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Combining ability and heterosis in early maturing pigeonpea [*Cajanus cajan* (L.) Millsp] hybrids

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Abstract

The genetic analysis of 36 hybrids involving 3 male sterile lines and 12 pollinator lines evaluated for twelve characters revealed the predominance of non-additive gene action for all the characters under study. The parents QMS-1 and MS Prabhat (DT) among male steriles while Sel 90309, Sel 90306, Sel 90310, Sel 90311 and Sel 90307 among pollinators were identified as good general combiners. The crosses QMS-1 × Sel 90307, QMS-1 × Sel 90311 and MS Prabhat (NDT) × Sel 90214 were the best specific combiners for yield and its components, and favours heterosis breeding programme. Heterosis to the extent of 51.3 and 171.6% over the standard check Sel 90308 and better parent, respectively, were recorded for seed yield/plant. Best five hybrids exceeding 40% standard heterosis were identified as promising for seed yield and its components.

Key words: Pigeonpea, combining ability, heterosis, male steriles, yield and yield components

Introduction

Exploitation of hybrid vigour in pigeonpea is one of the potential avenues for quantum jump in its grain yield. Efforts are underway for commercial exploitation of heterosis in pigeonpea using natural out-crossing coupled with discovery of stable genic male sterility system, and the development of technology for hybrid seed production [1, 2]. The heterosis component is largely dependent on diverse parents with good general combining ability (*gca*). In practical heterosis breeding, it is necessary to select combinations with high degree of specific combining ability (*sca*) as well as parents with high *gca*. The magnitude of heterosis particularly for yield is of paramount importance and if the heterosis is practically and economically feasible it can help to achieve high yield levels and thereby high productivity in pigeonpea. The present investigation was undertaken to study the combining ability of parents and hybrids as well as to evaluate the nature and magnitude of heterosis in early maturing pigeonpea hybrids involving three genetic male steriles.

Materials and methods

Three male sterile lines MS Prabhat (DT), MS Prabhat (NDT) and QMS-1 were used as female parents and these were pollinated by each of twelve pollinator lines *viz.*, Sel 90214, Sel 90304, Sel 90306, Sel 90307, Sel 90308, Sel 90309, Sel 90310, Sel 90311, Sel 90312, P610, H 87-2 and 12-33 in a Line × tester mating design. The resulting 36 hybrids and parents were evaluated in a Randomized Block Design with three replications at the Indian Agricultural Research Institute, New Delhi during *kharif* season. Each entry was sown in 4m long row plots at 50cm × 20cm inter and intra-row spacing with non-experimental rows at borders. The observations were recorded from five competitive plants selected randomly from each plot on plant height (cm), plant spread (cm), number of clusters/ plant, pods/cluster, pods/plant, seeds/pod, 100-seed weight (g), seed yield/plant(g), biomass/plant(g) and harvest index (%) whereas data on days to 50% flowering and days to maturity were recorded on per plot basis. The data were subjected to combining ability analysis [3] as well as for estimation of relative heterosis (H), heterobeltiosis (HB) and standard heterosis (HS) over a best high yielding pureline (Sel 90308) in the set as standard check, and expressed as per cent.

Results and discussion

The analysis of variance (Table 1) revealed significant differences among the parents and hybrids for all the characters indicating large parental diversity. The partitioning of hybrid mean sum of squares revealed the variances due to males, females as well as interaction of males × females were significant for all the characters indicating the manifestation of parental genetic variability in their crosses and presence of uniformity among the hybrids. Apparently additive and non-additive gene actions were operating in the expression of all the characters. However, important role of the non-additive portion of genetic variance was observed for all the characters except 100-seed weight

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Table 1. Analysis of variance and estimates of combining ability variances for twelve characters in pigeonpea

Source of variation	d.f.	Mean sum of squares											
		Days to 50% flowering	Days to maturity	Plant height	Plant spread	Clusters per plant	Pods per cluster	Pods per plant	Seeds per pod	100-seed weight	Seed yield per plant	Biomass	Harvest index
Replications	2	5.80	13.75**	37.02	9.87	3.05	0.01	18.09	0.01	0.02**	4.94	1.78	0.81
Treatments	50	1128.52**	1501.35**	14598.56**	709.13**	2286.98**	31.97**	88072.77**	4.67**	8.14**	11731.66**	195975.30**	199.06**
Parents	14	119.59**	204.10**	4317.97**	99.95**	123.38**	0.86**	1740.70**	0.18**	1.82**	250.04**	5526.71**	44.51**
Crosses	35	215.99**	226.00**	2691.34**	296.56**	482.25**	3.89**	4593.41**	0.13**	2.32**	420.50**	12937.82**	57.52
Parents vs Crosses	1	792.94**	1071.25**	7589.25**	312.62**	1681.35**	27.22**	81738.66**	4.36**	4.00**	11060.62**	179507.00**	97.03**
Males	11	196.68**	272.48**	2592.58**	305.83**	603.35**	7.35**	7097.90**	0.20**	5.23**	550.18**	12155.68**	42.24**
Females	2	1642.49**	687.19**	14960.50**	865.29**	301.86**	0.25	9916.46**	0.010*	0.38**	1172.40**	67047.80**	290.50**
Male × Females	22	95.96**	160.84**	1625.35**	140.22**	438.11**	2.48**	2857.25**	0.11**	1.04**	287.30**	8409.81**	43.98**
Error	70	2.70	2.40	28.53	9.65	6.69	0.08	36.90	0.01	0.01	7.72	33.38	0.91
$2\sigma^2$ gca/($2\sigma^2$ gca+σ^2sca)		0.70	0.35	0.54	0.28	0.01	0.13	0.35	0.02	1.00	0.35	0.50	0.43

*,**Significant at 5% and 1% level, respectively.

and days to 50% flowering. However, predominance of additive genetic variance was found operative for 100-seed weight and days to 50% flowering. These results are in agreement with those published earlier for days to maturity [4], plant height [5], plant spread [6], clusters/plant [7], pods/cluster, pods/plant and seeds/pod [8], seed yield/plant [9,10] and for biomass and harvest index [11]. However, the predominance of additive gene action for seed weight and days to 50% flowering was revealed by Sharma *et al.* [12] and Gupta *et al.* [13] which corroborated the results of the present study. On contrary, predominance of additive gene action for yield and most of its components were also revealed in pigeonpea [14-16].

Among the male sterile lines, QMS-1 was a good general combiner for all the traits except pods/plant and biomass while MS Prabhat (NDT) was a good combiner for six traits *viz.*, plant spread, clusters/plant, pods/plant, 100-seed weight, seed yield /plant and biomass (Table 2). Among the pollinator lines Sel 90310 was a good general combiner for early maturity, pods/cluster, pods/plant, seed yield/plant and biomass. Besides these parents, Sel 90309 for plant spread, clusters/plant and seeds /pod, and Sel 90310 for 100-seed weight exhibited moderate *gca* effects. The genotype Sel 90311 expressed favourable *gca* effects for early flowering and maturity, pods/cluster and pods/plant while Sel 90306 for seeds/pod and biomass. The evaluation of parents based on both *per se* performance as well as *gca* effects indicated that P610 was the best parent for incorporating dwarfness, Sel 90311 for pods/cluster and Sel 90312 for 100-seed weight.

A perusal of sca effects revealed 11 hybrids for days to 50% flowering, pods/cluster, and seeds/pod, 13 for days to early maturity and seed yield/plant, 15 for short height and biomass and 10 for plant spread, 12 for clusters/plant and 14 for harvest index expressed significant *sca* effects (Table 3). The hybrids QMS-1 × Sel 90311 and QMS-1 × Sel 90310, QMS-1 × Sel 90307, MS Prabhat (NDT) × 12-33 and QMS-1 × Sel 90309 were most outstanding for seed yield with significantly higher *sca* effects for early flowering and maturity, clusters/plant, pods/plant, 100-seed weight, biomass and harvest index. The range of heterosis and highly heterotic crosses with significant *sca* effects for different characters were computed to identify the superior cross combinations for their potential use in hybrid breeding (Table 4). The manifestation of relative heterosis in F_1 hybrids indicated the positive dominance for all yield and its components except for days to flowering, plant height and plant spread whereas heterobeltiosis revealed considerable overdominance for seed yield/plant, seeds/pod, pods/plant, pods/cluster, biomass and clusters/plant. The manifestation of positive dominance for yield and its components was reported in pigeonpea by Dahiya and Brar [9], Sharma *et al.* [12] and Gupta *et al.* [13]. The highest level of relative heterosis and heterobeltiosis was revealed for biomass (224.91% and 211.11%, respectively) followed by seed yield/plant (197.43% and 171.58%), clusters/plant (145.95% and 111.21%), pods/cluster (140.04% and 93.24%) and pods/plant (139.80% and 131.78%) while the lowest level of heterosis was manifested for all the developmental traits *viz.*, early flowering (–8.05% and –5.71%), early maturity (–14.53% and –12.17%) and plant height (–18.53% and –29.12%). On contrary, the highest magnitude of standard heterosis was observed for pods/cluster (129.20%) followed by clusters/plant (97.40%), plant spread (84.10%) and pods/plant *(76.98%) while the low magnitude of standard heterosis*

Table 2. General combining ability effects for lines and testers for different traits.

Parents	Days to 50% flowering	Days to maturity	Plant height	Plant spread	Clusters per plant	Pods per cluster	Pods per plant	Seeds per pod	100-seed weight	Seed yield per plant	Biomass	Harvest index
Testers (females)												
MS Prabhat DT	−4.91**	1.30**	−8.89**	−5.66**	−3.33**	0.04	−18.96**	−0.01	−0.11**	−6.53**	−27.54**	−0.03
MS Prabhat NDT	7.70**	3.57**	23.32**	2.67**	1.91**	0.06	7.04**	−0.01	0.09**	2.51**	49.74**	−2.82**
QMS-1	−2.80**	−4.87**	−14.43**	2.99**	1.42**	−0.10*	11.92**	0.02*	0.03**	4.03**	−22.20**	2.86**
Lines (males)												
Sel 90214	−2.13**	2.85**	−8.07**	−6.71**	−4.27**	−0.79**	−33.62**	0.02	0.81**	−5.04**	−61.29**	3.54**
Sel 90304	7.76**	8.74**	7.18**	3.37**	−5.25**	1.03**	15.70**	0.08**	−0.54**	2.22*	−7.31**	0.89**
Sel 90306	1.76**	2.63**	3.82**	−1.25	8.12**	−0.21*	22.75**	0.19**	0.11**	10.49**	54.71**	−0.85**
Sel 90307	5.09**	2.07**	−4.14**	8.69**	6.03**	−0.83**	−9.38**	0.11**	0.15**	−0.02**	28.71**	−2.26**
Sel 90308	1.20*	−2.93**	−11.09**	10.20**	2.79**	−0.65**	−6.51**	0.13**	−0.26**	−2.12*	38.16**	−3.73**
Sel 90309	−0.46	−2.93**	27.16**	2.48*	17.60**	0.22*	40.44**	0.08**	−0.29**	11.05**	36.94**	0.03
Sel 90310	−2.24**	−5.04**	18.86**	−1.82**	−6.68**	1.01**	14.09**	0.03	0.39**	8.04**	28.83**	0.00
Sel 90311	−9.91**	−11.48**	20.00**	−7.00**	−5.21**	1.91**	45.41**	−0.11**	−1.16**	3.84**	−9.40**	0.89
Sel 90312	−4.02**	−4.59**	−7.20**	3.70**	−7.54**	−0.31**	−31.90**	0.05**	1.83**	0.06	−16.84**	1.31**
P610	2.76**	5.07**	−29.78**	−7.32**	−2.63**	0.01	0.25	−0.18**	−0.24**	−4.17**	−46.17**	3.28**
H87-2	3.09**	3.30**	˙4.36*	−2.91**	−9.60**	−0.24*	−35.66**	−0.32**	−0.26**	−14.62**	−23.29**	−2.04**
12-33	−2.91**	2.30**	−21.11**	−1.44	6.64**	−1.14**	−21.56**	−0.10**	−0.53**	−9.74**	−23.06**	−1.06**
SEm (Testers) ±	0.27	0.25	0.88	0.52	0.43	0.05	1.01	0.01	0.01	0.46	0.96	0.16
SEm (Lines) ±	0.54	0.52	1.78	1.04	0.86	0.10	2.02	0.02	0.02	0.93	1.93	0.32
CD (Testers) at												
P = 0.05	0.54	0.50	1.78	1.04	0.86	0.10	2.02	0.02	0.02	0.92	1.92	0.32
P = 0.01	0.72	0.66	2.36	1.38	1.14	0.13	2.68	0.03	0.03	1.22	2.55	0.42
CD (Lines) at												
P = 0.05	1.08	1.04	3.55	2.08	1.72	0.20	4.04	0.04	0.04	1.86	3.86	0.64
P = 0.01	1.43	1.38	4.72	2.76	2.28	0.27	5.36	0.05	0.05	2.47	5.12	0.85

*,**Significant at 5% and 1% level, respectively.

was revealed for the traits *viz.*, early flowering and maturity and seeds/pod. Heterosis for seed yield components were reported by Reddy *et al.* [16] and Patel *et al.* [8] for early flowering and maturity, dwarf plant height, seed yield, pods/plant, clusters/plant, seeds/pod and 100-seed weight, and Mehetre *et al.* [17] for plant spread and Singh *et al.* [11] for biomass and harvest index.

For seed yield and plant spread, QMS-1 × Sel 90307 expressed the highest heterosis of 51.31 and 84.10 per cent over the check variety. It also had significant *sca* effects coupled with high *gca* of female parent for both the traits. Therefore, both additive and non-additive type of gene action seemed to influence seed yield while predominance of additive gene effects on plant spread. Similarly, the crosses QMS-1 × Sel 90311 (50.90%), QMS-1 × Sel 90310 (48.44%), QMS-1 × Sel 90309 (47.30%) and MS Prabhat (NDT) × Sel 90306 (40.00%) also expressed high standard heterosis and *sca* effects coupled with high *gca* of both parents. Therefore, both additive and non-additive type of gene action seemed to influence seed yield in these crosses but with predominance of additive gene action, hence, better selection advance can be expected in subsequent generations. The heterosis observed in these crosses for seed yield was also manifested through yield components *viz.*, pods/plant, seeds/pod, pods/cluster and days to maturity. Therefore, it may be possible to utilize the heterosis in hybrid breeding as well as part thereof may be fixed in subsequent generations.

For days to flowering and maturity, MS Prabhat (DT) × 12-33 and QMS-1 × Sel 90311 exhibited significant desirable standard heterosis as well as significant negative *sca* effects indicating the operation of non-additive gene action. However, negative *gca* (desirable for earliness) of the respective parents involved in the cross MS Prabhat (DT) × 12-33 suggested the role of additive and additive × additive type of interaction for early flowering. For the major yield contributing characters, namely, pods/plant, pods/cluster, seeds/pod and seed weight, the heterosis observed was either due to high *gca* effects of the parents or due to high *sca* effects of the respective cross. The role of both additive as well as non-additive gene action for standard heterosis expression was evident suggesting the development of heterotic combination for use in hybrid breeding programme. It was noted that parents with high × high (QMS-1 × Sel 90307 for dwarfness and QMS-1 × Sel 90311 for pods/plant), high × low (MS Prabhat (NDT) × P610 for pods/plant, QMS-1 × Sel 90309 for seeds/pod, MS Prabhat (DT) × Sel 90309 for clusters/plant and MS Prabhat (NDT) × Sel 90311

Table 3. Specific combining ability effects for twelve characters for crosses from a line × tester (12 × 3) mating in pigeonpea

Hybrids	Days to 50 % flowering	Days to maturity	Plant height	Plant spread	Clusters per plant	Pods per cluster	Pods per plant	Seeds per pod	100-Seed weight	Seed yield per plant	Biomass	Harvest index
MS Prabhat DT x												
Sel 90214	–1.20	–1.41	–15.76**	1.11	0.85	–0.53**	–5.46**	–0.04	0.23**	–1.51	–23.69**	3.15**
Sel 90304	–2.09*	0.70	–10.41**	–7.23**	–4.64**	0.97**	10.42**	–0.37**	0.07*	–0.10	–28.66*	2.57**
Sel 90306	3.57**	4.48**	8.22**	12.26**	3.73*	0.00	32.23**	0.07*	–0.62**	6.10**	62.65**	–1.91**
Sel 90307	2.24*	2.37**	–11.20**	–3.75*	–13.18**	0.25	–21.40**	0.04	0.14**	–5.67**	–66.35**	2.40**
Sel 90308	7.46**	8.70**	38.13**	–9.66**	–3.81*	0.94**	32.37**	0.17**	–0.35**	9.45	–0.80	2.67**
Sel 90309	2.80**	8.70**	4.54**	14.59**	29.61**	–0.25	1.81	–0.09**	0.27**	0.65	20.42**	–1.23*
Sel 90310	0.24	–0.19	–7.93*	4.46*	–5.47**	–0.19	–28.67**	–0.01	–0.25**	–10.25**	66.87**	–7.16**
Sel 90311	9.57**	–0.07	–2.53	–1.03	–0.41	–1.23**	–31.72	–0.01	–0.81**	–11.17**	14.09**	–5.08**
Sel 90312	–4.65**	–4.96**	17.57**	0.00	–0.28	–0.02	5.66	0.06*	0.06	29.54**	–3.16**	4.01**
P610	–5.43**	–7.63**	2.35	1.26	–2.42	–0.09	–8.43*	0.16**	0.46**	3.01	–2.13	0.29
H87-2	–4.43**	–1.52	–30.80**	–5.85**	–0.32	0.12	6.78	0.01	0.55**	4.76**	–58.69**	6.13*
12-33	–8.09**	–9.19**	7.82**	–6.15**	–34.66*	0.03	6.41	0.11**	0.25**	4.57**	–13.24**	1.32*
MS Prabhat NDT x												
Sel 90214	2.85**	–2.35*	18.89**	–1.81	1.54	0.62**	28.49**	0.12**	–0.12**	10.55**	17.71**	0.65
Sel 90304	–1.04	–0.57	5.48	4.18*	8.49**	1.15**	2.16	0.21**	0.03	4.07*	1.66	1.00
Sel 90306	1.30	4.20**	5.77	–10.64**	–14.35**	1.09**	–5.36	–0.14**	1.07**	3.78*	–26.29**	2.89**
Sel 90307	–0.37	6.43**	–28.38**	–11.95**	11.38**	–1.36**	–32.23**	–0.14**	–0.17**	–12.11**	8.04**	–2.92**
Sel 90308	–7.15**	–7.57**	–14.62**	3.78*	6.58**	–1.29**	–32.43**	–0.06*	–0.32**	–11.85**	–48.07**	0.26
Sel 90309	1.19	–4.24**	–14.01**	–9.60**	–14.04**	–0.37*	–16.15**	–0.23**	0.18**	–5.58**	–47.18**	1.93**
Sel 90310	4.96**	3.87**	–7.11**	–4.17*	–3.28*	0.70**	10.11**	–0.05	–0.05	1.79	–65.40**	4.91**
Sel 90311	–7.04**	2.31*	–10.64**	–0.79	–11.22**	1.69**	–11.45**	0.02	0.26**	–2.57	–43.18**	2.66**
Sel 90312	–0.26	0.43	–23.28**	2.84	–6.26**	0.41*	–3.40	–0.05	0.09**	–0.53	0.60	–0.74
P610	–1.37	–7.57**	30.94**	5.46**	8.96**	0.28	54.57**	0.17**	–1.27**	8.50**	49.93**	–2.47**
H87-2	5.96**	5.87**	23.82**	13.12**	–4.24**	–0.04	–11.41**	–0.05	0.07*	–2.83	80.71**	–5.54**
12-33	0.96	–0.80	13.14**	9.59**	16.43**	–0.59**	17.09**	0.20**	0.23**	6.77**	71.49**	–2.12**
QMS-1 x												
Sel 90214	–1.65	3.76**	–3.13	0.70	–2.40	–0.10	–23.03**	–0.09**	–0.11**	–9.04**	5.98	–3.80**
Sel 90304	3.13**	–0.13	4.93	3.06	–3.85**	0.18	–12.59**	0.16**	–0.09**	–3.97**	27.00**	–3.57**
Sel 90306	–4.87**	–8.69**	–13.98**	–1.62	10.61**	–1.09**	–26.88**	0.07*	–0.46**	–9.83**	–36.35**	–0.98
Sel 90307	–1.87	–8.80**	39.57**	15.70**	1.80	1.12**	53.62**	0.10**	0.04	17.78**	58.31**	0.52
Sel 90308	–0.31	–1.13	–23.51**	5.89**	–2.76	0.35*	0.06	–0.11**	0.66**	2.40	48.87**	–2.41**
Sel 90309	–3.98**	–4.46**	9.47**	–4.99*	–15.57**	0.62**	14.34**	0.31**	–0.45**	4.93**	26.76**	–0.70
Sel 90310	–5.20**	–3.69**	15.04**	–0.29	8.75**	–0.50**	18.56**	0.06*	0.31**	8.45**	–1.46	2.25**
Sel 90311	–2.54**	–2.24*	13.17**	1.82	11.64**	–0.46**	42.17**	0.00	0.55**	13.74**	29.09**	2.41**
Sel 90312	4.91**	4.54**	5.70	–2.84	6.54**	–0.39*	–2.25	0.10**	–0.15**	0.37	–30.13**	3.89**
P610	6.80**	15.20**	–33.28	–6.72**	–6.54**	–0.18	–46.14**	–0.33**	0.81**	–11.52**	–47.80**	2.18**
H87-2	–1.54	–4.35**	6.97*	–7.27**	4.56**	–0.08	4.64	0.04	–0.62**	–1.93	–22.02**	–0.59
12-33	7.13**	–7.98**	–20.95**	–3.43	–12.77**	0.55*	–23.50**	–0.31**	–0.48**	–11.34	–58.24**	0.80
SEm (Sij) ±	0.95	0.89	3.08	1.79	1.49	0.17	3.51	0.03	0.03	1.60	3.34	0.55
CD at 5% level	1.90	1.78	6.15	3.57	2.97	0.34	7.00	0.06	0.06	3.19	6.67	1.10
1% level	2.52	2.36	8.17	4.75	3.95	0.45	9.31	0.08	0.08	4.24	8.86	1.46

*,**Significant at 5% and 1% level, respectively.

for pods/cluster and MS Prabhat (NDT) × H87-2 for biomass) and low × low (MS Prabhat (DT) × H 87-2 for harvest index) *gca* effects could produce desirable transgressive segregants if additive genetic system present in the good combiner and complementary epistatic effects in F_1 act in the same direction to maximize the desirable plant attributes [14].

Results of the present study suggested some concept on breeding methodology to be followed in pigeonpea and cross combination to be followed for further improvement. Seed yield and major yield components showed the significance of both additive and non- additive type of gene action in different cross combinations for different characters. The presence of additive and additive x additive gene action for seed yield in QMS-1 × Sel 90311, QMS-1 × Sel 90310, QMS-1 × Sel 90309 and MS Prabhat (NDT) × Sel 90306 suggested that part of heterosis can be fixed in subsequent generations. For a fuller utilization of both additive and non-additive gene effects as evident in QMS-1 × Sel 90307 for seed yield could favour heterosis breeding programme. The present study also identified the parents QMS-1 and MS Prabhat (DT) among male sterile lines and Sel 90307, Sel 90309, Sel 90310 and Sel 90312 among pollinators had potentiality for generating high heterotic cross combinations for most of the traits. It is also suggested for further commercial exploitation of heterosis observed in these five hybrids *viz.*, QMS-1 × Sel 90307, QMS-1

Table 4. Range of heterosis and most heterotic crosses for twelve characters in pigeonpea

	Character	Range of heterosis (%)			Best heterotic cross (over standard check)	sca effect	gca effects	
		Relative heterosis	Heterobeltiosis	Standard heterosis			Female	Male
1.	Days to flowering (early)	−8.05-16.91	−5.71-22.22	−9.51-20.55	MS Prabhat (DT) × 12-33	−8.09**	−4.91**	−2.91*
2.	Days to maturity (early)	−14.53-9.60	12.17-12.27	−18.48-2.46	QMS-1 × Sel 90311; MS Prabhat (DT) × 12-33 (−10.47%)	−2.24** −9.19**	−4.87** 1.30**	−11.48* 2.30*
3.	Plant height (dwarfness)	−18.53-53.14	−29.12-32.59	−32.89-33.00	QMS-1 × P610	−33.28	−14.13**	−29.78*
4.	Plant spread	−22.75-57.82	−30.80-50.48	−25.06-84.10	QMS-1 × Sel 90307	15.70**	2.99**	8.69*
5.	Clusters/plant	−25.78-145.95	−35.45-111.21	−71.63-97.40	MS Prabhat (DT) × Sel 90309	29.61**	−3.33**	17.60*
6.	Pods/cluster	−28.01-140.04	−36.50-93.24	−41.59-129.20	MS Prabhat (NDT) × Sel 90311	1.69**	0.06	1.91*
7.	Pods/plant	−12.08-139.80	−26.56-131.78	−33.37-6.98	QMS-1 X Sel 90311 MS Prabhat (NDT) × P610(50.09%)	43.17** 54.57**	11.92** 7.04**	45.41* 0.25
8.	Seeds/pod	1.52-25.12	−1.38-18.66	−12.24-11.46	QMS-1 × Sel 90309	0.31**	0.02*	0.08*
9.	100-seed weight	−26.87-36.48	−31.69-25.49	−29.3-22.93	MS Prabhat (NDT) × Sel 90312	1.07**	0.09**	0.11*
10.	Seed yield/plant	5.75-197.43	−23.57-171.58	−36.19-51.31	QMS-1 × Sel 90307; QMS-1 × Sel 90311 (50.90%); QMS-1 × Sel90310 (48.44%); QMS-1 × Sel 90309 (47.30%); MS Prabhat (NDT) × Sel 90306 (40.0%)	17.78** 13.74** 8.45** 4.93** 3.78**	4.03** 4.03** 4.03** 4.03** 2.51**	−0.02 3.84* 8.04* 11.05* 10.49*
11.	Biomass/plant	−18.38-224.91	−41.63-211.11	−53.62-56.57	MS Prabhat (NDT) × H87-2	80.71**	49.74**	−23.29*
12.	Harvest index	−27.20-34.14	−36.87-26.49	−35.62-31.23	QMS-1 × P610	6.13*	−0.03	−2.04*

Figures in parenthesis denote standard heterosis values; *,** significant at 5% and 1% level, respectively

× Sel 90311, QMS-1 × Sel 90310, QMS-1 × Sel 90309 and MS Prabhat (NDT) × Sel 90214 after evaluating their performance and stability in multi-environment and in large plots for yield potential.

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