The Bioscan 13(1):89-94,2018
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.com

HETEROSIS STUDIES FOR YIELD AND YIELD COMPONENTS IN GREENGRAM [*Vigna radiata* (L.) Wilczek]

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KEYWORDS
Mungbean
Heterosis
Diallel analysis
Yield components

Received on :
28.06.2017

Accepted on :
07.05.2017

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ABSTRACT

Twenty eight hybrids of greengram along with their eight parental lines in 8 x8 half diallel fashion excluding reciprocal crosses were studied to assess the extent of heterotic effects over mid and better parent for yield and nine component characters. Out of 28 F1 hybrids, two crosses BM-4 x PDM-139 and RMG-1035 x RMG-1045 showed superior *per se* performance with significant positive heterosis for seed yield and most of the yield contributing characters. IPM 99-125 X ML 131 exhibited high heterosis for100 seed weight and harvest index, where as cross RMG 344 X RMG -1045 showed excellent heterosis for plant height and pods per cluster. Based on heterotic studies, the best direct yield contributing character were pods per cluster, pods per plant, plant height, 100 seed weight and harvest index. These hybrids could be utilized for developing high yielding mungbean cultivars.

INTRODUCTION

Pulses constitute an important ingredient of the vegetarian diet in the Indian sub-continent and play a significant role in Indian farming because of their value in providing quality food to teeming million and restoring soil fertility through biological nitrogen fixation. Green gram [*Vigna radiata* (L.) Wilczek) (2n = 2 x = 22.) family Leguminaceae, subfamily Papillionaceae; most important pulse crop in India after chickpea and pigeonpea. It is an outstanding source of easily palatable protein containing about 24 per cent proteins (Yadav and Lavanya, 2011) with all essential amino acids, which is almost three times more than that of cereals (Saini *et al.,* 2010). Among various pulse crops grown in India, green gram is grown on an area of 2.75 million hectares with production 1.19 million tonnes and productivity of 436 kg/ha. Maharashtra, Rajasthan, Madhya Pradesh, Bihar, Punjab and Andhra Pradesh are the leading producers of green gram. In Rajasthan, it was grown on 965.6 thousand hectares with a production status of 453.6 thousand tonnes and yield of 470 kg/ha (Commissionerate of Agriculture, Rajasthan-Jaipur. 2015-16). The country has experienced progressive decline in per capita availability of pulses per day from 70.3 g in 1956 to 41.9 g in 2014 (Agril. Statistics at a glance, 2014). This decline is mainly due to low yield potential, smaller grain size and high susceptibility to various abiotic and biotic stresses. It generally felt that there is an urgent need to break the bottleneck for increasing productivity of this crop and have to hit out the superior crosses by utilization of heterosis (Srivastava and Singh, 2013). For any successful breeding programme to improve grain yield and component characters, it is essential to know precisely the genetic architecture of these characters under prevailing conditions. It is very much essential to measure the extent of genetic dissimilarity among the parental lines involved in hybridization programmes for exploitation of heterotic vigour because high genetic dissimilarity among parental lines exhibits high heterotic response (Moll and Stuber, 1976).Serious attention is required to develop high yielding varieties of green gram using various crop breeding techniques. Exploration of heterosis on commercial scale in major field crops has increased both production and productivity per unit area of land. In many cross pollinated species like maize, cotton, onion, alfalfa and some vegetables, heterosis has been successfully commercially exploited (Singh *et al.,* 2007). Green gram being a highly self pollinated crop, utility of heterosis *per se* may not be of much use, so the production of economically viable hybrid in green gram still remains a challenge to breeders, but cross combinations showing good heterosis involving parents with high general combining ability can be used in developing high yielding pure lines. The study of heterosis will provide 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. In short the study of heterosis helps the plant breeder in eliminating the less productive crosses in early generations. Now a days, it has been mandatory to exploit heterosis in self pollinated crops like pulses for enhancing crop productivity. In pulses, a number of researchers exploited heterosis appreciably for various characters, including yield contributing traits (Ghafoor *et al.*, (1990); Gupta *et al.,* 2006 and Adeyanju, 2009). Selection of parental cross combinations should be exploited on the basis of manifestation of heterosis for varietal improvement (Zubair *et al.*, 2010). The objective of this experiment was to estimate the magnitude of heterosis for grain yield and its component characters and to elucidate the gene action and to identify suitable parents and crosses for future breeding programme. In short, the aim of the present study in green gram is to spot out cross combination which might generate desired segregants in the succeeding generations.

MATERIALS AND METHODS

The experimental material for the present investigation comprised of 36 entries including 8 parents and their 28 F_1 crosses. Eight homozygous namely IPM-99-125, BM-4, ML-131, IPM 02-03, PDM-139, RMG-1035, RMG-344 and RMG-1045 but highly diverse and well adapted genotypes of green gram were selected as parents for crossing programme (Table 1.). These parents and F_1s were grown in randomized block design with three replications during *kharif*, 2014 at Department of Plant Breeding and Genetics, Rajasthan College of Agriculture, MPUAT, Udaipur. Cross success percentage was very less in open field at normal environmental condition, therefore crosses were attempted at green house during *spring*, 2013-14 in diallel fashion (excluding reciprocals) to obtain 28 F_1 crosses. Sowing was done by dibbling the seeds at a distance of 10 cm in the rows of 2 m length with row to row spacing of 30 cm. Non-experimental rows were planted around the layout to eliminate border effects. A basal dose of 20 kg N and 40 kg P_2O_5 ha-1 was applied at sowing time. All recommended cultural practices and plant protection measures were adopted to raise a good crop. The data on ten randomly selected competitive plants in 8parents and 28 F_1s per treatment per replication were recorded for nine quantitative traits *viz.*, days to 50% flowering, secondary branches per plant, plant height, clusters per plant, pods per cluster, pods per plant, 100 seed weight, seed yield per plant and harvest index . The averaged data was statistically analyzed and analysis of variance was worked out according to Fisher and Yates (1938). Per cent increase or decrease of F_1 over the mid parent referred as relative or average heterosis, while heterobeltiosis (Fonseca and Patterson, 1968) denotes the increase or decrease of F_1 over the better parent and economic heterosis defined as the increase or decrease of F_1 over the best parent.

RESULTS AND DISCUSSION

The commercial exploitation of heterosis in crop plant is

Table 1: Name, pedigree and source of the parents used for research work

Parent	Pedigree	Source
IPM 99-125	PM 3 x APM 36	IIPR, Kanpur
BM 4	MUTANT of T44	ARS, Badnapur
ML 131	ML 1 x ML 23	ARS, Durgapura
IPM 02-03	IPM 99-125 x Pusa bold 2	IIPR, Kanpur
PDM 139	ML 20/19 x ML 5	IIPR, Kanpur
RMG 1035	RMG 492 x ML 818	ARS, Durgapura
RMG 344	MOONG SEL.1 x J 45	RAU, Durgapura
RMG-1045	RMG-62 x KM 2170	RAS, Durgapura

Table 2: Eight superior heterotic crosses for seed yield and its component traits

Superior heterotic crosses	Significant heterosis over mid parent (MP) and better parent (BP) for seed yield and its component traits
RMG 1035 X RMG 1045	Days to 50% flowering, seed yield per plant, plant height, secondary branches per plant, biological yield
BM-4 X PDM 139	Seeds per pod, pods per plant and seed yield per plant
IPM 02-03 X RMG-1045	Days to 50% flowering, maturity, plant heightand pods per plant
IPM 99-125 X ML 131	100 seed weight, harvest index, days to 50% flowering
RMG 344 X RMG -1045	Plant height, pods per cluster, pods per plant, and harvest index
ML131 X PDM 139	Plant height and days to 50% flowering
ML 131 X RMG-1045	Days to 50% flowering, plant height, primary branches per plant, and pod length
M1L31 X RMG 344	Days to 50% flowering and plant height

Table 3: Analysis of variance showing mean squares for nine characters in Green gram

S. No	Characters	Rep [2]	Genotype [35]		Parent [7]		F1 [27]	P vs F1	Error [1]	[70]
1	Days to 50 % flowering	19.06	18.81	**	35.30	**	15.21	*	0.57	7.82
2	Plant height	77.49*	244.46	**	67.30	**	262.38	**	1000.66**	22.23
3	Secondary branches / plant	1.06	1.66	**	1.35	**	1.80	**	0.06	0.43
4	Clusters / plant	0.62	1.35	**	0.69	*	1.57	**	0.02	0.55
5	Pods / cluster	0.05	0.34	**	0.32	**	0.34	**	0.60**	0.07
6	Pods / plant	5.58	131.66	**	209.25	**	100.21	**	437.59**	5.00
7	100 Seed weight	0.11	1.36	**	0.66	**	1.49	**	2.94**	0.16
8	Seed yield / plant	1.89	4.57	**	9.31	**	3.49	**	0.25	0.69
9	Harvest index	21.11	44.65	**	76.78	**	37.97	**	0.26	9.51

Table 4: Grand Mean, Mean ± SE(m) and range of nine characters in parents and F1 in green gram

S.No	Characters	GM	Parents		F_1s	
			Mean ± SE(m)	Range	Mean ± SE(m)	Range
1	Days to 50% flowering	39.71	39.84 ± 2.33	33.16-44.24	39.67 ± 2.33	35.38-43.53
2	Plant height	51.00	46.41 ± 2.72	39.58 - 54.00	53.73 ± 2.72	34.18 - 66.72
3	Secondary branches / plant	7.05	7.01 ± 0.55	5.93-7.70	7.06 ± 0.55	5.08-8.03
4	Clusters / plant	7.13	7.12 ± 0.62	6.39-7.77	7.13 ± 0.62	5.51-8.08
5	Pods / cluster	3.39	3.63 ± 0.15	2.93 - 3.97	3.45 ± 0.15	2.83 -3.96
6	100 Seed weight	3.94	4.38 ± 0.23	3.41 - 5.08	3.98 ± 0.23	3.2 - 6.13
7	Pods / plant	18.14	22.37 ± 1.29	10.96 - 33.04	17.53 ±1.29	9.29 - 33.18
8	Seed yield / plant	11.41	11.32 ± 0.70	3.27-4.68	11.44 ± 0.70	3.27-6.13
9	Harvest index	28.53	28.44 ± 2.58	22.82-38.43	28.56 ± 2.58	22.82-36.89

Table 5: Mean (%) and range of Heterosis, Heterobiosis and Economic heterosis for nine characters in green gram

Characters	Heterosis		Heterobiosis		Economic heterosis	
	Mean	Range	Mean	Range	Mean	Range
Days to 50 % flowering	-0.29	-9.35 - 9.94	-5.10	-14.11 - 2.58	-10.32	-20.02 - (-)2.60
Plant height	16.78	-34.56 - 59.90	25.4	8.01 - 52.07	12.88	2.16 - 23.56
Secondary branches / plant	0.76	-21.56 - 20.24	-4.43	-27.85 -18.38	-8.3	-34.10 -4.28
Clusters / plant	0.04	-21.14 - 14.46	-3.73	-26.03 - 14.43	-8.25	-29.04 - 4.08
Pods / cluster	-4.53	-25.72 - 17.23	4.32	0.46 - 6.63	(-)	(-)
Pods / plant	-14.00	-61.31 - 183.24	81.55	5.32 - 166.19	0.41	0.41
100 Seed weight	-9.40	-25.00 - 41.28	25.85	4.21 - 40.52	18.05	15.49 - 20.60
Seed yield / plant	-0.48	-19.85 - 9.93	8.07	-27.47 - 4.60	-16.05	-35.68 - 3.95
Harvest index	1.24	-31.22 - 37.14	7.42	-40.63 - 32.39	-25.70	-40.63 - (-)4.02

Table 6: Extent of heterosis for Days to 50% flowering, Plant height and secondary branches per plant

Crosses	Days to 50% flowering			Plant height			Secondary branches / plant		
	Het	Hb	EH	Het	Hb	EH	Het	Hb	EH
IPM 99-125 * BM-4	5.28	2.57	-2.61	-30.71**	-	-	4.99	4.28	4.28
IPM 99-125 * ML-131	-4.67	-7.86	-12.51*	-34.5**	-	-	-2.29	-2.76	-4.07
IPM 99-125 * IPM-02-03	9.94	-1.63	-6.60	4.19	-	-	-4.47	-8.11	-9.35
IPM 99-125 * PDM-139	-0.47	-0.82	-5.82	-9.33	-	-	4.51	-0.31	-1.64
IPM 99-125 * RMG-1035	-2.21	-4.68	-4.68	-8.42	-	-	-18.91**	-27.85**	-28.82
IPM 99-125 * RMG-344	3.27	2.58	-2.60	-5.91	-	-	-1.12	-3.29	-4.59
IPM 99-125 * RMG-1045	-8.85	-14.11*	-18.44**	-0.25	-	-	8.70	-1.93	-3.25
BM-4 * ML-131	-6.63	-7.39	-16.58**	-3.5	-	-	4.27	3.07	3.07
BM-4 * IPM-02-03	-0.75	-9.08	-18.11**	19.39*	16.15	-	3.55	-1.04	-1.04
BM-4 * PDM-139	3.23	0.92	-4.84	-13.49	-	-	9.38	3.68	3.68
BM-4 * RMG-1035	-8.99	-13.51*	-13.51*	-3.52	-	-	-7.29	-18.00*	-18.00
BM-4 * RMG-344	-9.35	-11.10	-16.71**	12.19	11.55	-	4.83	1.86	1.86
BM-4 * RMG-1045	-3.77	-7.01	-16.24**	48.68**	37.77**	18.35*	2.39	-8.18	-8.18
ML-131 * IPM-02-03	8.32	-0.02	-11.42*	28.87**	16.79*	16.79*	-0.14	-3.50	-5.71
ML-131 * PDM-139	-6.94	-9.75	-14.90**	25.78**	13.43	13.43	8.96	4.43	2.03
ML-131 * RMG-1035	-0.36	-6.04	-6.04	32.23**	21.01**	21.01**	-12.52	-21.83**	-23.63
ML-131 * RMG-344	-6.18	-8.73	-14.49**	15.58*	8.01	8.01	-0.23	-1.95	-4.20
ML-131 * RMG-1045	2.86	0.20	-11.23*	31.93**	14.32*	14.32*	0.39	-9.03	-11.12
IPM-02-03 * PDM-139	9.66	-1.58	-7.20	35.72**	34.96**	9.66	6.08	5.18	-4.15
IPM-02-03 * RMG-1035	5.43	-7.77	-7.77	43.94**	42.39**	18.23*	-21.56**	-27.68**	-34.10
IPM-02-03 * RMG-344	8.71	-2.16	-8.33	40**	35.45**	17.7*	-2.75	-4.40	-9.82
IPM-02-03 * RMG-1045	0.63	-4.79	-20.02*	59.9**	52.07**	23.56**	5.03	-1.76	-10.47
PDM-139 * RMG-1035	-2.95	-5.72	-5.72	20.68**	18.74*	-	-0.60	-7.63	-17.27
PDM-139 * RMG-344	0.01	-0.31	-6.00	24.53**	19.84*	4.14	9.22	6.47	0.43
PDM-139 * RMG-1045	2.63	-2.97	-8.51	37.12**	31.1**	5.34	-3.02	-8.55	-18.09
RMG-1035 * RMG-344	-6.86	-9.80	-9.80	20.24**	17.57*	2.16	-8.21	-16.70*	-21.42
RMG-1035 * RMG-1045	-3.57	-11.29*	-11.29*	37.18**	29.14**	7.22	20.24*	18.38*	-6.06
RMG-344 * RMG-1045	4.54	-0.86	-7.12	41.44**	30.37**	13.28	11.96	3.07	-2.77

regarded as one of the major breakthrough in the field of plant breeding. Use of heterosis on commercial scale in major field crops has increased both production and productivity per unit area of land. The analysis of variance for experimental design was performed for nine quantitative characters (Table 3.). It revealed significant differences for all the characters

Table 7: Extent of heterosis for clusters per plant, pods per cluster and pods per plant

Crosses	Clusters / plant			Pods/ cluster			Pods / plant		
	Het	Hb	EH	Het	Hb	EH	Het	Hb	EH
IPM 99-125 * BM-4	5.45	3.30	3.30	-1.52	-	-	-8.18	-	-
IPM 99-125 * ML-131	-0.27	-0.93	-3.69	-16.58**	-	-	-50.33**	-	-
IPM 99-125 * IPM-02-03	0.07	-2.24	-6.22	-6.51	-	-	-4.83	-	-
IPM 99-125 * PDM-139	8.47	5.64	1.33	-25.72**	-	-	-54.90**	-	-
IPM 99-125 * RMG-1035	-21.14**	-26.03**	-29.04**	6.95	6.32	-	-49.75**	-	-
IPM 99-125 * RMG-344	1.88	-0.76	-4.80	11.40*	0.46	-	-49.54**	-	-
IPM 99-125 * RMG-1045	3.68	-3.71	-7.64	-3.62	-	-	-53.67**	-	-
BM-4 * ML-131	4.98	3.52	3.52	-12.68**	-	-	-27.62**	-	-
BM-4 * IPM-02-03	-4.48	-8.54	-8.54	-14.27**	-	-	183.24**	166.19**	0.41
BM-4 * PDM-139	5.57	0.77	0.77	-10.44*	-	-	8.47*	-	-
BM-4 * RMG-1035	2.47	-5.71	-5.71	5.28	3.49	-	-22.91**	-	-
BM-4 * RMG-344	6.40	1.59	1.59	17.23**	3.58*	-	-12.53	-	-
BM-4 * RMG-1045	0.56	-8.37	-8.37	-18.64**	-	-	-9.28	-	-
ML-131 * IPM-02-03	1.66	-1.32	-4.08	-5.20	-	-	-19.29**	-	-
ML-131 * PDM-139	7.27	3.80	0.90	-22.00**	-	-	-4.46	-	-
ML-131 * RMG-1035	-5.51	-11.92	-14.37	6.31	5.42	-	-43.50**	-	-
ML-131 * RMG-344	1.92	-1.37	-4.12	-9.33	-	-	-61.31**	-	-
ML-131 * RMG-1045	-2.32	-9.84	-12.36	-7.53	-	-	-17.27**	-	-
IPM-02-03 * PDM-139	4.42	4.08	-4.76	0.81	-	-	-37.97**	-	-
IPM-02-03 * RMG-1035	-10.70	-14.35	-21.62**	-14.67**	-	-	3.55	-	-
IPM-02-03 * RMG-344	-0.87	-1.17	-9.57	14.86*	6.63*	-	-3.64	-	-
IPM-02-03 * RMG-1045	-2.12	-7.08	-14.97	-8.34	-	-	108.29**	73.13**	-
PDM-139 * RMG-1035	-4.32	-7.93	-16.30*	-6.83	-	-	-31.25**	-	-
PDM-139 * RMG-344	14.46	14.43	4.08	6.62	-	-	-40.95**	-	-
PDM-139 * RMG-1045	-16.70*	-20.67*	-27.89**	-23.06**	-		--34.39**	-	-
RMG-1035 * RMG-344	-6.89	-10.42	-18.53*	0.30	-	-	-49.75**	-	-
RMG-1035 * RMG-1045	-5.47	-6.48	-21.41**	-2.22	-	-	-30.76**	-	-
RMG-344 * RMG-1045	12.51	7.12	-2.57	12.45*	-	-	22.66**	5.32	-

indicating presence of adequate genetic variation among the genotypes.The scope of exploitation of hybrid vigour depends on directions and magnitude of heterosis and type of gene action involved. Heterosis is measured as per cent increase or decrease over mid parent (relative heterosis), over better parent (heterobeltiosis) and over best parent (economic heterosis) Table 4. and Table 5.

Perusal of heterosis values of the twenty eight crosses showed that significant negative heterobeltiosis and economic heterosis for days to flowering was observed in three crosses and thirteen crosses, respectively. Heterobeltiosis, i.e. improvement over the early flowering parent of cross, was observed in three crosses, IPM 99-125 x RMG 1045 (-14.11 %), BM-4 x RMG-1035, and RMG-1035 x RMG 1045. Significant negative economic heterosis for this trait was ranged from – 20.02 % to -2.60 % and the highest estimates of economic heterosis was recorded in the hybrid IPM 02-03 x RMG 1045 (-20.02%) followed by IPM 99-125x RMG-1045 (-18.44%) and BM-4 x IPM 02-03 (Table 6). significant average heterosis, heterobeltiosis and economic heterosis in desired direction for days to 50% flowering as also reported by Dethe and Patil (2008) Aher *et al.* (2001), Loganathan *et al.* (2001), Reddy *et al.* (2003), Anbumalarmathi *et al.* (2004), Saravanan *et al.* (2009) and Reddy *et al.* (2011)

Table 6. revealed seventeen, fifteen and seven cross combinations, which depicted significant heterosis, heterobeltiosis and economic heterotis (respectively) in desired positive direction for plant height. For this trait relative heterosis, heterobeltiosis and economic heterosis ranged from -13.49% - 59.90%, 8.01% - 52.07% and 2.16% - 23.56 %. Heterosis values revealed cross IPM 02-03 x RMG-1045 followed by cross IPM 02-03 x RMG-1035, BM-4 x RMG-1045, IPM 02-03 x RMG-344, and ML-131 x IPM 02-03 showed maximum significant positive heterosis, as well as heterobeltiosis and economic heterosis for plant height. It has been found that, crosses IPM 02-03 x RMG-1045, ML-131 x RMG-1045 and ML-131 x PDM-139 has good *per se* performance with significant heterosis, heterobeltiosis and economic heterosis for plant height and days to earliness. The present findings were in close association with results reported by Joseph and Santoshkumar (2000), Reddy *et al.* (2003), Kumar *et al.* (2007) and Saravanan *et al.* (2009).

RMG-1035 x RMG-1045 exhibited the highest estimates of significant average heterosis, however, this cross also highlighted positive heterobeltiosis for secondary branches per plant as also observed by Anbumalarmathi *et al.* (2004), Intwala *et al.*, Patel *et al.* (2009), and Dhuppe *et al.* (2010) . Heterosis for pods per cluster range from -25.72% (IPM 99-125) to 17.23% (BM-4 x RMG-344) and was significant in thirteen crosses, four of these crosses depicted positive heterosis for this trait. Maximum significant positive heterosis was recorded in cross BM-4 x RMG-344 followed by cross IPM 02-03 x RMG-344, IPM 99-125 x RMG-344 and RMG-344 x RMG-1045. Cross BM-4 x RMG-344 showed significant heterosis as well as heterobeltiosis and turned out to be the best as indicated in Table 7.

Further a perusal of table 7 indicated that relative heterosis for pods per plant ranged from -61.31% to 183.24 %. It was

Table 8: Extent of heterosis for 100 seed weight, Seed yield/ plant and Harvest index

Crosses	100 seed weight			Seed yield / plant			Harvest index		
	Het	Hb	EH	Het	Hb	EH	Het	Hb	EH
IPM 99-125 * BM-4	41.28**	40.52**	20.60**	3.23	2.16	2.16	-10.73	-18.11**	-18.11**
IPM 99-125 * ML-131	33.69**	32.83**	15.49*	3.55	2.52	0.39	18.86**	-4.02	-4.02
IPM 99-125 * IPM-02-03	-25.00**	-	-	-6.47	-11.92*	-13.75*	-31.22**	-40.63**	-40.63**
IPM 99-125 * PDM-139	-19.44**	-	-	0.60	0.48	-1.61	-4.79	-15.63*	-15.63*
IPM 99-125 * RMG-1035	-5.96	-	-	-3.63	-22.77**	-24.38**	-24.63**	-39.94**	-39.94**
IPM 99-125 * RMG-344	-5.47	-	-	-3.07	-7.09	-9.02	-8.89	-24.20**	-24.20**
IPM 99-125 * RMG-1045	-22.30**	-	-	-6.30	-15.21**	-16.97**	-9.22	-22.23**	-22.23**
BM-4 * ML-131	-18.37**	-	-	4.65	2.55	2.55	8.32	-5.93	-21.47**
BM-4 * IPM-02-03	-4.76	-	-	-4.22	-10.68	-10.68	-3.14	-9.42	-24.39**
BM-4 * PDM-139	-0.65	-	-	5.17*	3.95	3.95	2.86*	-0.98	-17.34*
BM-4 * RMG-1035	-17.05*	-	-	-0.44	-20.84**	-20.84**	-9.10	-22.22**	-35.07**
BM-4 * RMG-344	4.66	4.21	-	-2.85	-7.80	-7.80	-9.05	-18.36*	-31.84**
BM-4 * RMG-1045	-19.53**	-	-	-0.64	-10.91*	-10.91*	-6.18	-13.01	-27.38**
ML-131 * IPM-02-03	-20.25**	-	-	2.68	-2.38	-6.31	11.51	2.97	-25.20**
ML-131 * PDM-139	-12.35	-	-	5.53	4.60	2.18	12.90	1.40	-21.68**
ML-131 * RMG-1035	-16.35*	-	-	8.01	-12.78*	-16.29**	15.13	13.14	-30.41**
ML-131 * RMG-344	-10.87	-	-	-2.64	-5.77	-9.56	14.49	10.27	-26.78**
ML-131 * RMG-1045	-19.27**	-	-	-1.17	-9.75	-13.38*	3.19	-3.92	-31.46**
IPM-02-03 * PDM-139	-8.23	-	-	-0.37	-6.07	-8.24	0.82	-2.18	-24.45**
IPM-02-03 * RMG-1035	-12.76	-	-	9.93	-7.54	-20.01**	-5.85	-14.44	-37.85**
IPM-02-03 * RMG-344	-12.41*	-	-	-3.70	-5.47	-15.10**	2.58	-1.83	-28.69**
IPM-02-03 * RMG-1045	-14.58*	-	-	-1.27	-5.38	-18.14**	-10.50	-11.30	-35.57**
PDM-139 * RMG-1035	-12.91	-	-	9.05	-12.53*	-14.55	19.20*	5.42	-18.57**
PDM-139 * RMG-344	-15.63*	-	-	-5.73	-9.74	-19.94**	1.79	-5.35	-26.90**
PDM-139 * RMG-1045	-1.75	-	-	-9.62	-14.82	-30.87**	6.74	2.66	-20.71**
RMG-1035 * RMG-344	-15.64*	-	-	2.72	-12.20	-22.13**	-4.83	-9.86	-40.15**
RMG-1035 * RMG-1045	-20.35**	-	-	3.30*	-3.10	-30.41**	17.35	7.52	-23.30**
RMG-344 * RMG-1045	-0.81	-	-	-19.85**	-27.47**	-35.68**	37.14**	32.39**	-5.55

found significant in twenty crosses, out of which three significant positive heterosis was recorded The highest estimates of significant positive heterobeltiosis and relative heterosis for pods per plant was noticed by cross BM-4 x IPM 02-03 and IPM 02-03 x RMG-1045. The results reported by Aher *et al*. (2000), Sawale *et al*. (2003), Dethe and Patil (2008) and Reddy *et al*. (2011) were in close association with the present findings for pods per cluster and pods per plant. Relative heterosis for 100-seed weight ranged from -25.00 % (IPM 99-125x IPM 02-03) to 41.28% (IPM 99-125 x BM-4) as showed in table 7. High magnitude of significant relative, better parent and economic heterosis was recorded in cross IPM 99-125 x BM-4 followed by cross IPM 99-125 x ML-131. Five, nine and eleven crosses were significant for heterosis, heterobeltiosis and economic heterosis respectively. These results are in parallel with the findings of Intwala *et al*. (2009) and Patel *et al*. (2009).

For seed yield per plant, significant heterosis was recorded in the cross BM-4 x PDM-139 (5.17) and RMG-344 x RMG-1045 (Table 8.). For harvest index, relative heterosis and heterobeltiosis ranged from -31.22% to 37.14% and -40% to 32.39% respectively. Cross RMG-344 x RMG-1045, PDM-139 x RMG-1035 and IPM 99-125 x ML-131 showed significant positive heterosis for the trait (Table 8). While, the highest estimate of significant heterosis as well as heterobeltiosis was exhibited by the hybrid RMG-344 x RMG-1045 and turned out to be the best. Similar to the present findings, Ghafoor *et al*. (1990), Intwala *et al*. (2009), Sujatha *et al*.(2011), Singh *et al*. (2013) and Yadav *et al*.(2015) also reported heterosis for seed yield per plant and harvest index in green gram.

Therefore, the results revealed significant positive as well as negative heterosis and heterobeltiosis in many crosses for different characters studied (Table 2). The high values for heterotic effects indicated that the parents used for the study appeared to be genetically diverse. Considerable high heterosis in certain cross combination and low in other revealed that nature of gene action varied with the genetic architecture of the parents which might help in identifying superior cross combination . A perusal of Table 2 revealed best heterotic cross for seed yield and yield contributing traits involving genetically as well as geographically diverse parents thereby, confirming the established facts as enunciated by Falconer. It has been found that cross BM-4 x PDM-139 and RMG-1035 x RMG-1045 showed significant heterosis for seed yield with most of the yield contributing characters. It is well established that there could be no separate gene system for yield *per se* as yield was an end product of the multiplicative interaction between its various components. Thus heterosis for grain yield could be determined by finding the effect of heterosis for individual yield components. Based on heterotic studies, the best direct yield contributing character was seeds per pod, pods per plant, plant height and harvest index. Importance of these characters was also emphasized by Khattak *et al*. (2002), Intwala *et al*. (2009), Sujatha *et al*. (2011), Makani *et al*. (2013), Sharma and Sengupta (2013) and Yadav *et al*. (2015) in green gram.

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