86**	-6.08**	26.27**	-3.7**	2.2**	6.6**	8.01	-10.2**	-10.2**	6.3	-2.1	-12.1*	58.3**	48.7**	48.7**
LBS x SL-96	-10.31**	5.14*	5.14*	-1.3	0.4	4.7**	-14.8**	-41.8**	-41.8**	-3.2	-17.0**	-37.2**	13.5**	-22.5**	-22.5**
DS-74-62 x SL-96	-3.07	16.14**	16.14**	-2.9**	1.2	9.3**	-22.9**	40.2**	-60.4**	-7.0	-26.5**	-33.1**	0.6	-28.8**	-37.4**
Range: min.	-20.0	-19.25	0.28	-8.5	-5.5	0.3	-39.4	-57.5	-64.6	-25.9	-39.8	-51.4	-30.4	-43.7	-50.8
max.	15.39	31.19	34.75	5.3	8.0	15.0	54.3	40.2	30.3	80.9	69.1	1.9	112.4	110.1	59.5

(Contd.)

Table 1 (contd.)

Hybrid	Seeds per pod			100-grain weight			Seed yield per plant			Protein content			Oil content		
	MP	BP	BeP	MP	BP	BeP	MP	BP	BeP	MP	BP	BeP	MP	BP	BeP
Bragg x Hardee	4.1	0.4	0.4	12.5**	6.6	- 16.8**	113.2**	85.1**	- 1.3	0.2	- 2.0	- 7.6**	0.8	- 2.4	- 2.9
Bragg x Monetta	7.6*	0.1	- 3.1	23.7**	8.9*	- 15.7**	170.9**	121.9**	- 12.9	- 1.3	- 2.1	- 6.3**	0.1	- 0.6	- 7.3
Bragg x KHSb-2	- 12.7	- 0.3	- 13.3**	15.2**	12.9**	- 12.6**	- 18.9**	- 43.6**	- 43.6**	2.9	0.5	- 5.3**	2.7	- 0.8	- 0.8
Bragg x LBS	- 4.3	- 4.2	- 10.2**	- 2.9	- 22.0**	- 39.6**	26.5**	7.4	- 39.6**	- 4.9*	- 7.6**	- 7.6**	8.4	3.3	- 3.7
Bragg x DS-74-62	- 1.4	0.0**	- 8.0	14.2**	11.5**	- 13.7**	60.2**	22.2**	- 8.8**	- 8.0*	- 10.8**	- 15.9**	15.1**	11.3	11.1
Bragg x SL-96	- 5.5*	0.3	- 9.3**	21.2**	7.5*	7.5*	39.6**	29.6**	- 40.7**	2.5	0.3	- 5.5**	4.5	2.8	- 1.0
Hardee x Monetta	0.3	0.7	- 13.3**	- 4.1	- 11.4*	- 38.5**	18.7**	- 12.8**	- 53.5**	- 3.4*	- 6.2**	- 10.2**	1.7	- 2.1	- 2.6
Hardee x KHSb-2	1.6	0.4	- 2.7	- 3.4	- 6.7	- 30.6**	14.1**	- 12.5	- 12.5**	0.9	0.7	- 9.3**	- 1.4	- 1.6	- 1.6
Hardee x LBS	- 0.5	0.3	- 10.2**	45.3**	21.7**	- 15.5**	10.0*	7.1	- 39.8**	0.2	- 4.8**	- 4.8**	5.6	- 2.3	- 2.8
Hardee x DS-74-62	1.5	0.9	- 8.9**	- 4.7	- 7.5*	- 31.8**	4.7	- 10.3*	- 33.0**	2.0	1.2	- 8.9**	1.2	1.0	0.8
Hardee x SL-95	17.2**	0.7	8.4**	- 0.3	- 15.6**	- 15.6**	26.0**	17.1**	- 37.6**	12.3**	12.2**	1.3	- 8.4	- 9.9	- 10.3
Monetta x KHSb-2	26.5**	0.0	- 5.3	- 1.3	- 11.6**	- 34.3**	3.0	- 35.6**	35.6**	8.7**	5.3**	0.8	- 10.7*	- 14.2*	- 14.2*
Monetta x LBS	- 9.2**	0.1	- 23.5**	- 3.5	- 13.3**	- 49.0**	0.1	- 27.7**	- 59.4**	- 2.1	- 4.2*	- 4.2*	- 0.2	- 4.2	- 11.9*
Monetta x DS-74-62	4.5	0.5	- 12.8**	12.2**	0.9	- 25.6**	47.5**	- 1.5	- 26.5**	3.4*	0.5	- 4.8**	- 9.2	- 12.7*	- 12.9**
Monetta x SL-95	1.2	0.7*	- 15.0**	- 22.3**	- 38.3**	- 38.3**	89.8**	46.8**	- 32.8**	3.9*	1.0	- 3.4*	- 3.8	- 6.0	- 9.5
KHSb-2 x LBS	11.6**	0.4	4.6	- 10.7*	- 27.2**	- 45.9**	55.1**	21.1**	21.1**	- 6.0**	- 10.8**	- 10.8**	9.1	0.6	0.6
KHSb-2 x DS-74-62	- 9.3**	0.8	- 16.9**	- 7.7*	- 8.1*	- 31.7**	32.2**	15.4**	15.4**	- 1.2	- 1.9	- 11.9**	3.0	2.9	2.9
KHSb-2 x SL-96	7.2*	0.6	2.2	- 12.8**	- 24.0**	- 24.0**	- 8.8*	- 33.5**	- 33.5**	- 4.8**	- 5.0**	- 14.2**	3.9	1.9	1.9
LBS x DS-74-62	6.1*	0.6	- 7.5**	- 10.7*	- 26.9**	- 46.1**	65.1**	44.8**	8.0*	- 3.9*	- 9.4**	- 9.4**	8.9	0.6	0.4
LBS x SL-96	14.8**	0.0	3.1	- 25.8**	- 45.5**	- 45.5**	10.1**	- 0.1	- 43.8**	- 3.8*	- 8.4**	- 8.44**	6.7	0.3	- 3.5
DS-74-62 x SL-96	12.4**	0.1*	0.4	- 2.7	- 15.5**	- 15.5**	10.0**	- 11.3**	- 33.8**	7.1**	6.1**	- 4.2**	- 2.8	- 4.6	- 4.8
Range: min.	- 12.7	- 0.8	- 23.9	- 25.8	45.5	- 49.0	- 18.9	- 43.6	- 59.4	- 6.0	- 10.8	- 15.9	- 10.7	- 14.2	- 14.2
max.	26.5	0.7	8.4	45.3	21.7	7.5	170.9	121.9	21.1	12.3	12.2	1.3	15.1	11.3	11.1

*,**Significant at 5 and 1%, respectively; + MP—midparent; BP—better parent; BeP—best parent.

to Bragg, the best parent for this character. For seed size, only one out of five hybrids with significant BP heterosis had the parent with boldest seeds, SL-96 (18 g/100 seeds) with Bragg (medium seed size). Other four hybrids had medium x medium (Bragg x Monetta, Bragg x KHSb-2, Bragg x DS-74-62) and medium x small (Hardee x LBS) seeded parents.

Heterosis for grain yield up to 170.9% over midparent and 121.9% over better parent was noticed in the hybrid Bragg x Monetta. Two hybrids of KHSb-2, the best yielding parent, with LBS and DS-74-62 yielded 21.1 and 15.4% more grain than KHSb-2, respectively, indicating the potential for their exploitation. Three hybrids, viz. Hardee x SL-96, Monetta x KHSb-2 and DS-74-62 x SL-96 had 12.2, 5.3 and 6.1% more protein than their better parents, respectively, however none of the 21 hybrids was superior to the best parent, LBS (43.54%). For oil content also, only one hybrid, i.e. Bragg x DS-74-62, showed significant positive MP heterosis (15.1%) and none was better than their respective parents or KHSb-2 the best parent in the study.

The most important attribute of a plant is its yielding ability. In soybean beside yield, protein and oil contents are two other important economic attributes. In the present study, nine hybrids showed yield superiority over better parent and three of them were significantly high yielding than the best parent. Considerable heterosis was noticed for all other characters except oil content. These results are in close agreement with earlier reports [3–10]. Nelson and Bernard [11] reported only 13–19% BP heterosis, however, the parents in their study were not selected for combining ability.

Yield is a very complex character and highly influenced by environment. Grafius [12] suggested that there may not be any 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. Out of the nine hybrids with significant positive BP heterosis, none showed heterosis for all the three yield components (number of pods, seeds per pod, 100-seed weight). In five hybrids (Bragg x Hardee, Monetta x SL-96, KHSb-2 x LBS-96, KHSb-2 x DS-74-62 and LBS x DS-74-62), the manifestation of heterosis for yield was through pods per plant only. Seeds per pod in the hybrid Hardee x SL-96 and 100-seed weight in Bragg x DS-74-62 were responsible for yield heterosis. Combination of pods per plant and 100-grain weight in two hybrids, Bragg x Monetta and Bragg x SL- 96, contributed to the heterosis for yield. This clearly shows that pods per plant, 100-seed weight and seeds per pod, in that order of importance, were responsible for manifestation of heterosis for yield in soybean. This is in agreement with the findings of Chaudhary and Singh [7].

For quality characters like protein content, the crosses Hardee x SL-96, Monetta x KHSb-2 and DS-74-62 x SL-96 showed positive BP heterosis. The first two of these hybrids have protein contents similar to the best parent LBS (43.5%). All these hybrids with high protein content had negative heterosis for oil, reaffirming the negative correlation between these two traits.

The comparison of parents and F_1 hybrids (Table 2) revealed that, in general, the hybrids had better than parental means for number of primary branches, number of pods, seeds per pod, 100-seed weight, yield per plant, and oil content. Hybrids were equal to parental means in protein content, and were dwarf, earlier in flowering and maturity.

Table 2. Mean performance of parents and F_1 hybrids in soybean

Character	Mean of parents	Mean of hybrids	Mean heterosis (%)
Days to flower	49.3	46.9	-4.90
Days to maturity	103.5	99.8	-3.60
Plant height (cm)	39.5	37.7	-4.60
Primary branches	5.27	5.69	7.97
Pods per plant	61.9	78.9	27.50
Seeds per pod	2.06	2.11	2.43
100-grain weight (g)	13.01	13.27	2.42
Yield per plant (g)	15.53	20.45	31.68
Protein content (%)	40.35	40.42	0.17
Oil content (%)	19.91	20.23	1.61

The hybrid KHSb-2 x DS-74-62 appears to be promising with BP heterosis in desirable direction for days to flowering, and maturity, plant height, pods per plant and 15.4% more yield than the best yield parent, and 2.9% more oil than the best oil parent. This potential can be exploited through use of male sterility gene as suggested by Nelson and Bernard [11] using ms_1 or ms_2, and by Graybosch [13] and Carter et al. [14] with ms_2. These studies have clearly demonstrated that the mean seed yield in excess of 100 seeds per plant can be achieved in the lines carrying ms_2 gene and thus it should be possible to exploit heterosis commercially in soybean.

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