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COMBINING ABILITY STUDIES FOR GRAIN YIELD AND ARCHITECTURAL TRAITS IN MUNGBEAN [*VIGNA RADIATA* (L.) WILCZEK]

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ABSTRACT

Eight lines were crossed with four testers in line x tester fashion to estimate combining ability for yield and yield attributing traits in mungbean. The analysis of variance revealed significant differences among genotypes, crosses, lines, testers and line x tester interaction for most of the traits. Preponderance of non-additive gene effects was realized from higher values of specific combining ability compared to general combining ability and ratio of variances of SCA to GCA. The parents *viz*., GM-9926, GM-9924 and IPM-02-19 were good general combiners for grain yield per plant. Parents, GM-2K-3, GM-4 and IPM-02-03 were good general combiners for 100-seed weight. Cross combinations *viz*., IPM-02-03 × GM-4 and GM-9926 × K-851 were found to be good specific combinations for grain yield per plant and other desirable traits. These cross combinations could be utilized for further amelioration of grain yield in mung bean.

INTRODUCTION

Legumes represent the second largest family of higher plants,second only to grasses, in agricultural importance (Kumar *et al.,* 2013). Among legumes, mungbean (*Vigna radiata* (L.) is the third most important annual crop of Asia (Alam *et al.,* 2014), due to high protein content, broad adaptation, lesser agronomical requirement and high ability to increase soil fertility. According to the Vavilov (1926), mungbean is originated in Hindustan and central Asiatic regions. It belongs to the family fabaceae with chromosome number 2n = 22. In literature, both additive and non-additive genetic systems, controlling grain yield and yield-relating traits in greengram, have been reported by Barad *et al*. (2008); Sathya and Jayamani (2011); Sujatha and Kajjidoni (2013) and Suresh (2014). However, the major part of genetic variation for yield and its components was conditioned due to higher magnitude of non-additive genetic effects (Sathya and Jayamani (2011); Sujatha and Kajjidoni (2013) and Suresh (2014).

In-spite of high demand, the yield of mungbean worldwide is low and limited success has been achieved so far in augmenting its yield. To enhance the present yield levels, it is essential a systemic varietal improvement through hybridization and exploitation of generated variability through recombination breeding. Combining ability is a powerful tool to select good combiners and thus selecting the appropriate parental lines for hybridization programme. In addition information on nature of gene action will be helpful to develop efficient crop improvement programme. Grain yield and several yield contributing characters lack stability due to strong environmental influence suggesting the need for breeding for specific environment. Therefore the present investigation was undertaken with an objective to assess the nature of gene action involved and combining ability of parental genotypes for various traits for evolving productive varieties in mungbean.

MATERIALS AND METHODS

Five lines were crossed with four testers in line × tester design at Centre of Excellence for Research on Pulses, Sardar krushinagar Dantiwada Agricultural University, Sardar krushinagar (Gujarat). All the genotypes (32 hybrids and 12 parents) were grown in a randomized block design with three replications during *kharif*, 2012. Each genotype was grown in a single row of 4.0 m length with a spacing of 45 cm between rows and 10 cm plants. The guard rows were provided on all sides of each block. All recommended agronomical and plant protection measures were followed to raise healthy crop. Data were recorded on five randomly selected plants from each net plot of parents and F_1s in all the three replications. Mean value on per plant basis were recorded for various 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. Protein content of the grinded sample was estimated by NIR (Near Infra-red Spectrophotometry) as described by Williams and Norris (2001). Methionine was estimated by the method described by McCarthy and Paille (1959). The mean data was analysed to compute combining ability effect and their variance according to Kempthrone (1957).

RESULTS AND DISCUSSION

The results obtained under the present investigation are presented in Table 1 to 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.

The analysis of variance for combining ability Table 1 indicated that mean square due to lines were significant for days to flowering, days to maturity, plant height, pods per plant, seeds per pod, 100-seed weight, harvest index, whereas, mean squares due to testers were significant for days to flowering and days to maturity. The mean square due to lines × testers were observe to be significant for all the characters except plant height, number of branches per plant, seeds per pod and protein content these trends indicated that the experimental material possessed considerable variability and that additive and non-additive gene actions were involved in

Table 1: Analysis of variance (mean square) for combining ability, estimates of components of variance and their ratio 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	0.22	0.39	1.33	1.03**	3.38	0.33	2.27	0.15*	5.02	1.07	0
Females (Lines)	7	13.35**	69.40**	88.82**	0.32	461.19*	5.16*	21.92	1.06*	212.58*	0.79	0.01
Males (Testers)	3	47.34**	43.52**	11.52	0.57	338.53	1.16	16.16	0.5	122.49	1.72	0.02
Females × Males	21	4.83**	5.22*	12.25	0.22	147.82**	1.42	10.13**	0.19**	83.03**	1.07	0.04**
Errors	62	1.97	2.65	5.05	0.14	7.73	1.4	2.01	0.045	7.68	0.52	0
Components of variance												
$\tilde{A}^2_{l}$		0.71*	5.34**	6.38**	0.009	26.11*	0.31	0.98	0.072**	12.46*	-0.023	-0.0025
$\tilde{A}^2_{t}$		1.77**	1.59**	-0.03	0.015	7.94	-0.01	0.25	0.012	2.47	0.027	-0.0012
$\tilde{A}^2_{gca}$		1.42**	2.85**	2.10**	0.013**	14.00**	0.096**	0.49**	0.032**	5.80**	0.01	-0.0017
$\tilde{A}^2_{sca}$		0.95**	0.86**	2.39**	0.011	46.68**	0.073	2.67**	0.050**	18.45**	0.112	0.014**
$\tilde{A}^2_{gca} / \tilde{A}^2_{sca}$		1.49	3.31	0.88	1.18	0.29	1.31	0.18	0.65	0.31	0.091	-0.11

* P d≤0.05, ** P d≤0.01.

Table 2: Estimates of general combining ability (gca) effects of the parents for eleven characters in mungbean

Sr. No.	Parents	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)
Lines (Female parents)												1
IPM-02-19		0.52	-0.08	0.48	0.18	10.78**	-0.56	1.15**	-0.20**	-2.12*	0.01	0.01
2	IPM-02-17	0.44	-1.17*	0.99	-0.27*	-7.13**	0.57	-2.47**	-0.06	-8.84**	0.36	0
3	GM-9926	-1.65**	-2.25**	2.57**	0.15	0.37	0.44	1.45**	0	3.11**	-0.28	0.04**
4	MH-521	0.02	2.42**	2.02**	-0.05	-4.43**	0.52	-0.7	-0.45**	2.70**	-0.07	-0.05**
5	GM-2K-3	0.85*	4.25**	3.11**	-0.18	-5.76**	-0.3	-0.46	0.58**	2.73**	0.39	0.01
6	GM-9924	1.19**	0.25	-1.86**	0	4.43**	0.44	1.41**	0.09	0	-0.3	-0.05**
7	IPM-02-03	0.19	-0.25	-3.41**	0.02	4.60**	-1.27**	0.33	0.13*	-1.45	-0.1	0.04**
8	Pusa-0871	-1.56**	-3.17**	-3.89**	0.17	-2.87**	0.16	-0.7	-0.09	3.86**	0	-0.01
	S.Em. ±	0.41	0.46	0.65	0.12	0.8	0.31	0.41	0.06	0.79	0.24	0.01
Testers (Male parents)												1
GM-3	0.48	0.58	0.35	-0.1	-5.62**	-0.19	-1.22**	0.03	-3.27**	-0.07	0.01	
2	GM-4	-1.73**	-1.63**	-0.26	0.09	1.96**	-0.06	0.39	0.12**	0.35	0.39*	-0.03*
3	K-851	-0.35	-0.46	0.75	0.17	2.14**	0.32	0.55	0.06	1.1	-0.11	0.03**
4	Meha	1.60**	1.50**	-0.84	-0.16	1.52**	-0.07	0.28	-0.21**	1.82**	-0.214	-0.02
	S.Em. ±	0.29	0.33	0.46	0.088	0.56	0.22	0.29	0.044	0.56	0.17	0.01

* P d≤0.05, ** P d≤0.01.

Table 3 : Estimates of specific combining ability (sca) effects for eleven characters in mungbean

Sr. No.	Crosses	Days to flowering	Days to maturity	Plant height (cm)	No. of branches per plant	Pods per plant	Seeds per pod	Grain yield/ plant (g)	100-seed weight (g)	Harvest index (%)	Protein content (%)	Methionine content (% in protein)
1	IPM-02-19 × GM-3	-0.4	-0.5	-2.66*	-0.38	-9.11**	-0.23	-1.26	-0.58**	-1.75	-0.54	0.01
2	IPM-02-19 × GM-4	-0.85	-0.96	-0.82	-0.1	6.84**	-0.74	-0.34	0.48**	5.99**	1.06*	0.02
3	IPM-02-19 × K-851	0.44	0.54	2.94*	0.33	6.70**	0.67	0.68	0.11	-2.71	-1.08*	0.01
4	IPM-02-19 × Meha	0.81	0.92	0.54	0.15	-4.42**	0.29	0.93	-0.01	-1.53	0.56	-0.04
5	IPM-02-17 × GM-3	-0.31	-0.42	3.85**	-0.13	3.47*	0.54	1.46	0.03	1.21	-0.32	0.06
6	IPM-02-17 × GM-4	2.90**	2.79**	-0.64	-0.32	-0.7	-0.64	-0.57	-0.08	-0.98	-0.18	0.14**
7	IPM-02-17 × K-851	-1.15*	-1.04	-2.25	0.16	-0.62	-0.01	-0.92	0.03	-0.34	0.53	-0.23**
8	IPM-02-17 × Meha	-1.44*	-1.33	-0.97	0.29	-2.15	0.11	0.03	0.02	0.11	-0.03	0.03
9	GM-9926 × GM-3	-0.23	-0.33	-1.33	0.15	7.38**	0.32	1.24	0.25*	7.62**	0.39	-0.02
10	GM-9926 × GM-4	0.65	0.54	0.47	0.06	0.72	-0.7	0.28	-0.36**	0.75	-0.59	0.05
11	GM-9926 × K-851	0.6	0.71	-0.03	0.11	3.75*	0.3	2.13*	0.12	1.63	-0.54	0.09**
12	GM-9926 × Meha	-1.02	-0.92	0.86	-0.33	-11.85**	0.08	-3.65**	-0.01	-9.99**	0.73	-0.12**
13	MH-521 × GM-3	0.1	0	-2.28	-0.02	6.03**	0.47	0.53	-0.28*	-5.04**	-0.05	0.15**
14	MH-521 × GM-4	-0.35	-0.46	2.42	0.13	-10.41**	-0.18	-2.46**	0.08	-0.76	0.31	-0.23**
15	MH-521 × K-851	-0.06	0.04	2.42	0.01	1.09	0.28	1.74*	0.19	2.35	-0.11	-0.04
16	MH-521 × Meha	0.31	0.42	-2.57	-0.13	3.30*	-0.57	0.18	0.01	3.45*	-0.15	0.12**

Table 3: Cont.....

Sr. No.	Crosses	Days to flow ering	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)
17	GM-2K-3 × GM-3	-1.4	-1.5	-0.17	0.12	0.1	0.61	1.6	0.51**	3.80*	0.57	-0.19**
18	GM-2K-3 × GM-4	0.15	0.04	-0.4	-0.27	-3.65*	0.71	-0.32	-0.05	0.82	0.05	0.05
19	GM-2K-3 × K-851	0.77	0.86	-0.17	0.11	-3.82*	-1.37*	-2.38**	-0.29*	-5.95**	-0.16	0.03
20	GM-2K-3 × Meha	0.48	0.58	0.74	0.04	7.37**	0.05	1.1	-0.17	1.33	-0.46	0.12**
21	GM-9924 × GM-3	1.94*	1.83	3.17*	-0.06	-10.26**	-0.29	-1.90*	-0.07	-0.71	-0.14	-0.02
22	GM-9924 × GM-4	-1.85*	-1.96*	-0.53	-0.18	-2.67	0.19	-0.71	0.03	-5.11**	-0.09	-0.05
23	GM-9924 × K-851	-0.23	-0.13	-1.06	0.04	5.74**	-0.59	1.33	-0.05	1.7	0.55	0.07*
24	GM-9924 × Meha	0.15	0.25	-1.58	0.2	7.18**	0.69	1.29	0.09	4.12*	-0.32	0
25	IPM-02-03 × GM-3	1.27	2.00*	-0.51	0.12	-1.92	-0.95	-1.44	0.04	-7.07**	0.08	-0.07*
26	IPM-02-03 × GM-4	-1.19	-0.46	-0.34	0.48	7.50**	0.89	3.50**	0.08	-0.7	-0.73	0.13**
27	IPM-02-03 × K-851	-1.23	-1.96*	-0.51	-0.35	-4.48**	0.74	-1.72*	-0.05	4.35**	1.02*	0.02
28	IPM-02-03 × Meha	1.15	0.42	1.37	-0.25	-1.1	-0.68	-0.35	-0.07	3.43*	-0.36	-0.09**
29	Pusa-0871 × GM-3	-0.98	-1.08	-0.07	0.2	4.32**	-0.47	-0.23	0.1	1.94	0	0.10**
30	Pusa-0871 × GM-4	0.56	0.46	-0.17	0.19	2.37	0.47	0.62	-0.18	0	0.16	-0.12**
31	Pusa-0871 × K-851	0.85	0.96	-1.34	-0.41	-8.35**	-0.02	-0.86	-0.06	-1.03	-0.2	0.04
32	Pusa-0871 × Meha	-0.44	-0.33	1.58	0.02	1.66	0.02	0.47	0.14	-0.91	0.04	-0.02
	S.Em. ±	0.82	0.93	1.3	0.25	1.6	0.63	0.83	0.12	1.59	0.49	0.03

* P d≤ 0.05, ** P d≤ 0.01.

the genetic control of various characters.

The estimates of the components due to various sources revealed that variance due to lines (ó$^{2}_{l}$) were significant for days to flowering, days to maturity, plant height, pods per plant, 100-seed weight and harvest index. Estimates of variance due to testers (ó$^{2}_{t}$) were significant for days to flowering and days to maturity. Similar results were recorded by Rahecha *et al*, (2006), Zubair *et al*. (2007), Barad *et al*. (2008), Dethe *et al*. (2008) for the same traits. Further, the variance components due to lines was higher in magnitude than that of due to testers for all the characters except days to flowering, protein content and methionine content, which indicate greater contribution of lines towards the ó$^{2}_{gca}$ for those traits. The variance due to interaction effect (Lines × Testers) showed significant difference for all the characters except for plant height, number of branches per plant, seeds per pod and protein content indicating specific combining ability involvement in the expression of these traits and the importance of dominance or non-additive variances for majority of the characters. The importance of dominance variance for most of the traits was also reported by Bainade *et al*. (2014). Variance estimates due to general combining ability (ó$^{2}_{gca}$) were observed to be significant for all the characters except protein content and methionine content, which revealed that these characters are governed by additive gene action. The estimates due to specific combining ability (ó$^{2}_{sca}$) also differed significantly for all characters except number of branches per plant, seeds per pod and protein content, indicating the importance of non-additive gene action for the inheritance of all the characters except number of branches per plant, seeds per pod and protein content. Occurrence of both additive and non additive gene effects for yield and important yield component traits in greengram were reported from earlier studies by Marappa (2008), Barad *et al*. (2008), Sathya and Jayamani (2011), Sujatha and Kajjidoni (2013) and Suresh (2014). As variance due to both gca and sca were found to be significant for days

Table 4 : Three top ranking parents with respect to *per se* performance and gca effects and the three top ranking hybrids with respect to *per se* performance and their sca effects

Character	Best performing parent (*per se* performance)	Best general combiners	Best performing hybrids (*per se* performance)	Status of the parents	sca effects
Days to flowering	GM-4	GM-4	Pusa-0871 × GM-4	G × G	0.56
	MH-521	GM-9926	GM-9926 × GM-4	G × G	0.65
	Pusa-0871	Pusa-0871	IPM-02-03 × GM-4	A × G	-1.19
Days to maturity	Pusa-0871	Pusa-0871	Pusa-0871 × GM-4	G × G	0.46
	IPM-02-03	GM-9926	GM-9926 × GM-4	G × G	0.54
	GM-4	GM-4	Pusa-0871 × GM-3	G × A	-1.08
Plant height (cm)	IPM-02-19	Pusa-0871	Pusa-0871 × K-851	G × A	-1.34
	Pusa-0871	IPM-02-03	Pusa-0871 × GM-4	G × A	-0.17
	GM-9924	GM-9924	IPM-02-03 × GM-4	G × A	-0.34
No. of branches per plant	MH-521	IPM-02-19	IPM-02-19 × K-851	A × A	0.33
	GM-4	Pusa-0871	IPM-02-03 × GM-4	A × A	0.48
	GM-9926	GM-9926	Pusa-0871 × GM-4	A × A	0.19
Pods per plant	MH-521	IPM-02-19	IPM-02-19 × K-851	G × G	6.70**
	GM-4	IPM-02-03	IPM-02-19 × GM-4	G × G	6.84**
	K-851	GM-9924	IPM-02-03 × GM-4	G × G	7.50**
Seeds per pod	IPM-02-03	IPM-02-17	MH-521 × K-851	A × A	0.28
	GM-2K-3	MH-521	GM-9924 × Meha	A × A	0.69
	IPM-02-17	GM-9924	GM-9926 × K-851	A × A	0.3
Grain yield per plant (g)	MH-521	GM-9926	IPM-02-03 × GM-4	A × A	3.50**
	GM-4	GM-9924	GM-9926 × K-851	G × A	2.13*
	GM-2K-3	IPM-02-19	GM-9924 × K-851	G × A	1.33
100-seed weight (g)	GM-4	GM-2K-3	GM-2K-3 × GM-3	G × A	0.51**
	Pusa-0871	GM-4	GM-2K-3 × GM-4	G × G	-0.05
	GM-9924	IPM-02-03	IPM-02-19 × GM-4	P × A	0.48**
Harvest index (%)	GM-4	Pusa-0871	MH-521 × Meha	G × G	3.45*
	GM-2K-3	GM-9926	GM-9926 × GM-3	G × P	7.62**
	Meha	GM-2K-3	MH-521 × K-851	G × A	2.35
Protein content (%)	GM-4	GM-4	IPM-02-19 × GM-4	A × G	1.06*
	GM-9924	GM-2K-3	GM-2K-3 × GM-3	A × A	0.57
	Pusa-0871	IPM-02-17	GM-2K-3 × GM-4	A × G	0.05
Methionine content	Pusa-0871	IPM-02-03	GM-9926 × K-851	G × G	0.09**
(% in protein)	GM-4	GM-9926	IPM-02-03 × GM-4	G × P	0.13**
	k-851	K-851	GM-2K-3 × Meha	A × A	0.12**

to flowering, days to maturity, plant height, pods per plant, grain yield per plant, 100-seed weight and harvest index, these characters appeared to be under the influences of both additive and non-additive gene action. The ratio $ó^2_{gca}/ó^2_{sca}$ however, indicated the predominance of non-additive gene action except days to flowering, days to maturity, number of branches per plant and seeds per pod where additive gene action was more pronounced.

The above results are in accordance with the findings of Gupta *et al.* (2006), Barad *et al.* (2008), for plant height; Kumar *et al.* (2005), Gupta *et al.* (2006), Zubair *et al.* (2007), Rout *et al.* (2009), Patil *et al.* (2011), Sujatha and Kajjidoni (2013) and Suresh (2014) for grain yield per plant; Kumar *et al.* (2005), Gupta *et al.* (2006), Barad *et al.* (2008), Rout *et al.* (2009), Patil *et al.* (2011) for 100-seed weight and Marappa (2008) for harvest index.

An overall appraisal of general combining ability effects of parents (Table 2) revealed that none of the parent was found to be good general combiners for all the characters. The results showed that the parents, IPM-02-19, GM-9926 and GM-9924 were found to be good general combiner for grain yield per plant; GM-9926, Pusa-0871 and GM-4 for days to flowering; IPM-02-17, GM-9926, Pusa-0871 and GM-4 for days to maturity; GM-9924, IPM-02-03 and Pusa-0871 for plant height; IPM-02-19, GM-9924, IPM-02-03, GM-4, K-851 and Meha for pods per plant; GM-2K-3, IPM-02-03 and GM-4 for 100-seed weight; GM-9926, MH-521, GM-2K-3, Pusa-0871 and Meha for harvest index; GM-4 for protein content; GM-9926, IPM-02-03 and K-851 for methionine content were found to be good general combiners. None of the parents found to be good general combiner for the characters, number of the branches per plant and seeds per pod. In general, it was evident from the Table 2 that the parents which were good general combiners for grain yield per plant were also good general combiners for some of its yield contributing traits like days to flowering, days to maturity, plant height, pods per plant and harvest index. Similar results were reported by Sathya and Jayamani (2011), Sujatha and Kajjidoni (2013) and Suresh(2014). From the results, it is observed that the use of parents IPM-02-19 and GM-9924 in future breeding programme would be more useful for augmenting gene for high yield in mungbean, as they are found to be good general combiners for grain yield per plant and some of the important yield components.

The estimates of sca effects Table 3 revealed that none of the hybrid was consistently superior for all the traits. Considering the overall performance of the hybrids, in respect of grain yield per plant, three hybrids manifested significant positive sca effects. Among these three hybrids, two hybrids exhibited positive sca effects for pods per plant. The three best hybrids, on the basis of significant positive sca effects for grain yield per plant were IPM-02-03 × GM-4 (3.50), GM-9926 × K-851 (2.13) and MH-521 × K-851 (1.74), among which IPM-02-03 × GM-4 (7.50) and GM-9926 × K-851 (3.74) exhibited desired sca effects for pods per plant. The hybrids *viz*., GM-2K-3 × GM-3 (0.51), IPM-02-19 × GM-4 (0.48) and GM-9926 × GM-3 (0.25) exhibited significant and positive sca effects for 100-seed weight indicating the best specific combiner for developing bold seeded varieties whereas, two hybrids, IPM-02-19 × GM-4 (1.06) and IPM-02-03 × K-851 (1.02) were the best specific combiners for increasing protein content as they had positive and significant sca effects. Therefore the crosses showing significant sca effects are expected to trough off transgressive segregants in segregating generations and thus, such crosses can be exploited for the improvement of yield and specific yield contributing characters. Significant sca effects for grain yield per plant were also reported by Natarajan and Palanisamy (1990).

In the present study, in general the parents exhibiting high mean performance also having high general combining ability effects for the characters like plant height, number of branches per plant, 100-seed weight, harvest index *etc*. The close relationship between the mean performance and general combining ability effects was noted by Kute *et al*. (2000), Jahagirdhar (2001), Gawande and Patil (2002), Singh and Dikshit (2003), Sujatha and Kajjidoni (2013) and Suresh (2014). This indicated that, while selecting the parents for hybridization programme, *per se* performance of the parents should also be given due weightage along with combining ability of the parents.

The three best hybrids selected on the basis of *per se* performance, their sca effects are presented in Table 4. A perusal of the data indicated that, in general, the best performance hybrid involved at the one good general combining parent. From these results, it can be concluded that *per se* performance of the parents and hybrids was related with gca effects of parents and heterotic response of the hybrids, respectively. Thus, the potentiality of a strain to be used as a parent in hybridization programme or a cross to be used as a commercial hybrid may be judge by comparing *per se* performance of parents and hybrids along with gca of parents and heterotic response of the hybrids. The crosses exhibiting high *per se* performance and significant desirable sca effects Table 4 for various traits involved either good × good or good × average or average × good or poor × poor combining parents. Therefore, the cross exhibiting high sca effects did not always involve the parents with high gca effects. The results thus, suggested that interallelic interaction were also important for these characters.

From the above discussion, it is concluded that the hybrids IPM-02-03 × GM-4 and GM-9926 × K-851 having high mean values and desirable sca effects for grain yield per plant can be exploited in practical plant breeding. It is also clear that high magnitude of non-additive type of gene action for grain yield per plant and some of its important components traits observed in the present study favours hybrid breeding programme.

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