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Research Article

HETEROSIS STUDIES FOR GRAIN YIELD AND ITS RELATED CHARACTERS IN MUNGBEAN (*Vigna radiata* L. Wilczek)

BHAVANI R.T.[1], CHAUHAN R.M.[2], PATEL J.R.[3*], PATEL R.A.[4] AND PATEL DIXITA K.[5]
[1,4]Department of Genetics and Plant Breeding, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, 385 506, Gujarat
[2]Seed Technology Department, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, 385 506, Gujarat
[3]Castor-Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, 385 506, Gujarat
[5]Department of Genetics and Plant Breeding, B. A. College of Agriculture, AnandAgricultural University, Anand, 388110, Gujarat
*Corresponding Author: Email- pateljignesh212@gmail.com

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Abstract- A study was conducted in mungbean (*Vigna radiata* L.) at Department of Genetics and Plant Breeding, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar (Gujarat) to assess the extent of heterosis for thirteen characters including grain yield per plant. Eight lines and four testers were crossed in line × tester mating design to develop 32 F_1 hybrids. The analysis of variance revealed considerable genetic differences among the genotypes. The parents (except plant height and seed per pod), hybrids(except number of branches per plant and protein content) and parents *vs.* hybrids comparisons were significant for days to flowering, days to maturity and pods per plant. A perusal of mean values revealed that the parent MH-521 (13.68 g) was superior in respect of grain yield per plant, whereas among the all hybrids, IPM-02-03 × GM-4 (14.55 g) and GM-9926 × K-851 (14.45 g) recorded maximum grain yield per plant. In the present study, extent of heterosis varied from character to character. The highest standard heterosis for grain yield per plant was registered for the hybrid IPM-02-03 × GM-4 (17.34 %) and GM-9926 × K-851 (16.56 %). Low values of heterosis were observed for days to flowering, days to maturity and protein content, while moderate values of heterosis were recorded for the remaining characters.

Keywords- Line x Tester, Heterosis, Grain yield and Mungbean.

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Introduction

Pulses are basic ingredient in the diets of a vast majority of Indian population as they provide a perfect mix of high biological value protein when supplemented with cereals. Importance of pulses is relatively more in India as its contribution in nutrient supply is greater than Asia and world as a whole. Pulses are also an excellent feed and fodder for livestock. Mungbean (*Vigna radiata* (L.) Wilczek) or green gram is one of the important pulse crop cultivated widely in India, Pakistan, Sri Lanka, Philippines, Taiwan, Nepal, Thailand, Laos, Kampuchea, Vietnam, Indonesia, Eastern Malaysia, South China and in the dry parts of Java. The leading mungbean growing states in India are Rajasthan, Maharashtra, Andhra Pradesh, Karnataka, Orissa, Gujarat and Bihar. Throughout the India, the mungbean is used for different purposes. The major portion is utilized in making dal, curries, soup, sweets and snacks. Moreover, its food values lie in high and easily digestible protein. The grains contain approximately 25-28 per cent protein, 1.0-1.5 per cent oil, 3.5-4.5 per cent fiber, 4.5-5.5 per cent ash and 62-65 per cent carbohydrates on dry weight basis. According to the [1], mungbean is originated in Hindustan and central Asiatic regions. It belongs to the family *fabaceae* with chromosome number 2n = 22. Mungbean is cultivated in about 3.38 million hectares with a total production of 1.61 million tonnes and a productivity of 474 kg/ha in India [2]. Mungbean has established itself as a highly valuable short duration grain legume crop having many desirable characteristics like wider adaptability, low input requirement and ability to improve the soil fertility by fixing atmospheric nitrogen with the help of symbiotic bacteria present in root nodules. Although high degree of heterosis has been reported for mungbean, its commercial exploitation has not been possible because of cleistogamous nature of flower and non-availability of proper sterility mechanisms. The development of pure lines from the variable population is therefore has been the main approach pursued by the plant breeders working on this crop. The yield levels in this crop could be increased by the way of genetic improvement such as incorporation of earliness, uniform maturity, better fertilizer response, photo thermo-insensitivity, high harvest index, wider adaptability and resistance to biotic and abiotic stresses. Study of heterosis provides the basic information regarding the breeding methodology to be employed for the varietal improvement. It also helps in rejecting large number of crosses in first generation itself and selecting only those with high potential. Therefore, the present study was undertaken to study the extent of heterosis for various characters in mungbean.

Materials and Methods

The field experiment was conducted with line × testers set of 8 lines (females) and 4 testers (males)during *kharif* 2012 at Centre of Excellence for Research on Pulses, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar (Gujarat). The experimental material comprising of 44 entries (32 hybrids and 12 parents) were raised in a Randomized Block Design with three replications. Each genotype was sown in single row of 4.0 m length with spacing of 45 x 10 cm. Standard package of practices were followed to raise the crop. Data were recorded on five randomly selected plants in each treatment over replications for 11 characters *viz*., days to flowering, days to maturity, plant height (cm), number of branches per plant, pods per plant, seeds per pod, grain yield per plant (g), 100 seed weight (g), harvest index (%), protein content (%) and methionine content (% in protein).The observations on days to flowering and days to maturity were recorded on plot basis. The mean values for each character were statistically analysed for Randomized Block Design as per [3]. Heterosis expressed as per cent increase or decrease in the mean value of F_1 hybrid over mid parent *i.e.*, relative heterosis [4], over better parent *i.e.*, heterobeltiosis [5] and over standard check (GM-4) *i.e.*, standard heterosis [6] were computed for each character. For the characters *viz.*, days to 50 per cent flowering, days to maturity and plant height, low scoring parents were considered as better parents for the estimation of heterobeltiosis and standard heterosis whereas, high scoring parents were considered as better parents for the rest of the characters.

Results and Discussion

The results obtained under the present investigation are presented in [Table-1-4]. The analysis revealed significant differences in parents for all characters except for plant height and seed per pod indicating considerable amount of variability among the parents for various characters under study. The crosses showed significant differences for all the characters except for number of branches per plant and protein content, which indicate the variability among the crosses for most of the traits. Parent *vs.* hybrid comparisons were significant for days to flowering, days to maturity and pods per plant.

Table-1 *Analysis of variance (mean square) for eleven characters in mungbean*

Source of variation		d.f.	Days to flowering	Days to maturity	Plant height (cm)	No. of branches per plant	Pods per plant	Seeds per pod	Grain yield per plant (g)	100-seed weight (g)	Harvest index (%)	Protein content (%)	Methionine content (% in protein)
Replications		2	1.69	1.23	6.96	0.032	0.73	0.99	1.24	0.22	16.38	0.87	0.00
Genotypes		43	9.86**	20.11**	23.11**	0.38**	234.76**	1.89*	12.48**	0.42**	83.94**	1.39**	0.04**
Parents		11	4.41*	7.66**	6.37	0.68**	241.81**	1.01	10.77**	0.44**	36.48**	2.41**	0.06**
L	**Lines**	7	3.98	9.23**	5.15	0.85**	284.81**	0.67	13.11**	0.32**	38.59**	1.80*	0.07**
ii.	**Testers**	3	4.66	4.67	2.68	0.47	170.73**	0.56	7.05*	0.81**	39.74**	4.60**	0.04**
iii.	**Line vs. Tester**	1	6.72	5.56	25.96*	0.14	154.08**	4.70	5.50	0.10	11.93	0.09	0.05**
iv.	**Parent vs. hybrid**	1	10.87**	23.41**	10.18	0.22	86.88**	0.65	3.43	0.09	29.27	0.06	0.00
v.	**Hybrids**	31	38.67**	54.62**	29.47**	0.28	237.03**	2.24*	13.37**	0.42**	102.55**	1.07	0.03**
Error		86	1.976	2.53	5.07	0.18	7.75	1.20	2.09	0.04	7.66	0.74	0.00

* P ≤ 0.05, ** P ≤ 0.0

Table-2 *Estimates of per cent heterosis over mid parent (MP), better parent (BP) and standard check (SC) for days to flowering, days to maturity, plant height and number of branches per plant*

Sr. No.	Crosses	Days to flowering			Days to maturity			Plant height (cm)			Number of branches per plant		
		MP	BP	SC	MP	BP	SC	MP	BP	SC	MP	BP	SC
1	IPM-02-19 x GM-3	-1.61	0.00	3.39	-3.39	-3.14	-1.07	-0.62	-6.1	-10.64*	1.67	-4.4	-26.21*
2	IPM-02-19 x GM-4	-6.56**	-3.39	-3.39	-6.60**	-5.35	-5.35*	0.51	-7.19	-7.19	4.05	-12.62	-12.62
3	IPM-02-19 x K-851	-1.21	0.83	3.39	-3.14	-2.63	-1.07	18.54**	12.46*	6.09	40.67**	31.87*	2.43
4	IPM-02-19 x Meha	1.98	2.38	9.32**	-1.03	-2.04	2.67	5.85	0.2	-5.02	21.62	15.38	-12.62
5	IPM-02-17 x GM-3	-0.81	0.00	3.39	-4.21*	-3.70	-2.67	14.57**	14.45**	8.92	-17.4	-22.22	-32.04**
6	IPM-02-17 x GM-4	3.31	5.93*	5.93*	-1.60	-1.06	-1.07	-2.86	-5.3	-5.3	-27.46**	-32.04**	-32.04**
7	IPM-02-17 x K-851	-4.49	-3.31	-0.85	-6.60**	-6.35**	-5.35*	-1.72	-2.05	-6.97	2.35	-3.33	-15.53
8	IPM-02-17 x Meha	-2.79	-1.61	3.39	-5.45**	-3.70	-2.67	-2.84	-2.94	-7.81	-3.57	-10	-21.36*
9	GM-9926 x GM-3	-7.20**	-4.92	-1.69	-7.73**	-6.28**	-4.28*	3.65	3.4	-1.12	0.28	-10.78	-11.65
10	GM-9926 x GM-4	-8.94**	-5.08	-5.08	-8.85**	-6.42**	-6.42**	4.51	2.23	2.23	-8.29	-8.74	-8.74
11	GM-9926 x K-851	-6.83**	-4.13	-1.69	.7 49**	-5.79**	-4.28*	9.1	8.36	3.62	7.69	-3.92	-4.85
12	GM-9926 x Meha	-8.24**	-7.87**	-0.85	-8.40**	-8.16**	-3.74	6.88	6.41	1.77	-16.67	-26.47*	-27.18*
13	MH-521 x GM-3	0.41	0.83	3.39	2.65	3.74	3.74	0.94	-0.49	-5.3	-18.99*	-32.20**	-22.33*
14	MH-521 x GM-4	-4.60	-3.38	-3.39	-0.53	-0.53	-0.53	10.28*	6.13	6.13	-18.55*	-23.73 *	-12.62
15	MH-521 x K-851	-1.65	-1.64	0.85	1.33	2.14	2.14	16.62**	15.47**	8.92	-10.1	-24.58 **	-13.59
16	MH-521 x Meha	1.61	4.14	6.78*	3.39	5.88**	5.88**	-3.23	-4.41	-9.39	-23.47*	-36.44**	-27.18*
17	GM-2K-3 x GM-3	-4.38	-1.64	1.69	1.83	2.09	4.28*	11.02*	8.89	3.62	2.89	0.63	-22.33*
18	GM-2K-3 x GM-4	-4.45	0.00	0.00	1.85	3.21	3.21	5.79	1.3	1.3	-17.32	-28.16**	-28.16**
19	GM-2K-3 x K-851	-0.80	2.48	5.08	4.19*	4.74*	6.42**	12.72**	11.03*	4.74	12.82	10	-14.56
20	GM-2K-3 x Meha	0.78	1.57	9.32**	5.15**	4.09*	9.09**	10.45*	8.53	2.88	-1.3	-2.56	-26.21*
21	GM-9924 x GM-3	6.50**	7.38**	11.02**	2.12	3.21	3.21	7.73	4.1	-0.93	0.95	0.63	-22.33*
22	GM-9924 x GM-4	-6.61**	-4.24	-4.24	-6.42**	-6.42**	-6.42**	-7.73	-12.92*	-12.92*	-9.89	-20.39	-20.39
23	GM-9924 x K-851	-0.41	0.83	3.39	-2.39	-1.60	-1.60	-3.45	-6.31	-11.62*	14.47	13.75	-11.65
24	GM-9924 x Meha	2.79	4.03	9.32**	-0.26	2.14	2.14	-10.08*	-12.94*	.17 47**	9.55	8.86	-16.5
25	IPM-02-03 x GM-3	1.20	3.28	6.78*	2.40	4.35*	2.67	-9.78*	-11.23*	-15.52**	7.84	7.5	-16.5
26	IPM-02-03 x GM-4	-8.57**	-5.08	-5.08	-4.04*	-3.26	-4.81*	-13.30**	-16.73**	-16.73**	12.13	-0.39	-0.39
27	IPM-02-03 x K-851	-6.45**	-4.13	-1.69	-5.35**	-3.80	-5.35*	-8.18	-9.26	-14.41**	0	0	-22.33*
28	IPM-02-03 x Meha	1.57	1.57	9.32**	0.00	3.26	1.60	-7.51	-8.82	-13.57*	-7.22	-8.38	-28.83**
29	Pusa-0871 x GM-3	-5.00*	-4.20	-3.39	-6.00**	-3.33	-6.95**	-8	-11.33*	-15.61**	4.79	-5.1	-9.71
30	Pusa-0871 x GM-4	-5.49*	-5.08	-5.08	-6.27**	-4.44*	-8.02**	-12.44*	-17.57**	-17.57**	-1.99	-4.37	-4.37
31	Pusa-0871 x K-851	-2.50	-1.69	-0.85	-4.32*	-1.67	-5.35*	-10.23*	-13.10*	-18.03**	-6.74	-15.31	-19.42
32	Pusa-0871 x Meha	-3.25	-0.01	0.85	.4 79**	-0.56	-4.28*	-6.4	-9.61	-14.31**	-2.27	-12.24	-16.5
	S.Em.±	1.00	1.15	1.15	1.12	1.29	1.29	1.59	1.83	1.83	0.30	0.35	0.35
	Range	-8.94 to 6.50	-7.87 to 7.38	-5.08 to 11.02	-8.85 to 5.15	-8.16 to 5.88	-8.02 to 9.09	-13.30 to 18.54	-17.57 to 15.47	-18.03 to 8.92	-27.46 to 40.67	-36.44 to 31.87	-32.04 to 2.43
	Number of +ve significant	1	2	7	2	4	4	7	4	--	1	1	--
	Number of -ve significant	10	1	--	15	7	11	5	7	12	4	7	13

*** P ≤ 0.05, ** P ≤ 0.01**

In present investigation, several crosses depicted conspicuous heterotic response over mid parental values for different characters. However, apart from indicating genetic interactions, the measure of relative heterosis has relatively less importance than heterobeltiosis. Therefore, it is better to measure the heterosis in terms of superiority over the parent rather than mid parent. However, the commercial usefulness of a hybrid would primarily depend on its performance in comparison with the best commercial variety of the concerned crop species. Overall performance of the hybrids with respect to relative heterosis for yield per plant, yield components and quality parameters [Table-2-4] revealed that seven hybrids, GM-9926 × K-851 (49.78 %), GM-9924 × Meha (44.48 %), GM-9924 × K-851 (43.11 %), IPM-02-19 × Meha (41.52 %), GM-9926 × GM-3 (37.30 %), IPM-02-19 × K-851 (37.12 %) and IPM-02-03 × GM-4 (27.91 %) manifested significant desirable heterosis for grain yield per plant; ten hybrids for days to flowering, fifteen hybrids for days to maturity, five hybrids for plant height; one hybrid for number of branches per plant, nine hybrids for pods per plant, five hybrids for 100-seed weight; nine hybrids for harvest index, two hybrids for protein content and six hybrids for methionine content. It was observed that hybrids which showed significant heterosis for grain yield per plant also possessed desirable heterotic effects for one or more important yield contributing characters like, number of branches per plant, pods per plant, 100-seed weight and harvest index. Similar findings were reported by [7-16].

Table-3 *Estimates of per cent heterosis over mid parent (MP), better parent (BP) and standard check (SC) for pods per plant, seeds per pod, grain yield per plant and 100-seeds weight*

Sr. No.	Crosses	Pods per plant			Seeds per pod			Grain yield per plant (g)			100-seeds weight (g)		
		MP	BP	SC	MP	BP	SC	MP	BP	SC	MP	BP	SC
1	IPM-02-19 x GM-3	20.06*	-1.91	-36.60**	-1.59	-5.59	-7.72	9.58	3.53	-27.42**	-13.18**	-14.83**	-36.47**
2	IPM-02-19 x GM-4	67.39**	17 99**	17 99**	-10.24	-11.25	-11.25	14.64	-6.94	-6.94	3.68	-9.49*	-9.49*
3	IPM-02-19 x K-851	71.38**	21.96**	18.07**	9.47	8.39	5.95	37.12**	17.65	2.47	-0.63	-8.05	-19.37**
4	IPM-02-19 x Meha	59.65**	24.73**	-9.15	2	0.82	-1.45	41.52**	24.41*	2.34	-6.62	-8.82	-28.63**
5	IPM-02-17 x GM-3	-16.42*	-21.05*	-48.97**	12.64	3.77	10.61	-1.08	-6.79	-34.65**	7.6	2.68	-18.90**
6	IPM-02-17 x GM-4	-25.12**	-41.04**	-41.04**	-2.72	-5.73	0.48	-23.41*	-37.96**	-37.96**	-9.73*	-19.22**	-19.22**
7	IPM-02-17 x K-851	-22.82**	-38.50**	-40.46**	8.91	3.41	10.23	-18.97	-30.64**	-39.59**	-1.74	-6.62	-18.12**
8	IPM-02-17 x Meha	-16.22*	-25.05**	-45.41**	6.48	0.94	7.59	-8.63	-19.87	-34.09**	-4.34	-4.77	-24.78**
9	GM-9926 x GM-3	18.78**	17.66*	-22.49**	9.65	1.37	7.23	37.30**	35.77*	-4.81	15.56**	9.61	-12.31**
10	GM-9926 x GM-4	-3.98	-20.36**	-20.36**	-4.06	-6.69	-1.29	19.14	0.4	0.4	-16.08**	-24.47**	-24.47**
11	GM-9926 x K-851	7.03	-10.06	-12.94*	11	5.78	11.9	49.78**	33.83**	16.56	1.78	-2.68	-14.67**
12	GM-9926 x Meha	-28.65**	-32.06**	-50.51**	5.43	0.3	6.11	-10.02	-17.52	-32.15**	-3.96	-5	-24.00**
13	MH-521 x GM-3	-30.01**	-45.50**	-36.79**	15.76	10.19	9.49	-20.04*	-34.61**	-27.88**	-17.09**	-23.26**	-35.29**
14	MH-521 x GM-4	-60.48**	-63.20**	-57.32**	4.77	4.44	4.44	-41.91**	-44.63**	-38.92**	-18.38**	-24.78**	-24.78**
15	MH-521 x K-851	-34.45**	-39.87**	-30.26**	15.26	13.2	12.48	-2.57	-12.82	-3.84	-11.08*	-12.79**	-23.53**
16	MH-521 x Meha	-22.19**	-36.67**	-26.54**	3.3	1.29	0.64	-15.43	-26.18**	-18.58	-19.05**	-21.95**	-34.20**
17	GM-2K-3 x GM-3	-38.40**	-46.04**	-53.61**	4.64	-3.7	2.89	2.25	-9.72	-17.37	52.13**	50.05**	7.69
18	GM-2K-3 x GM-4	-40.55**	-44.72**	-44.72**	1.66	-1.59	5.14	-16.27	-19.81*	-19.81*	13.72**	-3.45	-3.45
19	GM-2K-3 x K-851	-39.51**	-42.89**	-44.72**	-12.42	-16.94*	-11.25	-27.40**	-29.16**	-35.16**	13.84**	2.24	-10.35*
20	GM-2K-3 x Meha	0.54	-7.15	-20.17**	-2.43	-7.61	-1.29	4.35	-0.94	-9.33	16.00**	9.72	-14.12**
21	GM-9924 x GM-3	-30.73**	-32.54**	-53.99**	5.37	-1.13	1.29	1.89	-0.88	-30.51**	2.19	-7.89	-17.65**
22	GM-9924 x GM-4	-3.46	-18.81**	-18.81**	5.97	4.71	7.27	10.8	-7.88	-7.88	-8.24*	-13.10**	-13.10**
23	GM-9924 x K-851	22.54**	4.43	1.1	4.28	0.91	3.38	43.11**	26.02*	9.76	-5.49	-6.4	-16.31**
24	GM-9924 x Meha	46.11**	41.45**	3.03	13.06	9.23	11.9	44.48**	30.46*	7.31	-3.93	-9.91*	-19.45**
25	IPM-02-03 x GM-3	0.35	-0.93	-34.28**	-20.30**	-26.73**	-21.54*	-15.95	-22.67	-35.46**	11.35*	4.19	-14.20**
26	IPM-02-03 x GM-4	26.44**	5.16	5.16	-5.81	-8.92	-2.48	27.91**	17.34	17.34	-2.37	-10.98*	-10.98*
27	IPM-02-03 x K-851	-4.64	-19.65**	-22.21**	-1.74	-6.91	-0.32	-10.26	-12.13	-23.47*	-0.46	-3.49	-15.37**
28	IPM-02-03 x Meha	21.00**	15.61*	-15.80**	-18.73*	-23.12**	-17.68*	3.07	2.32	-14.6	-3.13	-5.52	-22.20**
29	Pusa-0871 x GM-3	-16.67**	-27.12**	-37.11**	4.51	1.35	-3.12	-12.59	-18.41	-34.01**	-0.99	-12.75**	-17.88**
30	Pusa-0871 x GM-4	-18.44**	-24.03**	-24.03**	9.65	7.23	7.23	-5.1	-14.17	-14.17	-19.84**	-22.20**	-22.20**
31	Pusa-0871 x K-851	-43.75**	-46.81**	-48.50**	10.87	10.74	6.11	-10.55	-13.73	-24.87*	-12.77**	-15.75**	-20.71**
32	Pusa-0871 x Meha	-7.87	-15.05*	-26.70**	7.56	7.5	2.77	2.65	1.8	-16.26	-10.10*	-17.67**	-22.51**
	S.Em.±	1.96	2.27	2.27	0.77	0.89	0.89	1.02	1.18	1.18	0.15	0.17	0.17
	Range	-60.48 to 71.38	-63.20 to 41.45	-57.32 to 18.07	-20.30 to 15.76	-26.73 to 13.20	-21.54 to 12.48	-41.91 to 49.78	-44.63 to 35.77	-39.59 to 17.34	-19.84 to 52.13	-24.78 to 50.05	-36.47 to 7.69
	Number of +ve significant	9	6	2	--	--	--	7	5	--	5	1	--
	Number of -ve significant	16	20	26	2	3	2	4	7	14	11	15	30

*** P ≤ 0.05, ** P ≤ 0.01**

The highly significant heterobeltiosis of 33.83 per cent for grain yield per plant was recorded by the hybrid GM-9926 × K-851, which also registered significant sca effect (2.13). Several hybrids registered significant heterobeltiosis in desirable direction for various characters under study *viz.,* grain yield per plant (five hybrids), days to flowering (one hybrid), days to maturity (seven hybrids), plant height (four hybrids), number of branches per plant(one hybrid), pods per plant (six hybrids), 100-seed weight (one hybrid), harvest index (four hybrids) and methionine content (one hybrid). The best three hybrids, GM-9926 × GM-3 (35.77 %), GM-9926 × K-851 (33.83 %) and GM-9924 × Meha (30.46 %) exhibited significant heterobeltiosis for grain yield per plant also manifested significant heterobeltiosis for one or more important yield characters like, number of branches per plant, pods per plant, 100-seed weight and harvest index. The results are in confirmation with those reported by [7-9,11,12,17,18].

The variety, GM-4 released for general cultivation in Gujarat, therefore used as standard variety in order to obtain information regarding superiority of new hybrids over best cultivated variety. A perusal of the results [Table-2 to 4] revealed that hybrids which showed significant heterosis over standard check variety, GM-4 in desired direction *viz.,* eleven hybrids for days to maturity, eleven for plant height, two hybrids for pods per plant and one for harvest index. None of the hybrids however manifested significant desirable standard heterosis for days to flowering, number of branches per plant, seeds per pod, grain yield per plant, 100-seed weight, protein content and methionine content. As observed in the present study several workers have also reported the presence of considerable heterosis for number of branches per plant [11,17]; for pods per plant [18,19]; for harvest index [20].

The low to moderate heterosis observed in present study also been reported by several workers for days to flowering [20]; for protein content [21] and methionine content [21]. In contrast to the findings of the present investigation several workers also reported the considerable heterosis for grain yield per plant [9,11,12,18,19]; for days to maturity [11,20] and for 100-seed weight, [22].

Table-4 *Estimates of per cent heterosis over mid parent (MP), better parent (BP) and standard check (SC) for harvest index, protein content, and methionine content*

Sr. No.	Crosses	Harvest index (%)			Protein content (%)			Methionine content (% in protein)		
		MP	BP	SC	MP	BP	SC	MP	BP	SC
1	IPM-02-19 x GM-3	-11.12	-12.2	-29.54**	-2.73	-3.24	-9.20 **	4.58	-2.38	-8.26**
2	IPM-02-19 x GM-4	13.61*	2.39	2.39	3.37	-0.32	-0.32	-0.86	-10.04**	-10.04**
3	IPM-02-19 x K-851	-2.74	-5.1	-19.95**	-2.54	-4.95	-11.73**	4.12	-4.36	-6.92*
4	IPM-02-19 x Meha	-3.51	-11.73	-14.60*	4.21	2.19	-5.11	5.74*	5.45	-13.62**
5	IPM-02-17 x GM-3	-20.91**	-23.51**	-40.10**	-0.12	-0.61	-6.74*	-1.3	-2.1	-6.47*
6	IPM-02-17 x GM-4	-26.20**	-36.10**	-36.10**	-0.62	-4.15	-4.15	-0.68	-2.9	-2.9
7	IPM-02-17 x K-851	-13.85	-19.57*	-32.16**	6.79*	4.12	-3.27	-21.30**	-22.02**	-24.11**
8	IPM-02-17 x Meha	-16.29*	-26.49**	-28.88**	3.07	1.05	-6.12*	1.38	-5.84*	-10.04**
9	GM-9926 x GM-3	47 47**	42.43**	11.53	1.3	-0.29	-6.44*	-3.87	-5.09	-8.48**
10	GM-9926 x GM-4	18.37**	2.36	2.36	-4.32	-8.68**	-8.68**	-4.77*	-6.47*	-6.47*
11	GM-9926 x K-851	36.00**	26.81**	6.96	-0.24	-1.68	-10.64**	3.69	3.21	0.45
12	GM-9926 x Meha	-10.08	-21.14**	-23.70**	4.79	3.85	-5.61	-6.63*	-13.66**	-16.74**
13	MH-521 x GM-3	-9.47	-13.95	-25.22**	1.5	-1.37	-7.44*	5.58*	3.33	-2.9
14	MH-521 x GM-4	3.75	-3.05	-3.05	1.94	-3.9	-3.9	-26.67**	-30.36**	-30.36**
15	MH-521 x K-851	25.92**	24.07**	7.83	4.18	4.02	-7.90*	-8.46**	-11.93**	-14.29**
16	MH-521 x Meha	22.98**	16.73*	12.93*	2.9	2.48	-8.52**	8.57**	3.72	-6.70*
17	GM-2K-3 x GM-3	12.14	0.17	-0.28	3.42	3.24	-2.78	-12.39**	-16.86**	-21.88**
18	GM-2K-3 x GM-4	1.74	1.51	1.51	-0.14	-3.05	-3.05	-0.48	-8.26**	-8.26**
19	GM-2K-3 x K-851	-8	-15.03*	-15.41*	2.9	-0.32	-6.13*	3.93	-2.98	-5.58*
20	GM-2K-3 x Meha	9.09	7.55	7.07	0.43	-2.19	-7.89*	17.05**	15.34**	-2.68
21	GM-9924 x GM-3	-6.47	-13.17	-20.64**	-5.75*	-8.51**	-8.81**	6.83*	-9.03**	-14.51**
22	GM-9924 x GM-4	-19.39**	-22.86**	-22.86**	-6.44*	-6.59*	-6.59*	-1.61	-18.30**	-18.30**
23	GM-9924 x K-851	11.99	7.67	-1.59	0.02	-5.71	-6.02	13.66**	-4.59	-7 14**
24	GM-9924 x Meha	13.97*	10.82	7.22	-4.93	-9.89**	-10.19**	15.54**	4.36	-14.51**
25	IPM-02-03 x GM-3	-32.05**	-36.66**	-42.61**	0.22	-0.89	-7.00*	-4.46	-5.94*	-11.61**
26	IPM-02-03 x GM-4	-10.32	-14.53*	-14.53*	-4.6	-8.54**	-8.54**	4.44	-0.22	-0.22
27	IPM-02-03 x K-851	16.34*	12.32	1.78	7.60*	5.55	-3.15	1.9	-1.38	-4.02
28	IPM-02-03 x Meha	8.04	4.62	1.22	-0.07	-1.43	-9.56**	-0.9	-5.88*	-14.29**
29	Pusa-0871 x GM-3	11.74	1.2	-2.34	-1.81	-2.81	-6.91*	-0.92	-4.01	-3.79
30	Pusa-0871 x GM-4	4.17	2.34	2.34	-2.17	-4.23	-4.23	-20.40**	-20.49**	-20.31**
31	Pusa-0871 x K-851	12.35*	5.28	1.59	0.02	-3.91	-7.96*	-5.08*	-6.46*	-6.25*
32	Pusa-0871 x Meha	7.56	7.42	3.93	0.09	-3.32	-7.40*	-4.9	-13.59**	-13.39 **
	S.Em.±	1.95	2.26	2.26	0.60	0.70	0.70	0.034	0.039	0.039
	Range	-32.05 to 47.47	-36.66 to 42.43	-42.61 to 12.93	-6.44 to 7.60	-9.89 to 5.55	-11.73 to -0.32	-26.67 to 17.05	-30.36 to 15.34	-30.36 to 0.45
	Number of +ve significant	9	4	1	2	--	--	6	1	--
	Number of -ve significant	5	9	14	2	5	17	8	16	21

* P ≤ 0.05, ** P ≤ 0.01

Conclusion:

Based on mean values it is concluded that the parent MH-521 (13.68 g) was superior in respect of grain yield per plant, whereas among the all hybrids, IPM-02-03 × GM-4 (14.55 g) and GM-9926 × K-851 (14.45 g) recorded maximum grain yield per plant. Further the highest standard heterosis for grain yield per plant was registered for the hybrid IPM-02-03 × GM-4 (17.34 %) and GM-9926 × K-851 (16.56 %) which could be exploited through heterosis breeding programme in future to develop high yielding variety in mungbean.

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Author Contributions:

This work was carried out in collaboration between all authors. Authors BRT and CRM designed the study and wrote first draft of manuscript. Author PRA managed the analysis of the study and performed statistical analysis. Author PJR and PDK reviewed the study and wrote the final draft of the manuscript. All authors read and approved the final manuscript.

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This article does not contain any studies with human participants or animals performed by any of the authors.

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