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Heterosis study for grain yield and yield contributing characters in Mungbean

SB Chavan, DK Patil and VS Pawar

Abstract
The present study on was conducted during *Kharif* 2017 heterosis in respect of following characters *viz.* days to 50% flowering, days to maturity, plant height (cm), number of clusters per plant, number of pods per cluster, number of pods per plant, number of seeds per pod, 100 seed weight (g), pod length (cm), seed yield per plant (g) and protein per cent, involving four lines and five testers and their 20 hybrid combinations with one standard check. The experiment comprised of four female and five male parents and their 20 F_1s hybrid was conducted in randomized block design with two replications. Mean data of genotypes was analyzed as per line x tester mating design while mean data of 30 genotypes (including check and promising hybrids) was used for the estimation of heterosis. The significant heterosis for yield and yield component has been observed in number of pod per plant was recorded by F_1 cross BM 2002-1 x SML 668. While the crosses, BPMR 145 x SML 832 and BM 4 x BWUC 8-1-1 showed high percentage of heterosis for number of cluster per plant, number of pods per cluster and number of pods per plant. Useful heterosis in desirable direction was recorded in all characters except days to 50% flowering and days to maturity. The highest use full heterosis was observed in BPMR 145 x BWUC1-1-1 for number of cluster per plant. The best cross combination BPMR 145 x SML 832 was identified on the basis of mean performance heterosis and estimation of GCA and SCA effects. BPMR 145 x BWUC 10-1-1-2-1 was the best heterotic (201%) cross.

Keywords: Heterosis, contributing characters in Mungbean

Introduction
The word legume is derived from the word ‘Lerge’ which means ‘to gather’ because the pods have to be gathered or picked by hands, as distinct from reaping the cereal crops. Pulses, best known as “poor man’s meat”, constitute the major source of dietary protein of the large section of vegetarian population of the world. On an average, pulses contain 20 to 30 per cent protein, which is almost 2.5 to 3.0 times more than the value normally found in cereals. Besides their high nutritional value, they have a unique characteristic of maintaining and restoring soil fertility through biological nitrogen fixation and thus play a vital role in sustainable agriculture (Asthana, 1998). Besides their high nutritional value, they have a unique characteristic of maintaining and restoring soil fertility through biological nitrogen fixation and thus play a vital role in sustainable agriculture (Asthana, 1998).

Mungbean *Vigna radiata* L. Wilczek, also known as green gram, is an important short duration grain legume with wide adoptability. It is considered to be originated from *Vigna sublobata.* The origin of green gram is supposed to be India (De candolle, 1886; Vavilov, 1926; and Zukoveskij 1962) [6, 21]. Green gram is one of the most important pulse crop extensively grown in India. Among pulses it ranks third after Bengal gram and Red gram. In Maharashtra state, it is second important *kharif* crop grown after Red Gram. Mungbean is well suited to a large number of cropping system and constitutes an important source of cereal based diet. It is mainly utilized in making *dhal*, curries, soup, sweets and snacks. The germinated seed have nutritional value compared with *Asparagus* or mushroom. During sprouting, there is an increase in thiamine, niacin and ascorbic acid concentration. The food values of mungbean lie in its high and easily digestible protein.

India is the largest producer and consumer of pulses in the world accounting for 33 per cent of world area and 22 per cent of world production. In case of Maharashtra area under production is 453.1000 ha (*Kharif* + *Rabi*) Production is about 164.M ha. There is big gap between pulses production and requirement of growing population.

In heterosis breeding programmes, large number of hybrids are produced and evaluated to exploit hybrid vigor, which usually requires more resources and manpower.

It is possible to select the parental lines based on their genetic diversity status to effect limited crosses with better success, if there is a relationship between heterosis for yield and genetic diversity. The present yield potential of improved varieties is not enough to attract the farmers because of relatively smaller seed size, low yield potential and susceptibility to diseases. Study of heterosis in mungbean is an important for the plant breeder to find out the superior crosses in first generation itself.

Material and Methods

The present investigation was carried out during *Kharif* 2017 at experimental field of Agricultural Research Station, Badnapur.

Experimental material

The parents for experiment included five genotypes of mungbean *(Vigna radiata* L. Wilczek) as males and four varieties *viz*. BM 4, BM 2002-1, BM 2003-2 and BPMR 145 as females. Each female was crossed with five selected male genotypes. The testers (males) chosen for study along with their characteristic features are listed in Table. 1

Table 1: List of testers used in the present study with their salient features

Testers	Characteristics of testers
SML 832	PM resistant and suitable for Summer
SML 668	PM Resistant and suitable for Summer
BWUC 10-1-1-2-1-1	Derivatives of interspecific cross. *V. radiata X V. Sylvestis*
BWUC1-1-1	Derivatives of interspecific cross. *V. radiata X V. Sylvestis*
BWUC 8-1-1	Derivatives of interspecific cross. *V. radiata X V. Sylvestis*

Crossing programme

During summer 2017 parental material was planted to undertake crossing programme as per line x tester mating design. Each female line was crossed with each male line and the seed of 20 F_1 hybrids was obtained. The seed of four female lines and five male parent lines was also produced. Finally seeds of 30 entries were utilized for subsequent experiment to be carried out during *Kharif* 2017.

Testing of parents and hybrids

During *kharif* 2017, the hybrids and parental lines with one check were planted in randomised block design with two replications to study the heterosis.

Results and Discussion

The estimates of heterosis (%) for eleven characters over mid parent, better parent and standard check variety *viz.* AKM 4 in Table 2.

1. Days to 50% flowering

Earliness in flowering is highly desirable character in mungbean therefore the cross combination exhibited negative heterosis are considered as superior. The parents requiring less number of days to flower are considered as the better parents in respective cross. Out of 20 crosses, none of the crosses showed significant negative heterosis over mid parent However BM 2003-2 x BWUC 10-1-1-2-1-1 exhibits high negative value (-4.23). Whereas six crosses showed positive significant heterosis for this trait. The range of mid parent heterosis was -4.23% to 27.27%. For mid parent heterosis none of the cross showed negative value.

The range of heterobeltiosis was observed from -2.82% BM 2003-2 x BWUC 10-1-1-2-1-1 to 22.54% BM 4 x BWUC 8-1-1. Out of 20 crosses, no one crosses showed significant negative heterosis over check AKM 4. The range of standard heterosis over check is -4.23% BM 2003-2 x BWUC 10-1-1-2-1-1. To BM2002-1 x SML 832 (37.70%). Such results was also reported by Halkunde (1992) [8], Patil (1992) [16].

2. Days to maturity

As that of flowering, early maturity is desirable in mungbean hence the early maturing parents are considered as better parent and the negative heterosis is desirable for this trait. Out of 20 crosses, no one cross showed significant negative heterosis over mid parent, better parent and standard check. However cross combination BPMR 145 x SML 668 showed negative value (-0.74%) for mid parent better parent heterosis (-2.19%). Whereas three crosses showed positive significant effect in mid parent.

The range of hetrobeltosis ranged from -2.19% (BPMR 145 x SML 668) to 9.16% (BM 2002-1 x SML 832).The range of mid parent heterosis ranged from -0.74% (BPMR 145 x SML 668) to 10.42%. (BM 2002-1 x SML 832). For days to maturity negative significant values are not found mid parent, better parents and check heterosis. However cross combination BPMR 145 x SML 668 (-0.74%) showed negative value for this character. These results are in consonance with the finding of Halkunde (1992) [8], Patil (1992) [16], Kelkar (1993) [13] and Tyagi *et al.* (2006) [20].

3. Plant height

Out of 20 crosses, the per cent heterosis over mid parent ranged from -31.68% (BM 2002-1 x BWUC 8-1-1) to 22.18% (BPMR145 x BWUC 10-1-12-1-1).The crosses *viz.*,(BPMR 145 x SML 832 (21.45%) exhibited highest positive significant heterosis over mid parent. Five crosses shows negative significant effect. Out of 20 crosses, no one crosses showedsignificant positive heterosis over better parent. The range of better parent heterosis was from –43.44% (BM 2002-1x BWUC8-1-1) to 7.23% (BPMR 145 x BWUC 10-1-1-2-1-1).

Standard heterosis over the check AKM 4 ranged from -24.42% (BM 4 x SML 668) 82% to 42.63% (BPMR 145 x SML 832). Out of 20 crosses, one of cross was found negative significant for plant height over the check AKM 4. For plant height the highest positive significant mid parent and Standard heterosis was recorded in cross BPMR 145 x BWUC 10-1-1-2-1-1 (22.18%) and BPMR 145 x SML 832 (42.63%). These results were in agreement with the finding of Halkunde (1992) [8], Patil (1992) [16], Kelkar (1993) [13] and Jahagirdar (2001) [10].

4. Number of cluster per plant

The mid parent heterosis for this character ranged from -34.22% to 61.36%. Out of 20 crosses, six crosses exhibited positive significant mid parent heterosis for this trait. The cross BPMR 145 x BWUC 1-1-1 (61.36%) showed highest positive significant mid parent heterosis fo this trait followed by BPMR 145 x SML 668(60.41%), BPMR 145 x BWUC 10-1-1-2-1-1(58.24%). Out of 20 crosses, the range of better parent heterosis was from –41.27% (BM4 x SML 668) to 59.60% (BPMR 145 x SML 668). The cross BPMR 145 x SML 668 recorded highest significant positive better parent heterosis followed by BPMR 145 x BWUC10-1-1-2-1-1(46.94%).

Standard heterosis over the check AKM 4 ranged from -25.25% (BM 4 x SML 832) to 83.72% (BM 4 x BWUC 8-1-1). Out of 20 crosses, seven crosses found significant positive standard heterosis over the check AKM 4. The cross BM 4 x BWUC 8-1-1 recorded highest significant positive standard heterosis followed by BPMR 145 x BWUC 1-1-1 (82.05%).

For number of clusters per plant the highest positive significant mid parent heterosis recorded in BPMR 145 x BWUC 1-1-1 (61.36%), the highest better parent heterosis observed in BPMR 145 x SML 668 (59.60%), The highest significant positive standard heterosis was recorded in cross combination BM 4 x BWUC 10-1-1-2-1-1 (83.72%). Similar results have also been reported by Halkunde (1992) [8], Patil (1992) [16], Kelkar (1993) [13] and Jahagirdar (2001) [10].

5. Number of pod per cluster

The mid parent heterosis for number of pods per cluster was ranged from -35.75% (BM 4 x SML 832 to11.93% (BM 2003-2 x BWUC 10-1-1-2-1-1). Out of 20 crosses, no one cross exhibited positive significant mid parent heterosis for this trait. The range of better parent heterosis was from –43.64% (BM 4 x SML 832) to 10.89% (BM 2003-2 x BWUC 10-1-1-2-1-1). Out of 20 crosses, none of the cross showed positive significant effect.

Standard heterosis over the check AKM 4 was ranged from –25.28% (BM 4x SML832) to 14.86% (BPMR 145 x BWUC10-1-1-2-1-1). Out of 20 crosses, no one cross found positively significant for this trait.

For number of pods per cluster any cross combinations does not showed mid parent better and standard parent heterosis. However cross combination BM 4 x BWUC 8-1-1 showed highest positively values. (49.06%), (25.40%) and (83.72%). These results were in agreement with the finding of Halkunde (1992) [8], Patil (1992) [16] and Sonawane (1995) [18].

6. Number of pod per plant

Out of 20 crosses, seven crosses exhibited significant positive heterosis over mid parent. BPMR 145 x BWUC 1-1-1(112.29%) showed high positive significant effects followed by BPMR 145x SML 668 (78.32%). The range of mid parent heterosis for number of pod per plant was observed from -16.74% (BM 4x SML832) to 121.29% (BPMR145 x BWUC1-1-1). The range of better parent heterosis was from –29.53% (BM 4 x SML 832) to 113.97% (BPMR 145 x BWUC1-1-1).Out of 20 crosses, 6 crosses recorded significant positive better parent heterosis. The cross BPMR 145 x BWUC (113.97%) exhibited highest heterobeltiosis followed by BPMR 145 x BWUC 10-1-1-2-1-1(72.09%) and BPMR 145 X SML 668 (70.00%)

Standard heterosis over the check AKM 4 ranged from 1.70% (BM 4 x SML 832) to 129.13% (BPMR 145 x BWUC 1-1-1). Out of 20 crosses, 11 recorded significant positive heterosis for this trait among these crosses (BPMR 145 x BWUC 1-1-1) recorded highest useful heterosis followed by crosses BPMR 145 x BWUC 8-1-1(113.97%).

For number pods per plant the highest positively significant mid parent heterosis recorded by BPMR 145 x BWUC 1-1-1 (121.19%) and better parent heterosis (113.97%) and standard heterosis also recorded by this cross combination (129.13%). These results were in agreement with the finding of Kelkar (1993) [13], Jahagirdar (2001) [10] and Patel *et al.*, (2009).

7. Number of seeds per pod

The per cent heterosis over mid parent was ranged from -27.00% (BM 2002-1 x BWUC1-1-1) to 14.93% (BPMR 145 x SML 832). Among 20 crosses, four crosses showed significant positive heterosis over mid parent. The cross BPMR 145 x SML 832 (20.81%) recorded highest significant positive heterosis followed by BM 2003-2 x BWUC1-1-1 (14.16%), BM 2002-1 x SML 832 (14.3%) and BM 4 x BWUC8-1-1(14.1%). Out of 20 crosses, only one cross showed positive significant effect *viz.*, BM 2003-2 x BWUC1-1-1. The range of better parent heterosis was from –29.60% (BM 2002-1 x BWUC1-1) to 13.68% (BM 2003-2 x BWUC 1-1-1).

Standard heterosis over the check AKM 4 was ranged from –24.79% (BM2002-1 x BWUC1-1-1 to 30.10% (BM 2002-1 x SML 832). Among the crosses, eight crosses *viz.*, BM 4 x BWUC 8-1-1 (15.74%), BM 2002-1 x BWUC 8-1-1(14.86%) BM2003-2 x SML 832(20.14%) BM 2003-2 x BWUC 1-1-1(14.66%), BM 2003-2 x BWUC 8-1-1(13.51%) had significant positive standard heterosis over the check AKM 4.

For number of seeds per pod the highest positive significant mid parent heterosis was recorded in BPMR 145 x SML 832 (14.93%) and better parent heterosis in cross BM 2003-2 x BWUC 1-1-1 (13.68%). The highest standard heterosis was a recorded in BPMR 145 x SML 832 (29.59%) Similar results have also been reported by Sonawane (1995) [18], and Srivastava and singh (2013) [19].

8. Pod length

Among the 20 crosses, four crosses showed significant positive heterosis over mid parent. The per cent heterosis over mid parent was ranged from -6.25% (BM 4 x SML 832) to 108.92% (BM 2002-1 x BWUC1-1-1). The crosses (BM 2002-1 x BWUC 10-1-1-2-1-1) 97.78%, (BM2002-1 x BWUC 1-1-1.) and (BM 2003-2 x SML 668) (13.51%), (BM 2003-2 x BWUC 1-1-1) (21.63%), showed positive significant effect. The range of better parent heterosis ranges from -13.14% (BM2002-1 x BWUC 10-1-1-2-1-1) to 97.78% (BM 2002-1 x BWUC 1-1-1. Three crosses showed positive significant effect.

The range of standard heterosis parent heterosis was from -15.25% (BPMR 145 x BWUC 8-1-1) to 97.78% (BM 2002-1 x BWUC 1-1-1). Out of 20 crosses, eight crosses exhibited positive heterobeltiosis out of which (BM 2002-1 x SML 832) (19.57%), (BM 2003-2 x SML 668) (26.51%), (BM 2003-2 x BWUC 10-1-1-2-1-1) (19.20%), (BM 2003-2 x BWUC 1-1-1) (39.93%), (BM 2003-2 x BWUC 8-1-1) (30.32%) recorded highest significant positive heterosis.

For pod length, the highest significant mid parent heterosis, batter parant and standard heterosis was resorded in BM 2002-1 x BWUC 1-1-1 with values 108.92%, 97.78%, 121.39% respectively. This result was in agreement with the finding of Srivastava *et al.*, (2013) [19].

9. Hundred Seed weight

Among the 20 crosses, five crosses showed significant positive heterosis over mid parent. The per cent heterosis over mid parent range was observed from -30.64% (BM 4 x SML 668) to 43.97% (BM 2003-2 x BWUC 10-1-1- 2-1-1). The crosses *viz.*, BPMR 145 X SML 668 (19.85%), BPMR 145 X SML 832 (21.14%) and BM 2002-1 X BWUC 10-1-1-2-1-1 (21.65%) recorded height significant positive heterosis over mid parent. The range of better parent heterosis was from – 27.16% (BM 2002-1 x SML 668) 43.97% to (BM 2003-2 X BWUC 10-1-1-2-1-1) two crosses showed positive significant heterosis over better parent.

Standard heterosis over the check AKM 4 was ranged from -41.64% BM 4 x BWUC 8-1-1 to 43.97% (BM 2003-2 X BWUC10-1-1-2-1-1). Among the crosses, five crosses recorded significant positive standard heterosis.

For 100 seed weight the highest significant mid parent heterosis; better parent heterosis and standard heterosis recorded by BM 2003-2 x BWUC 10-1-1-2-1-1 with (45.30%). (43.97%) and 46.47%). Similar results have also been reported by Halkunde (1992) [8], Patil (1992) [16] and Kelkar (1993) [13]

10. Seed yield per plant

Among the 20 crosses, eleven crosses showed significant positive heterosis over mid parent. The percent heterosis over mid parent for seed yield per plant was ranged from -30.68% (BM 4x SML 668) to 125.56% (BM 2003-2 x BWUC 10-1-1-2-1-1). The crosses BPMR 145 x BWUC10-1-1-2-1-1(109.55%), BM 2002-1 x SML 10-1-1-2-1-1 (86.47%), BPMR145 x BWUC1-1-1 (70.90%) significant positive heterosis over mid parent. The range of better parent heterosis was from -17.49% (BM 4 x SML 832) to 97.66% (BM 2003-2 x BWUC 10-1-1-2-1-1). Out of 20 crosses, seven crosses showed positive heterosis over better parent in seed yield plant out of which BM 2003-2 x BWUC10-1-1-2-1-1(97.96%) exhibited highest positive better parent heterosis followed by BM 2002-1 x BWUC 10-1-1-2-1-1(66.20%) and BM 2002-1 x SML832(62.68%).

Standard heterosis over the check AKM 4 was ranged from -2.82% (BM4 x SML832) to (201.01%) BPMR 145 x BWUC 10-1-1-2-1-1.The crosses BM 2003-2 x BWUC 10-1-1-2-1-1 (162.09%), BPMR 145 x BWUC1-1-1 (55.59%) and BPMR 145 x SML 832 (94.36%) highly significant positive standard heterosis over the check AKM 4.

For seed yield per plant, the highest mid parent heterosis observed in BM 2003-2 x BWUC 10-1-1-21-1 (125.56%) and better parent a heterosis also recorded in similar cross (97.66%) and standard heterosis by BPMR 145 x BWUC 10-1-1-2-1-1 (201.01%). Similar results have also been reported by Halkunde (1992) [8], Patil (1992) [16], Lakshmi *et al.*, (2003) [14], Patel *et al.*, (2009), Srivastava and singh (2013) [19].

11. Protein content (%)

Among the 20 crosses, eight crosses showed significant positive heterosis over mid parent. The per cent heterosis over mid parent was ranged from -25.08% (BM 2002-1 x SML 668) to 33.15% (BM 4 x SML 668.) The crosses BPMR 145 x SML 668) 23.80%, BPMR 145 x BWUC 1-1-1 (21.80%), BM 2002-1 x SML 832 (16.2%) BPMR 145 x SML 832 (15.12%) recorded highest significant positive heterosis over mid parent. The range of better parent heterosis was from -12.73% (BM 2003-2 x SML 832) to 22.89% (BM 4 x SML 668).

Among the 20 crosses, five crosses *viz.* BM 4 x SM L 668 (22.89%), BPMR 145 x SML 668 (20.89%) and BPMR 145 x BWUC1-1-1(16.25%), BPMR 145 x SML 832 (13.74%) showed highest significant positive heterosis over better parent. Standard heterosis over the check AKM 4 ranged from -22.89% (BM 2002-1 x SML 668) to 45.28% (BM4 x SML668).

For protein per cent the highest significant mid parent and better parent and standard heterosis was exhibited by cross combination BM 4 x SML 668 with values (33.15%), (22.89%) and (45.28%). These results were in agreement with the finding of Patil *et al.* (2011) [15] Srivastava and singh (2013) [19].

Conclusion of study

The significant heterosis for yield and yield component has been observed in number of pod per plant was recorded by F_1 cross BM 2002-1 x SML 668. While the crosses, BPMR 145 x SML 832 and BM 4 x BWUC 8-1-1 showed high percentage of heterosis for number of cluster per plant, number of pods per cluster and number of pods per plant.

Useful heterosis in desirable direction was recorded in all characters except days to 50% flowering and days to maturity. The highest use full heterosis was observed in BPMR 145 x BWUC1-1-1 for number of cluster per plant.

The best cross combination BPMR 145 x SML 832 was identified on the basis of mean performance heterosis and estimation of GCA and SCA effects. BPMR 145 x BWUC 10-1-1-2-1 was the best heterotic (201%) cross.

Table 2: Mean values of parents, crosses and check for 11 characters of mungbean

s. No.	prents/crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of cluster/plant	no. of pods/ cluster	no. of pods/ plant	No. of seeds/ pod	Pod length (cm)	100 seed weight (g)	Yield/plant (g)	protein (%)
Lines												
1	BM 4	34.00	65.50	55.00	6.30	5.90	25.40	10.80	6.58	2.73	6.26	18.00
2	BM 2002-1	30.50	64.00	61.00	4.80	4.70	16.40	12.51	9.00	4.81	5.68	20.10
3	BM 2003-2	35.51	65.00	51.72	5.31	4.15	21.00	11.61	9.25	4.42	5.88	21.13
4	BPMR145	36.51	68.50	47.00	4.90	3.71	13.63	12.32	8.85	4.68	8.32	0.18
Testers												
5	SML832	35.50	65.52	34.84	4.50	4.45	17.60	9.81	7.55	4.11	3.43	20.18
6	SML668	33.55	66.51	43.00	4.95	4.40	15.00	14.00	8.30	5.82	5.06	21.18
7	BWUC10-1-1-2-1-1	35.50	3.51	5.50	4.20	4.25	7.21	1.81	7.97	4.80	4.44	20.23
8	BWUC1-1-1	36.55	66.00	43.05	3.91	4.22	12.71	11.71	8.04	5.70	4.47	18.43
9	BWUC8-1-1	35.53	67.00	40.00	4.30	4.40	4.32	11.11	6.61	4.59	4.51	23.24
Crosses												
10	BM 4 x SML832	37.00	69.00	39.25	5.20	3.32	17.91	10.95	6.75	4.39	4.39	21.23
11	M 4 x SML668	37.00	68.51	32.54	3.77	4.44	17.95	12.00	8.00	4.04	4.04	21.65
12	BM 4 x BWUC10-1-1-2-1-	36.00	66.00	50.00	5.80	4.43	25.80	11.44	7.24	4.04	4.08	21.23
13	BM 4 x BWUC1-1-1	40.51	70.52	49.81	4.52	4.85	22.15	11.80	7.86	4.12	4.12	19.39
14	BM 4 x BWUC8-1-1	43.50	71.00	50.00	7.90	4.00	30.35	12.52	7.75	3.62	3.62	20.26
15	M 2002-1 x SML832	42.00	71.51	48.00	4.91	4.25	17.10	12.75	9.05	3.98	3.98	23.71
16	BM 2002-1 x SML668	33.00	66.00	50.41	5.92	3.41	23.6	11.42	8.05	4.28	4.25	15.50
17	BM 2002-1 x BWUC10-1-1-2-1-1-	34.51	65.52	47.43	4.95	3.80	22.47	12.21	7.79	5.26	9.44	22.96
18	BM 2002-1 x BWUC1-1-1	35.50	67.00	32.55	3.62	3.50	18.00	11.88	8.75	5.05	7.77	18.44
19	M 2002-1 x BWUC1-1-1	34.00	65.50	39.53	4.40	3.12	15.30	11.90	10.50	5.80	9.22	21.62
20	BM 2003-2 x SML832	34.00	65.00	34.60	3.90	4.70	22.91	11.81	9.55	5.23	11.65	19.03
21	BM 2003-2 x SML668	34.50	66.51	38.00	4.04	3.98	17.11	13.30	11.25	5.03	6.95	19.48
22	BM 2003-2 X BWUC10-1-1-2-1-1	34.00	65.00	34.60	3.90	4.70	22.9	11.81	9.50	5.01	11.65	19.03
23	BM 2003-2 x BWUC1-1-1	34.50	66.50	38.00	4.04	3.90	17.10	13.30	11.25	5.03	6.60	19.48
24	BM 2003-2 x BWUC8-1-1	36.00	66.50	40.5	6.20	3.90	21.3	12.60	10.36	3.99	10.19	21.18
25	BPMR145 x SML832	35.50	67.00	49.7	6.50	3.30	24.65	12.71	9.13	5.64	10.33	23.63
26	BPMR145 x SML668	35.50	67.00	47.40	7.90	3.80	25.5	12.70	8.83	4.56	11.71	25.72
27	MR145 xBWUC10-1-2-1-1	38.00	67.50	50.40	7.20	4.25	29.60	13.00	9.25	5.73	13.38	18.26
28	BMR145 x BWUC1-1-1	35.00	67.50	48.00	7.10	4.10	29.10	13.2	9.20	5.08	10.90	23.57
29	BMR145 x BWUC8-1-1	36.00	67.51	50.00	6.30	4.10	24.00	12.15	7.50	5.21	9.95	20.03
3o	AKM 4 Check	36.00	65.51	50.30	8.00	5.25	39.4	12.9	9.00	4.21	12.21	22.85
	Mean	35.93	66.76	44.37	5.35	4.15	21.02	12.00	8.82	4.56	7.99	21.02
	S. E. ±	0.86	1.12	3.28	0.49	0.28	2.01	0.48	0.40	0.36	0.80	0.53
	CD at 5%	2.48	3.26	9.49	1.44	0.83	5.81	1.40	1.17	1.04	2.32	1.55

Table 3: Per cent relative heterosis, heterobeltiosis and standard heterosis in mungbean (*Vigna radiata* (L.) Wilczek)

Sr. No.	Crosses	Days to 50% flowering			Days to maturity			Plant height		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
1	BM 4 x SML832	6.47 *	4.23	8.82 *	5.34 *	5.34 *	5.34 *	-12.63	-28.64 **	12.64
2	BM 4 x SML668	9.63 **	8.82 *	10. 45 **	3.79	3.01	4.58	-33.67 **	-40.91 **	-24.42 *
3	BM 4 x BWUC 10-1-1-2-1-1	3.60	1.41	5.88	2.33	0.76	3.94	10.5	-9.09	40.85 **
4	BM 4 x BWUC1-1-1	14.89 **	10.96 **	19.12 **	7.22 **	6.82 *	7.63 **	1.58	-9.45	15.68
5	BM 4 x BWUC 8-1-1	25.18 **	22.54 **	27.94 **	7.17 **	5.97 *	8.40 **	5.26	-9.09	25.00 *
6	BM 2002-1 x SML832	27.27 **	18.31 **	37.70 **	10.42 **	9.16 **	11.72 **	0.16	-21.31 *	37.75 *
7	BM 2002-1 x SML668	3.13	-1.49	8.20	1.15	-0.75	3.13	-3.08	-17.38 *	17.21
8	BM 2002-1 x 10-1-1-2-1-1-	4.55	-2.82	13.11 **	2.75	2.34	3.15	-1.76	-22.30 **	33.52 *
9	BM 2002-1 x BWUC1-1-1	5.97	5.97	16.39 **	0.00	-1.52	1.56	-27.92 **	-38.52 **	-12.89
10	BM 2002-1 x BWUC8-1-1-	9.09 *	9.09 *	18.03 **	0.76	-1.49	3.13	-31.68 **	-43.44 **	-13.75
11	BM 2003-2 xSML832	0.00	0.00	0.00	2.68	2.29	3.08	-24.89 *	-37.14 **	-6.73
12	BM 2003-2 x SML668	-1.45	-1.45	1.49	-0.38	-1.50	0.77	-16.58	-23.60 *	-8.14
13	BM 2003-2 x BWUC 10-1-1-	-4.23	-4.23	-4.23	1.17	0.00	2.36	-20.64 *	-33.08 **	-2.54
14	BM 2003-2xBWUC1-1-1	-4.17	-4.17	-2.82	1.53	0.76	2.31	-19.79 *	-26.50 **	-11.73
15	BM 2003-2x BWUC 8-1-1	1.41	1.41	1.41	0.76	-0.75	2.31	-11.67	-21.66 *	1.25
16	BPMR145 xSML832	-1.39	-1.39	0.00	0.00	-2.19	2.29	21.45 *	5.74	42.63 **
17	BPMR145 x SML668	1.43	1.43	5.97	-0.74	-2.19	0.75	5.33	0.85	10.23
18	BPMR145 x BWUC10-1-1-2-1-1	5.56	5.56	7.04	2.27	-1.46	6.30 *	22.18 *	7.23	41.97 **
19	BPMR145 xBWUC1-1-1	-4.11	-4.11	-4.11	0.37	-1.46	2.27	6.61	2.13	11.5
20	BPMR145 x BWUC 8-1-1	0.00	0.00	1.41	-0.37	-1.46	0.75	14.94	6.38	25.00 *
	CD at 5%	2.54	2.54	2.57	2.94	3.40	3.40	8.56	9.88	9.88
	CD at 1%	3.44	3.47	3.47	24.02	4.64	4.64	11.70	13.51	13.51

* and ** indicates significance at 5 and 1 per cent level respectively

Table 4: Per cent relative heterosis, heterobeltiosis and standard heterosis in mungbean (*Vigna radiata* (L.) Wilczek)

Sr. No.	Crosses	No. of clusters / plant			No. of pod/cluster			No. of pod/plant		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
1	BM 4 x SML832	-3.70	-17.46	15.56	-35.75 **	-43.64 **	-25.28 *	-16.74	-29.53 *	1.70
2	BM 4 x SML668	-34.22 **	-41.27 **	-25.25	-14.56	-25.42 **	0.00	-11.14	-29.33 *	19.67
3	BM 4 x BWUC 10-1-1-2-1-1	10.48	-7.94	38.10 *	-12.71	-24.92 **	4.24	21.13	1.57	50.00 **
4	BM 4 x BWUC1-1-1	-11.76	-28.57 *	15.38	-3.96	-17.80 *	15.48	16.27	-12.8	74.41 **
5	BM 4 x BWUC 8-1-1	49.06 **	25.40 *	83.72 **	-22.33 **	-32.20 **	-9.09	52.90 **	19.49	112.24 **
6	BM 2002-1 x SML832	5.38	2.08	8.89	-7.10	-9.57	-4.49	0.59	-2.84	4.27
7	BM 2002-1 x SML668	21.03	19.19	22.92	-25.27 **	-27.66 **	-22.73 *	50.32 **	43.90 *	57.33 **
8	BM 2002-1 x 10-1-1-2-1-1-	10.00	3.12	17.86	-15.08	-19.15 *	-10.59	33.33 *	30.23	36.59 *
9	BM 2002-1 x BWUC1-1-1	-1.15	-10.42	10.26	-13.48	-18.09	-8.33	11.34	-1.22	27.56
10	BM 2002-1 x BWUC8-1-1	14.29	8.33	20.93	-6.59	-9.57	-3.41	11.4	4.27	19.58
11	BM 2003-2 x SML832	-26.02	-31.60 *	-19.44	-18.60 *	-21.35 *	-15.66	-6.74	-14.29	2.27
12	BM 2003-2 x SML668	-14.15	-16.98	-11.11	-26.90 **	-28.98 **	-24.70 *	-15	-27.14	2.00
13	BM 2003-2 x BWUC10-1-1-2-1-1	-17.89	-26.42	-7.14	11.93	10.59	13.25	19.9	9.05	33.14
14	BM 2003-2 x BWUC1-1-1	-12.07	-23.68	3.72	-6.59	-7.14	-6.02	1.48	-18.57	34.65
15	BM 2003-2 x BWUC8-1-1	29.17 *	16.98	44.19 *	-8.77	-11.36	-6.02	20.68	1.43	48.95 *
16	BPMR145 x SML832	38.30 **	32.65 *	44.44 *	-19.02 *	-25.84 *	-10.81	58.01 **	40.06 *	81.25 **
17	BPMR145 x SML668	60.41 **	59.60 **	61.22 **	-6.17	-13.64	2.70	78.32 **	70.00 **	87.50 **
18	BPMR145 x BWUC10-1- 1-2-1-1	58.24 **	46.94 **	71.43 **	6.92	0.00	14.86	92.21 **	72.09 **	117.65**
19	BPMR145 x BWUC 1-1-1	61.36 **	44.90 **	82.05 **	3.80	-2.38	10.81	121.29 **	113.97 **	129.13**
20	BPMR145 x BWUC 8-1-1	36.96 *	28.57	46.51 *	1.23	-6.82	10.81	72.04 **	67.83 **	76.47 **
	at 5%	5.56	9.88	9.88	0.75	0.87	0.87	5.02	5.79	7.92
	CD at 1%	11.70	13.51	13.51	1.03	1.19	1.19	6.86	5.92	7.92

* and ** indicates significance at 5 and 1 per cent level respectively.

Table 5: Per cent relative heterosis, heterobeltiosis and standard heterosis in mungbean (*Vigna radiata* (L.) Wilczek)

Sr. No.	Crosses	No. of seeds /pod			Pod length			100 seed weight		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
1	BM 4 x SML832	6.31	1.39	11.73	-6.25	-10.60	-1.46	5.40	4.15	6.68
2	BM 4 x SML668	-3.23	-14.29 **	11.11	5.61	-3.61	16.79	-19.52*	-30.64 **	-4.15
3	BM 4 x BWUC 10-1-1-2-1-1	0.88	-3.39	5.56	-2.29	-9.16	5.69	-10.37	-15.83	-4.15
4	BM 4 x BWUC1-1-1	4.89	0.85	9.26	5.64	-2.18	14.82	-16.79	-27.63 **	-2.14
5	BM 4 x BWUC 8-1-1	14.10*	12.61	15.74 *	15.16	13.14	17.25	-30.46**	-41.63 **	-14.00
6	BM 2002-1 x SML832	14.3*	2.00	30.10**	9.37	0.56	19.87 *	25.33**	9.55	46.42 **
7	BM 2002-1 x SML668	-13.9**	-18.57 **	-8.80	-6.94	-10.56	-3.01	10.91	7.81	14.18
8	BM 2002-1 x 10-1-1-2-1-1-	0.41	-2.40	3.39	-8.19	-13.44 *	-2.26	21.65 *	13.91	30.52 **
9	BM 2002-1 x BWUC1-1-1	-27.**	-29.60**	-24.79**	108.92**	97.78 **	121.39 **	30.63**	-31.84**	-29.36**
10	BM 2002-1 x BWUC8-1-1	8.05	2.00	14.86 *	12.11	-2.78	32.38 **	3.76	-2.17	10.45

11	BM2003-2x SML832	10.28	1.72	20.24**	4.17	-5.41	15.89	12.27	3.37	22.84
12	BM 2003-2 x SML668	-7.03	-15.0**	2.59	19.66 **	13.51 *	26.51 **	8.35	-0.34	18.71
13	BM 2003-2 x BWUC10-1-1-2-1-1	0.98	0.13	1.85	10.34	2.70	19.20 *	45.30 **	43.97 **	46.67 **
14	BM 2003-2 x BWUC1-1-1	14.16 *	13.68*	14.66 *	30.13 **	21.62**	39.93 **	-5.00	-11.75	2.86
15	BM 2003-2 x BWUC8-1-1	11.01	8.62	13.51 *	30.71 **	12.05	56.81 **	12.16	0.24	27.30 *
16	BPMR145 x SML832	14.93 *	3.25	29.59 **	11.34	3.16	20.93 *	21.14 *	8.45	37.18 **
17	BPMR145 x SML668	-3.42	-9.29	3.25	2.97	-0.23	6.39	19.85 *	13.48	26.99 **
18	BPMR145 x BWUC10-1-1-2-1-1	7.88	5.69	10.17	9.99	4.52	16.06 *	14.54	10.09	19.37
19	BPMR145 x BWUC 1-1-1	10	7.32	12.82 *	9.53	4.52	15.05 *	-6.83	-10.88	-2.40
20	BPMR145 x BWUC8-1-1	3.85	-1.22	9.46	-2.98	-15.25*	13.46	4.95	-3.54	15.08
	CD at 5%	1.26	1.45	1.45	1.04	1.20	1.20	0.88	1.02	1.02
	CD at 1%	1.72	1.99	1.99	1.42	1.64	1.64	1.21	1.40	1.40

*and ** indicates significance at 5 and 1 per cent level respectively.

Table 6: Per cent relative heterosis, heterobeltiosis and standard heterosis in mungbean (*Vigna radiata* (L.) Wilczek)

Sr. No.	Crosses	Seed yield / Plant			Protein (%)		
		RH	HB	SH	RH	HB	SH
1	BM 4 x SML832	-10.76	-17.49	-2.82	9.49 *	2.17	17.94 **
2	BM 4 x SML668	-30.68	-34.01	-27.00	33.15 **	22.89 **	45.28 **
3	BM 4 x BWUC 10-1-1-2-1-1	33.96	14.54	61.30 *	11.08 **	4.94	17.97 **
4	BM 4 x BWUC1-1-1	14.39	-1.92	37.21	6.45	5.21	7.72
5	BM 4 x BWUC 8-1-1	29.91	28.54	31.31	-1.76	-12.84 **	12.56 **
6	BM 2002-1 x SML832	68.08 **	62.68 **	73.85 **	16.02 **	14.12 **	17.99 **
7	BM 2002-1 x SML668	14.40	4.12	26.94	-25.08 **	-27.16 **	-22.89 **
8	BM 2002-1 x 10-1-1-2-1-1-	86.47 **	66.20 **	112.37 **	13.85 **	13.47 **	14.23 **
9	BM 2002-1 x BWUC1-1-1	36.09	21.65	54.41 *	0.44	-3.73	4.99
10	BM 2002-1 x BWUC8-1-1	30.10	22.83	38.29	-0.8	-7.51 *	6.97
11	BM 2003-2 x SML832	38.84 *	32.12	46.28 *	-12.00 **	-12.73 **	-11.26 **
12	BM 2003-2 x SML668	43.95 *	33.14	56.67 **	1.98	1.62	2.34
13	BM 2003-2 x BWUC10-1-1-2-1-1	125.56 **	97.96 **	162.09 **	-7.97 *	-9.91 *	-5.93
14	BM 2003-2 x BWUC1-1-1	34.17	18.1	55.31 *	-1.49	-7.79 *	5.72
15	BM 2003-2 x BWUC8-1-1	66.04 **	59.42 **	73.24 **	-4.52	-8.86 *	0.26
16	BPMR145 x SML832	51.47 **	24.08	94.36 **	15.12 **	13.74 **	16.54 **
17	BPMR145 x SML668	53.57 **	40.66 **	69.10 **	23.80 **	20.89 **	26.85 **
18	BPMR145 x BWUC10-1-1-2-1-1	109.55 **	60.72 **	201.01 **	-9.84 **	-9.94 *	-9.74 *
19	BPMR145 x BWUC 1-1-1	70.39 **	30.99 *	143.69 **	21.80 **	16.25 **	27.92 **
20	BPMR145 x BWUC 8-1-1	35.19 *	19.52	55.59 **	1.23	-5.23	8.63 *
	CD at 5%	2.07	2.39	2.39	1.39	1.61	1.61
	CD at 1%	2.83	3.27	3.27	1.90	2.20	2.20

* and ** indicates significance at 5 and 1 per cent level respectively

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