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Combining Ability Studies for Seed Yield and its Quantitative Traits in F_2 Crosses of Mungbean [*Vigna radiata* (Wilczek)]

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ABSTRACT

Background: Combining ability is a measure that enables breeders to select better parents and outstanding hybrids. General combining ability and specific combining ability is used to determine best performing parents and vigorous hybrids respectively and provides an opportunity to understand the nature of gene action involved in inheritance of each character.

Methods: A combining ability analysis was carried out with six mungbean varieties and their 15 F_2 crosses derived from half diallel fashion. Data was recorded for 10 characters and were subjected to statistical analysis using method-II and model-1 of Griffing's approach.

Result: There was importance of both additive and non-additive gene action in inheritance of all the characters as apprehended from significant values in mean sum of square due to GCA and SCA. Studies on components of variance due to GCA and SCA indicated there was preponderance of additive gene action for days to 50% flowering, days to maturity and pod length whereas non-additive gene action was expressed for other characters. Four parents *viz*., Kamdev, Pant Mung-8, MGG-385 and OBGG-52 were considered as best general combiners on the basis of significant GCA effects for a number of yield and its related traits. Based on SCA effects and *per se* performance, the crosses IPM-02-14/OBGG-58, OBGG-52/OBGG-58 and MGG-385/OBGG-52 displayed significant SCA in desirable direction along with high mean for many of the yield attributing characters. Highest significant SCA for seed yield was observed by the cross Kamdev/IPM-02-14. These selected parents and crosses can be used for further breeding programmes for crop improvement in mungbean.

Key words: Combining ability, Diallel analysis, GCA, Griffing's method, Mungbean, SCA, Yield traits.

INTRODUCTION

Mungbean [*Vigna radiata* (L.) Wilczek] belongs to family Fabaceae with chromosome number 2n=22. Pulses have advantages of sustaining different cropping system and fit for multiple cropping due to its characteristic feature to fix atmospheric nitrogen in association with rhizobium which in turn enriches the soil. Its increasing demand among people is due to its excellent source of digestible protein which shows low flatulence and it is complementary staple food among the low income groups. In India, pulses occupy 15% of the gross cropped area, out of which mungbean constitute only 2% of the total pulse area.

Low productivity of pulses in general and mungbean in particular is due to their cultivation in marginal land under rainfed condition, lack of high yielding genotypes, low yield potential, narrow genetic base, lack of yield stability and susceptibility to pests and diseases. Therefore, there is a compelling demand for developing high yielding varieties which can be accomplished by recombination breeding followed by selection in segregating generations in autogamous crop like mungbean. The pre-requisite of choosing the desirable parents for crossing programme can be done by combining ability analysis. On that account, diallel method is one of the most efficient method for determining combining ability which estimates the general combining ability (GCA) and specific combining ability (SCA). GCA is the result of additive × additive gene action whereas, SCA is result of dominance, additive × additive and dominance × dominance gene action. The nature of gene action would determine both the rate of advance and the ultimate gain from selection, thus, helping in planning a sound breeding programme.

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MATERIALS AND METHODS

The basic experimental material comprised of six improved varieties of mungbean which included three improved varieties of OUAT, Odisha (Kamdev, OBGG-52 and OBGG-58), one each from PAU, Ludhiana (MGG-385), GBPUAT, Pantnagar (Pant Mung-8) and IIPR, Kanpur (IPM-02-14). Fifteen crosses were developed in half diallel fashion by growing six parental varieties at staggered sowing starting from September, 2018 to October, 2018. In summer 2018-19

the parents and F_1s were grown in EB-II, Experimental field of OUAT, Bhubaneswar to raise parental and F_2 cross seeds. During *Rabi* season of 2019-20, six parents and 15 F_2 crosses were evaluated in the same field in a randomized block design with three replications. They were grown in 3 rows of 3 m row length with spacing of 30×10 cm. Each entry was harvested replication wise when the green pods turned to blackish-brown colour. Sampling was done using 30 individual plants for each entry and each replication and observations were recorded for the ten different characters *viz*., days to 50% flowering, days to maturity, plant height (cm), number of branch/plant, number of cluster/plant, number of pods/plant, pod length (cm), number of seeds/ pod, seed yield/plant (gm) and 100-seeds weight (gm) from each entry of each replication. The mean data were subjected to various statistical analysis. Analysis of variance for randomized block design was carried out as per standard procedure of Panse and Sukhatme, (1978). Analysis of variance for combining ability was carried out on the parental and F_2s means following method 2 (excluding reciprocals) and model-I (Fixed effect model) of Griffing, (1956). The GCA and SCA effects for all parents and crosses respectively were calculated and significance was tested by 't' test.

RESULTS AND DISCUSSION

The results from analysis of variance (Table 1) and 'F' test indicated that there was existence of highly significant differences among genotypes, parents and F_2s for all the characters under study, pointing out that there was considerable genetic variability present in selected materials. The average performance of crosses was different from that of parents in characters like days to 50% flowering, plant height, number of branches, number of pods /plant, pod length, number of seeds/pod,100-seeds weight and seed yield/plant, as evident from mean square values of 'Parents vs crosses' for above characters. Surashe *et al.* (2017), Shalini and Lal, (2019), Gill *et al.* (2020) also reported presence of significant variability among parents and crosses. This implies that selected material was appropriate for study of combining ability and gene action involved in inheritance of different characters.

The ANOVA for combining ability of all the characters presented in Table 2 revealed that there was highly significant differences for GCA and SCA of all the characters, indicating the preponderance of both additive and non-additive genetic components of variation involved in inheritance of all these characters of yield and component traits. The crucial importance of both additive and non-additive gene effects for inheritance of characters was also supported by Barad *et al.* (2007), Selvam and Elangaimannan, (2010), Patil *et al.* (2011), Nath *et al.* (2018) and Samantaray *et al.* (2018).

As apprehended from the ratio of σ^2_{gca} and σ^2_{sca} (Table 3), there was preponderance of additive gene action for the characters *viz*., days to 50% flowering, days to maturity and pod length and rest of the characters exhibited non-additive gene action. The characters exhibiting additive gene action were in agreement with the findings of Priya *et al.* (2012) and Thamodharan *et al.* (2017). The non-additive type of gene action for yield characters was confirmed by Selvam and Elangaimannan, (2010), Narashimulu *et al.* (2014) and Gill *et al.* (2020). Heritability estimates of all the characters were very high except for the character number of primary branches/plant, indicating that there was less influence of environmental effects and the selection will be beneficial for crop improvement.

General combining ability (GCA) effects

GCA effect is outcome of additive gene action and additive × additive epistatic interaction. Based on the results of GCA effects (Table 4), it was apparent that Kamdev was high general combiner for six of the yield related traits which are days to 50% flowering, days to maturity, number of primary branches/plant, number of clusters/plant, pod length and 100-seeds weight. The parent Pant Mung 8 was considered as the high general combiner for four traits which are directly related to yield. The variety OBGG 58 is the good general combiner for traits of earliness and plant height, however, showed average GCA effects for other characters. The variety MGG 385 was the good general combiner for only two characters namely pod length and number of seeds / pod and medium general combiner for seed yield. From the above, it is inferred that although no single variety was a

Table 1: ANOVA of parents and F_2 crosses of a 6-parent half diallel crosses for ten different characters in mungbean.

Source of variation	d.f.	Mean sum of squares									
		Days to 50% flowering (days)	Days to maturity (days)	Plant height (cm)	Number of primary branches /plant	Number of clusters /plant	Number of pods /plant	Pod length (cm)	Number of seeds /pod	100-seeds weight (gm)	Seed yield/ plant (gm)
Replication	2	0.429	0.111	0.024	0.041	0.049	0.595	0.009	0.177	0.426	0.4265
Genotypes	20	6.886**	6.130**	52.112**	0.193**	1.226**	28.549**	1.538**	3.212**	2.369**	2.369**
Parents	5	12.189**	12.889**	39.659**	0.219**	1.779**	21.978**	2.796**	6.171**	2.534**	2.534**
Crosses	14	4.460**	4.117**	55.359**	0.196**	1.106**	23.527**	1.191**	2.267**	2.063**	2.063**
Parent vs crosses	1	14.325**	0.514	68.922**	0.012**	0.143	131.711**	0.113**	1.654**	5.825**	5.825**
Error	40	0.578	0.444	0.445	0.018	0.297	0.661	0.020	0.155	0.273	0.273

**Significant at 1%, *Significant at 5%.

good combiner for all the characters yet as a whole, varieties Pant Mung 8, MGG 385, Kamdev and OBGG 52 can be considered as good combiners for producing better performing crosses. Similarly, Singh and Dikshit, (2003), Barad *et al.* (2008), Rout *et al.* (2009), Selvam and Elangaimannan, (2010), Patil *et al.* (2011), Aher *et al.* (2012), Narashimulu *et al.* (2014), Viraj *et al.* (2020) and Sen *et al.* (2018) have isolated best general combiners on the basis of their GCA effects.

Specific combining ability (SCA) effects

In general, SCA does not contribute much in crop improvement of self-pollinated crops except for the crops where commercial heterosis is exploited. The SCA effects of 15 different crosses represented in Table 5 disclosed that the cross Kamdev/OBGG 58 and Pant Mung 8/OBGG 58 had desirable significant negative value for the character days to 50% flowering. For days to maturity, the desirable significant negative value was shown by crosses Kamdev/ OBGG 58 and IPM-02-14/OBGG 58. For plant height, cross combinations Pant Mung 8/OBGG 58 was having negative desirable significant SCA effects. The crosses IPM-02-14/ OBGG 58, Pant Mung 8/Kamdev, MGG 385/OBGG 52 showed positive significant SCA effects with high average performances for number of clusters / plant. The cross IPM-

Table 2: Analysis of variance (MS values) for GCA and SCA for seed yield and its contributing components in mungbean.

Source	d.f.	Mean sum of square									
		Days to 50% flowering	Days to maturity	Plant height	Number of primary branches /plant	Number of clusters /plant	Number of pods /plant	Pod length	Number of seeds /pod	100-seeds weight	Seed yield /plant
Genotypes	20	6.885**	6.131**	133.093**	0.193**	1.226**	28.549**	5.786**	3.212**	0.115**	2.369**
GCA	5	20.600**	20.061**	95.420**	0.468**	2.018**	49.439**	5.603**	8.965**	0.213**	3.781**
SCA	15	2.314**	1.487**	37.673**	0.102**	0.962**	21.586**	0.183**	1.295**	0.082**	1.898**
Error	40	0.579	0.444	0.445	0.018	0.297	0.661	0.020	0.155	0.025	0.273

**Significant at 1%, *Significant at 5%.

Table 3: Components of variance and for 10 characters in F_2 crosses of a 6-parent half diallel cross of mungbean.

Components	Days to 50% flowering	Days to maturity	Plant height	Number of primary branches /plant	Number of cluster /plant	Number of pods /plant	Pod length	Number of seeds /pod	100-seeds weight	Seed yield /plant
σ^2_{gca}	2.503	2.452	11.871	0.056	0.215	6.097	0.697	1.101	0.023	0.438
σ^2_{sca}	1.735	1.043	37.228	0.084	0.665	20.925	0.163	1.140	0.057	1.625
σ^2_e	0.579	0.444	0.445	0.018	0.297	0.661	0.020	0.155	0.025	0.273
$\sigma^2_{gca}/\sigma^2_{sca}$	1.442	2.351	0.318	0.669	0.323	0.291	4.281	0.966	0.412	0.269
Genotypic variance	6.740	5.947	60.971	0.196	1.095	33.119	1.558	3.342	0.104	2.502
Phenotypic variance	7.319	6.391	61.416	0.281	1.392	33.780	1.578	3.497	0.129	2.775
$h^2_{(bs)}$ (%)	92.08	93.05	99.27	69.804	78.66	98.04	98.73	95.56	80.62	90.16

σ^2_{gca}- Variance due to GCA; σ^2_{sca} - Variance due to SCA; σ^2_e - Environmental variance; $h^2_{(bs)}$ - Broad sense heritability.

Table 4: General combining ability (GCA) effects of 6- parents in 6 × 6 half diallel cross of mungbean.

Source	Days to 50% flowering	Days to maturity	Plant height	Number of primary branches /plant	Number of clusters /plant	Number of pods /plant	Pod length	Number of seeds /pod	100-seeds weight	Seed yield /plant
MGG - 385	0.667*	0.444*	0.486*	-0.227*	-0.272*	-1.891*	0.979*	1.052*	-0.069*	-0.172
Pant Mung -8	1.417*	1.486*	3.317*	-0.002	0.478*	1.746*	-0.297*	0.340*	-0.037	0.765*
Kamdev	-1.167*	-1.222*	-0.818*	0.182*	0.190	0.657*	-0.126*`	-0.632*	-0.012	-0.202
OBGG - 52	-0.167	-0.306*	0.830*	-0.034	-0.068	1.086*	-0.207*	-0.183*	-0.017	0.097
IPM-02-14	-0.083	0.028	-1.925*	0.106*	-0.272*	-1.427*	-0.189*	-0.440*	0.187*	-0.284*
OBGG - 58	-0.667*	-0.431*	-1.891*	-0.025	-0.056	-0.170	-0.160	-0.139	-0.052	-0.205*
SE($\hat{g}_i$)	0.142	0.124	0.124	0.025	0.102	0.151	0.027	0.073	0.029	0.097
SE($\hat{g}_i$-$\hat{g}_j$)	0.220	0.192	0.193	0.039	0.157	0.235	0.041	0.114	0.046	0.151

*Significant at 5%.

02-14/OBGG 58 was best cross for number of pods / plant. For number of seeds / pod, cross Pant Mung 8/Kamdev followed by OBGG 52/OBGG 58 and Pant Mung 8/IPM-02-14 were best combiner. The crosses Pant Mung 8/OBGG 52 followed by MGG 385/IPM-02-14 and IPM-02-14/OBGG 58 showed positive significant SCA for the character 100-seeds weight. There were five positive significant crosses for seed yield / plant and top three were Kamdev/IPM-02-14, MGG 385/OBGG 52, OBGG 52/OBGG 58. Selvam and Elangaimannan, (2010), Zuge Sopan *et al.* (2018) and Viraj *et al.* (2020) also have isolated best promising crosses on the basis of SCA effects.

Based on comparative study of *per se* performances and SCA values (Table 6), it specifies that not a single cross showed best SCA value for all the characters. From the table of SCA effects and *per se* performances it was observed that the cross, IPM-02-14/OBGG 58 was having high SCA effects and *per se* performances for five characters namely days to maturity, number of primary branches / plant, number of clusters / plant, number of pods / plant and 100-seeds weight, but it was significant for seed yield/plant. The next best cross was OBGG 52/OBGG 58 which was significant and having high desirable mean performance for four of the characters namely, seed yield / plant, number of seeds / pod, pod length and number of primary branches. It was followed by cross MGG 385/OBGG 52 having high SCA and mean performance for four characters like days to maturity, number of clusters / plant, pod length and seed yield / plant.

It was observed that the parental combinations in the crosses for different desirable characters like high × high, high × medium, high × low, medium × high, medium ×medium, medium × low, low × high and low × medium were in accordance with the findings of Pawale *et al.* 2017 and Gill *et al.* 2020. These desirable cross combinations involving high × high type may be due to additive type of gene actions which are fixable in nature and this type of combinations could be exploited further using simple line selection and pedigree method, which was aided by the findings of Singh and Dikshit, 2003 and Patil *et al.* 2011. The crosses having high SCA effects, but involving one good combiner and the other of medium or poor, might be due to epistasis like additive × dominance type of interaction which is considered as non-fixable. It was further suggested that for the characters governed by non-additive components, recurrent selection that is selection following hybridisation and inter-mating of superior parents in segregating generation will be beneficial for achieving improvement for yield and its related traits. Alternatively, it can be said that to achieve a maximum gain from selection, the selection has to be deferred to later generation of F_3 or F_4 which will reduce the distracting effect of non-additive gene action.

Table 5: Specific combining ability (SCA) effects of 15 crosses (F_2) for ten different characters of mungbean.

Source	Days to 50% flowering	Days to maturity	Plant height	Number of primary branches /plant	Number of clusters /plant	Number of pods /plant	Pod length	Number of seeds /pod	100-seeds weight	Seed yield /plant
MGG385 × Pant Mung 8	-0.607	-0.232	1.548*	0.150*	-0.802*	1.208*	-0.056	-1.080*	0.033	0.122
× Kamdev	-0.357	-0.190	-2.350*	-0.063	-0.482	-1.770*	-0.427*	-0.864*	-0.025	-0.611*
× OBGG 52	-0.690	-0.440	6.709*	-0.085	0.610*	2.468*	0.577*	0.153	0.074	1.074*
× IPM-02-14	-0.440	-0.440	-3.176*	0.142*	-0.319	-1.052*	0.193*	0.044	0.233*	-0.295
× OBGG 58	1.143*	1.018*	-0.890*	-0.161*	0.031	0.857*	-0.103	-0.024	-0.061	0.259
Pant Mung 8 × Kamdev	-0.107	0.101	1.586*	0.109	0.835*	2.993*	0.123	0.781*	-0.085	0.269
× OBGG 52	-0.107	-0.149	-0.786*	-0.149*	-0.007	-1.469*	-0.030	0.065	0.265*	0.004
× IPM-02-14	-0.524	-0.149	5.893*	-0.083	-0.836*	1.771*	0.236*	0.422*	-0.110	0.582*
× OBGG 58	-1.274*	-0.357	-3.808*	-0.018	-0.219	0.620	-0.160*	0.128	-0.037	0.272
Kamdev × OBGG 52	0.810*	1.226*	2.040*	0.107	-0.152	4.053*	-0.168*	-0.830*	-0.277*	-1.146*
× IPM-02-14	-0.607	0.226	1.962*	0.100	0.085	1.583*	0.112	0.094	-0.078	1.502*
× OBGG 58	-1.357*	-0.982*	5.027*	-0.169*	-0.398	-1.491*	0.103	0.460*	0.111	0.189
OBGG 52 × IPM-02-14	-0.274	0.310	-2.173*	-0.351*	-0.090	-0.929*	-0.271*	-0.322	0.071	-0.697*
× OBGG 58	-0.024	0.435	-0.071	0.367*	0.293	-0.053	0.200*	0.577*	0.090	0.757*
IPM-02-14 × OBGG 58	-0.107	-1.232*	-1.589*	0.240*	0.998*	4.927*	0.073	-1.142*	0.192*	0.605*
$SE_{(\hat{S}ii)}$	0.321	0.282	0.282	0.057	0.230	0.343	0.060	0.166	0.067	0.221
$SE_{(\hat{S}ij)}$	0.389	0.341	0.341	0.069	0.279	0.416	0.073	0.201	0.081	0.267
$SE_{(\hat{S}ii)} - SE_{(\hat{S}ij)}$	0.439	0.385	0.385	0.078	0.315	0.469	0.083	0.227	0.091	0.301
$SE_{(\hat{S}ij)} - SE_{(\hat{S}kl)}$	0.538	0.471	0.472	0.095	0.386	0.575	0.101	0.278	0.112	0.369

*Significant at 5%.

Table 6: Crosses showing significant SCA effect along with mean performance and GCA effects of the parents involved in the crosses for ten characters in mungbean.

Characters	Best specific combinations	SCA effects	*Per se* performance	GCA effects of the parents
Days to 50% flowering	Kamdev × OBGG 58	-1.357*	32.33	H × H
	Pant Mung 8 × OBGG 58	-1.274*	35.00	L × H
	Kamdev × IPM-02-14	-0.607	33.67	H × M
Days to maturity	IPM-02-14 × OBGG 58	-1.232*	65.00	M × H
	Kamdev × OBGG 58	-0.982*	64.00	H × H
	MGG 385 × OBGG 52	-0.442	66.33	L × M
Plant height	Pant Mung 8 × OBGG 58	-3.808*	54.10	L × H
	MGG 385 × IPM-02-14	-3.176*	51.87	M × H
	MGG 385 × Kamdev	-2.350*	53.80	M × M
Number of primary branches/plant	OBGG 52 × OBGG58	0.376*	1.23	L × M
	IPM-02-14 × OBGG 58	0.240*	1.23	H × M
	MGG 385 × IPM-02-14	0.142*	0.93	L × H
Number of clusters/plant	IPM-02-14 × OBGG 58	0.998*	6.40	L × M
	Pant Mung 8 × Kamdev	0.835*	7.23	H × H
	MGG 385 × OBGG 52	0.610*	6.00	L × M
Number of pods/plant	IPM-02-14 × OBGG 58	4.927*	25.63	L × M
	Kamdev × OBGG 52	4.099*	28.10	M × H
	Pant Mung 8 × Kamdev	2.993*	27.70	H × M
Pod length	MGG 385 × OBGG 52	0.577*	8.45	H × M
	MGG 385 × IPM-02-14	0.193*	8.08	H × M
	OBGG 52 × OBGG 58	0.200*	6.93	L × H
Number of seeds/pod	Pant Mung 8 × Kamdev	0.781*	12.70	H × L
	OBGG 52 × OBGG 58	0.577*	12.47	M × M
	Pant Mung 8 × IPM-02-14	0.422*	12.53	H × L
100-seeds weight	Pant Mung 8 × OBGG 52	0.265*	3.83	M × M
	MGG 385 × IPM-02-14	0.233*	3.97	L × H
	IPM-02-14 × OBGG 58	0.192*	3.95	H × L
Seed yield/plant	Kamdev × IPM-02-14	1.502*	8.63	M × L
	MGG 385 × OBGG 52	1.074*	8.62	M × H
	OBGG 52 × OBGG 58	0.757*	8.27	H × L

*Significant at 1%.

H = Desirable significant (+ or -) GCA effects, M = Desirable non-significant (+ or -) GCA effects and L= Undesirable significant (+ or -) GCA effects.

CONCLUSION

The combining ability study in six mungbean varieties along with their 15 F 2 half diallel crosses suggested the importance of both additive as well as non-additive gene action in inheritance of traits. Where some traits like days to 50% flowering, days to maturity and pod length showed additive gene action others showed non-additive gene action. Among all the varieties taken under study, Kamdev, Pant Mung-8, MGG-385 and OBGG-52 were the best general combiners whereas the crosses IPM-02-14/OBGG-58, OBGG-52/OBGG-58 and MGG-385/OBGG-52 were the best crosses among all. These best combiners among parents and crosses can be used for future mungbean breeding.

Conflict of Interest

I declare there is no conflict of Interest among the authors for the manuscript.

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