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Estimation of heterosis for yield contributing characters and seed yield in mungbean, [*Vigna radiata* (L.) Wilczek]

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Abstract
Analysis of variance showed significance differences among due to treatments, parents and parents *vs.* hybrids were significant for majority of the traits except pods per cluster and pod length of mungbean, [*Vigna radiata* (L.) Wilczek]. A perusal of mean performances for seed yield per plant revealed that among hybrids ranged from 9.35 gm (HYM-1 x MML-10) to 11.64 gm (MML-13 x MML-4) among parents from 7.74 gm (MML-8) to 9.90 gm (MML-7). On the basis of *per se* performance for seed yield per plant, five best high yielding identified hybrid are MML-13 x MML-4 (11.64 gm), HYM-2 x MML-4 (11.55 gm), MML-13 x MML-10 (11.46 gm), MML-12 x MML-14 (11.36 gm) and MML-8 x MML-4 (11.31 gm).

Keywords: Estimation, heterosis, characters, seed yield and mungbean

Introduction
Mungbean [*Vigna radiata* (L.) Wilczek] is a short duration legume crop. Mungbean probably originated in India or the Indo-Burmese region. The primary gene center of diversity for mungbean was suggested to be the central Asian region with India as the gene center and probable center of domestication**.** Mungbean is a major source of protein and minerals for the predominantly vegetarian population of India. Hundred gram of mungbean seeds composed of carbohydrates (62.62 g), sugars (6.60 g), dietary fibre (16.3 g), vitamin-C (4.8 mg), magnesium (189 mg), phosphorous (367 mg), potassium (1246 mg) and sodium (15 mg). Average protein content in the seeds is around 23% (USDA Nutrient Database). The protein is comparatively rich in lysine, an amino acid predominantly deficit in cereal grains.
Heterosis refers to the superiority of F1 hybrid in one or more character over its parents. In other world, heterosis refers to increase of F1 in fitness and vigour over the parental values. Heterosis leads to superiority in adaptation, yield, quality, disease resistance, maturity and general vigor over its parents. If the hybrid is superior to mid parent, it is regarded as average heterosis oe relative heterosis (Singh and Singh, 2005) [7]. The exploitation of the heterosis for the commercial purpose is very comman in pollinated crops (Priyanka *et al*, 2008, Ram *et al*, 2013) [2, 5]. However its scope in self pollinated crops like mungbean seems to be limited in the Production of hybrid seed. Among the self pollinated crops, the example of commercial exploitation of hybrid is scanty. However the information collected on the basis of heterosis effects of the crosses which need to be carried for further selection in the segregation generation. (Patil *et al.* (2014) [4] In present study, an attempt has been made to estimated the heterosis in F1 hybrids with respect to yield. Keeping the view of the the present experiment was conducted.

Material and Methods
The research experiment was carried out to derived information on heterosis and combining ability effects in mungbean during *Kharif* 2014-15 at the Field Experimentation Centre, Department of Genetics and Plant Breeding, Allahabad School of Agriculture, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad. The experimental materials consisted of 10 diverse genotypes (7 lines + 3 testers) of mungbean, These were selected on the basis of their diverse geographical origin, wide variation and their adaptability for different agro-climatic zones of India (Table: 1 & 2).
The experimental materials were crossed in Line x Tester mating design (Kempthorne, 1957) [1] in *Kharif* 2014-2015 to generate 21 crosses.

These 21 crosses along with 10 parents and 1 checks *viz*., Samrat were evaluated during *Zaid* 2014-2015 at the Field Experimentation Centre, Department of Genetics and Plant Breeding, Allahabad School of Agriculture, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad.

The ten inbred lines were crosses among themselves in line x tester fashion and thus 21 direct single crosses were obtained during *kharif*, 2014. These crosses were sown on 23 March, 2015 (Experiment 2) in a Randomized Block Design with three replications. The total numbers of entries are 63 of which 21 direct single crosses are included in each replication. The observations were recorded on five randomly selected competitive plants in each replication for all the characters except for days to 50 per cent flowering and days to maturity, which were recorded on plot basis.

The number of days was taken from the date of sowing to the day on which the flower buds come out and open completely in 50 per cent of the plants. The plant height (cm) was measured from bottom of the plant of mungbean *i.e*., from soil level to the top of the flower buds in centimeter. The total number of effective or productive branches/ plant bearing pod was recorded. The number of clusters per plant of all five plants mungbean from each plot was counted and average number of cluster per plant was calculated. Total number of pods/ plant in the primary branches were counted at the time of harvest and recorded. The length of five pods each from five tagged plants was taken with a help of a scale and average length of fruit was calculate. The length of fruit was measured in centimeter from basal end to the apex of the pod. Total number of seeds per pod was counted on the basis of the selected randomly from each of the five randomly selected plants and averaged. Number of days of maturity taken from the date of sowing to the time when more than 75 percent of the pod on the plant turns black was recorded. The weight of 100 seeds were recorded in grams by weighting the seed in precision electronic balance and seed index calculated. Total mungbean seeds harvested by manual threshing from five randomly selected plants were weighed in grams and then average was calculated.

The statistical analysis was done by using replication mean values based on the observations recorded and different statistical procedures of Analysis of variance (Panse and Sukhatme, 1967) [3], Estimation of Heterosis(Ha). The data obtained for each character in F_1's and parents were analyzed for each statistical procedure given by Panse and Sukhatme (1967) [3] 'F' test and't' test were worked out the analysis of variance to test the significance. It was carried out according to the procedure of RBD analysis for each character. The total variance and degree of freedom were portioned into three components *namely* replications, genotypes and error. Significance of variance was determined by F-test. Analysis of variance for experiment design was performed to test the significant differences between genotypes for all the character with fixed effect model.

Result and Discussion

Mean values of data obtained from five randomly selected mungbean plants were subjected to analysis of variance. The mean sums of squares values for all ten characters are presented in Table 1. Mean sum of squares due to treatments, parents and parents *vs.* hybrids were significant for majority of the traits except pods of mungbean per cluster and pod length. It was not significant for primary branches per plant, clusters per plant, pods per plant and seeds per pod due to parents and crosses. The analysis of variance revealed the presence of significant amount of variability among parents, their crosses (F_1) and among parent verses crosses for all the characters studied (Sirohi *et al.*, 2008, Suresh *et al*., 2010 and Srelakshi *et al.*, 2012) [8, 13, 10]. The phenomenon of the heterosis has been explained with some factors like heterozygosity (Shull, 1914, East and Hays, 1912 and East, 1936) accumulation of the favourable dominant gene in the heterozygous from each parents (Jones, 1917), allelic interaction (East, 1936) and non-allelic interaction over epistasis (Jones, 1917, Castle, 1946 and, 1955).

Table 1: Analysis of variance for yield component characters and seed yield in mungbean

S. No.	Characters	Mean Sum Of Squares											
	Degree of freedom	Replications	Treatments	Parents	Parents (line)	Parents (testers)	Parents (L vs T)	Parents vs crosses	Crosses	Line effect	Tester effect	Line x tester effect	Error
		2	30	9	6	2	1	1	20	6	2	12	60
1.	50% flowering	0.75	2.35**	1.72**	1.63**	0.44	4.80**	18.12**	1.84**	1.88	4.49	1.38	0.65**
2.	Plant height	3.00	2.46	5.75**	7.74**	0.38	4.59	12.02**	0.51	0.14	0.16	0.75	2.43
3.	Primary branches per plant	0.08	0.18**	0.06	0.07	0.01	0.11	2.63**	0.12*	0.20	0.09	0.08	0.06
4.	Clusters per plant	0.10	0.54**	0.19**	0.21*	0.19	0.09	13.27**	0.06	0.08	0.00	0.07	0.07
5.	Pods per plant	0.59	1.64**	1.07	1.48*	0.25	0.20	31.89**	0.38	0.22	1.28	0.32	0.62
6.	Pod length	0.03	0.22	0.15	0.22	0.01	0.01	1.62**	0.18	0.14	0.26	0.19	0.14
7.	Seeds per pod	0.24	0.98**	1.95**	1.19*	3.25**	3.88**	5.97**	0.29	0.23	0.12	0.35	0.39
8.	Days of maturity	0.64	4.05**	4.44**	3.42*	6.77**	5.90*	8.73**	3.64**	1.14	0.11	5.48**	1.26
9.	Seed index	0.01	0.05**	0.04*	0.05**	0.02	0.01	0.00	0.06**	0.01	0.41**	0.03	0.02
10.	Yield per plant	1.48	3.60**	1.10**	0.65	2.13*	1.73	69.59**	1.43**	1.37	5.42*	0.79	0.53

The mean value, parental mean, hybrid mean, check mean, grand mean, standard error of mean and critical difference (CD) of parents and hybrids for all eleven characters revealed a wide range of variations for all traits (table 2).

Days to 50 per cent flowering

The mean of parents for the character, days to 50 per cent flowering was recorded 41.50 cm, which ranged from 40.33 cm to 42.33 cm for parents MML-13 and HYM-1, respectively. The parents MML-13 was found to be statistically significant among ten parents. The mean of crosses for days to 50 per cent flowering was recorded as 41.02 cm, which ranged from 39.33 cm to 42.66 cm for cross MML8 x MML-4 and MML-5 Xmml-10, respectively. The was found to be statistically significant to other crosses.

Plant Height

The mean of parents for the character, mungbean plant height

was recorded 56.93 cm, which ranged from 54.93cm to 59.46cm for parents MML-8 and HYM-2, respectively. The parents MML-8 was found to be statistically significant among ten parents. The mean of crosses for plant height was recorded as 57.73 cm, which ranged from 57.00cm to 58.53cm for cross HYM-1 x MML-10 and MML-12 x MML-7 Respectively. The cross was found to be statistically significant to other crosses.

Table 2: Mean performance of parents and hybrids for ten characters in mungbean

S. No.	Genotypes	Days to 50% flowering	Plant height	Primary branches per plant	Clusters per plant	Pods per plant	Pod length	Seeds per pod	days of maturity	Seed index	Yield per plant
1	MML-1	41.33	57.30	6.86	6.53	16.26	7.27	10.80	62.66	3.30	8.64
2	MML-5	41.33	55.26	7.06	6.46	15.93	7.32	11.26	62.00	3.01	8.56
3	MML-8	42.00	54.93	7.06	6.73	15.26	8.03	11.63	64.33	2.99	7.74
4	MML-12	40.66	56.00	6.73	6.60	16.66	7.42	12.06	62.33	2.92	8.44
5	MML-13	42.33	56.16	6.80	6.66	16.60	7.29	12.40	64.00	2.97	8.08
6	HYM-1	40.33	57.93	6.86	6.80	17.00	7.43	12.60	63.00	3.08	9.23
7	HYM-2	40.66	59.46	6.66	7.26	17.40	7.27	11.73	61.33	2.86	8.50
8	MML-4	42.33	57.96	7.00	7.13	16.46	7.43	12.20	63.66	3.80	8.24
9	MML-7	41.66	57.50	7.06	6.66	15.93	7.49	10.33	65.33	3.05	9.90
10	MML-10	42.33	57.26	6.93	6.73	16.40	7.33	10.46	62.33	2.91	8.80
11	MML-1*MML-4	40.33	57.93	7.07	7.67	17.77	7.61	12.27	62.33	3.12	10.27
12	MML-1*MML-7	40.00	57.67	7.53	7.53	17.60	7.96	11.67	63.33	2.93	10.87
13	MML-1*MML10	40.67	57.87	7.20	7.60	17.07	7.64	12.20	61.33	3.00	10.63
14	MML-5*MML-4	40.33	57.40	7.33	7.60	18.27	8.02	12.27	62.00	3.15	10.70
15	MML-5*MML-7	42.67	57.70	7.40	7.67	17.07	7.47	12.27	63.67	2.95	9.60
16	MML-5*MML10	40.33	57.80	7.40	7.47	17.60	7.83	11.87	61.67	2.97	10.32
17	MML-8*MML-4	39.33	57.47	6.87	7.33	18.27	7.45	12.27	61.33	3.17	11.31
18	MML-8*MML-7	41.00	58.20	7.27	7.53	17.60	7.69	11.93	62.67	3.09	9.40
19	MML-8*MML10	40.33	58.03	7.33	7.53	17.73	7.77	11.53	65.33	2.99	10.33
20	MML-12*MML-4	39.67	58.03	7.07	7.67	17.80	7.49	11.93	62.33	3.23	11.36
21	MML-12*MML-7	39.67	57.00	6.87	7.13	17.80	8.36	12.47	61.33	2.83	10.05
22	MML-12*MML10	41.00	57.87	7.07	7.47	17.40	7.50	12.20	63.33	2.89	9.85
23	MML-13*MML-4	39.67	57.73	7.13	7.53	18.00	7.50	11.27	63.33	3.27	11.65
24	MML-13*MML-7	41.00	58.43	7.40	7.80	17.20	7.61	12.13	63.00	2.78	10.22
25	MML-13*MML10	39.67	56.93	7.53	7.80	18.20	7.45	12.27	61.67	3.05	11.47
26	HYM-1*MML-4	40.67	57.80	7.27	7.73	17.67	7.45	12.07	64.00	3.12	10.35
27	HYM-1*MML-7	41.00	57.40	7.27	7.60	17.27	7.77	12.13	61.67	2.91	9.94
28	HYM-1*MML10	41.33	58.53	7.27	7.53	17.33	7.69	12.13	61.00	2.91	9.35
29	HYM-2*MML-4	40.33	57.93	7.60	7.47	17.60	7.68	12.00	61.33	3.18	11.55
30	HYM-2*MML-7	41.33	57.20	7.27	7.67	17.40	7.90	12.53	62.00	3.01	10.18
31	HYM-2*MML10	41.33	57.80	7.47	7.60	17.93	8.15	12.53	62.67	2.75	10.39
32	SAMRAT	39.66	53.00	7.13	7.13	18.50	8.41	11.83	63.00	3.12	9.69
33	Grand mean	40.82	57.26	7.15	7.30	17.28	7.64	11.98	62.66	3.01	9.86
34	Parents mean	41.50	56.93	6.90	6.75	16.39	7.42	11.55	63.10	3.01	8.61
35	Hybrids mean	41.02	57.73	7.28	7.56	17.66	7.35	12.08	62.44	3.01	10.48
36	Maximum	42.66	59.46	7.60	7.80	18.50	8.41	12.60	65.33	3.30	11.64
37	Minimum	39.33	53.00	6.66	6.46	15.26	7.27	10.33	61.00	2.74	7.74
38	SE	0.46	0.88	0.14	0.15	0.44	0.21	0.635	0.64	0.08	0.42
39	CD (5%)	1.31	2.51	0.41	0.42	1.26	0.61	1.01	1.82	0.22	1.19
40	CV	1.97	2.68	3.51	3.60	4.50	4.96	5.21	1.78	4.64	7.42

Number of primary branches per plant

Among the parents, the mean performance of number of primary branches per plant was 6.90. The highest primary branches per plant, 7.06 was calculated for three parents, MML-5, MML-7 and MML-8. While lowest 6.73 was calculated for MML-12. However MML-5, MML-7 and MML-8 was statistically *at par* with parent MML-1 and HYM-1 (6.86). In case of crosses number of primary branches per plant ranged from 6.86 to 7.53 with men value of 7.28. Maximum primary branches per plant were recorded in cross MML-1 x MML-7. This was found to be statistically at par with all other twenty crosses. The minimum value of this character was recorded in the cross MML-12 x MML-4.

Number of clusters per plant

The mean of parents for this character was 6.75. The number of cluster per plant for parents ranged from 6.46 to 7.26. Maximum and minimum number of clusters per plant were recorded in parents HYM-2 and MML-7. In case of crosses, the mean of this character was 7.56. The highest number of clusters per plant was recorded in crosses MML-13 x MML-7 and MML-13 x MML-10 (7.80). However, it was statistically *at par* with crosses MML-1 x MML-4, MML-5 x MML-7, MML-12 x MML-4 and HYM-2 X MML-7 (7.66) followed by MML-1 x MML-10, MML-5 x MML-4, HYM-1 x MML-7 and HYM-2 x MML-10 (7.60). The lowest number of cluster per plant recorded in cross MML-12 x MML-7 (7.13).

Number of pods per plant

Number of pods per plantof mungbean ranged from 15.26 to 17.40 with the mean value of 16.39. Lowest value was

recorded in one parent MML-8 (15.26) While highest value was observed in parent HYM-2 (17.40). The parent HYM-2 was statistically highly significant to other ten parents. In case of crosses, mean recorded for number of pods per plant was 17.66 in which the highest was observed in crosses MML-5 x MML-4. However, it was statistically *at par* with crosses MML-1 x MML-4, MML-5 x MML-10, MML-8 x MML-7 and HYM-2 x MML-4 (17.60). The lowest number of mungbean pods per cluster was recorded in cross MML-1 x MML-10 (12.67).

Pod length

Then mungbean pod length ranged from 7.27 to 8.03 with the mean value of 7.42. Lowest value was recorded in parents MML-1 and HYM-2 (7.27) While highest value was observed in parent MML-8 (8.03). The parents MML-4 and HYM-1 (7.43) was statistically highly significant to other nine parents. In case of crosses, mean recorded for number of pod length was 7.35. in which the highest was observed in cross MML-12 x MML-7 (8.36). The lowest pod per were recorded in crosses MML-13 x MML-10 and HYM-1 x MML-4 (7.44).

Number of seeds per pod:

It is evident that with respect to parents, the mean recorded for number of seeds per pod was 11.55. Where the maximum seed (12.60) were observed for MML-13 while lowest number of seed (10.33) was observed for parent MML-7. it was found that parent MML-7 was statically at par with other ten characters. The mean recorded for number of mungbean seeds per pod in the different crosses was 12.08 with the highest being observed in HYM-2 x MML-10 (12.53) and the lowest with 11.26 being observed in cross MML-13 x MML-4. It was found that cross MML-13 x MML-4 was statistically at par with other 21 crosses.

Days to maturity:

Day to maturity in the parents ranged from 61.33 to 65.33 with an average value of 63.10. The maximum days was taken by MML-7 (65.33 days) followed by MML-7 (64.33 days) while the lower number of days was observed for parents HYM-2 (61.33). With respect to the different crosses, the mean for days to maturity was 62.44 with highest being observed for cross MML-8 x MML-10 (65.33). The minimum number of days was observed for cross HYM-1 x MML-10 with 61.00 days.

Seed index

The data for seed index character depicted that the mean for 100 seed weight in case of parents was recorded to be 3.01 g with the highest being recorded in parent MML-1 (3.30 g) followed by parent HYM-1 and MML-4 (3.08 g) while the lowest weight was observed in parent HYM-2 (2.86 g). Among the crosses , the mean was 3.24 g with the highest being recorded in cross MML-13 x MML-4 (3.26). The lowest being recorded in cross HYM-2 x MML-10 (2.74). MML-13 x MML-4 is statistically at par with all other crosses of mungbean.

Seed yield per plant:

A perusal of data for this economically important character in case of parents revealed that the seed yield per plant ranged from 7.74 to 9.90 with average value of 8.61 g also worked by (Srivastava and Singh 2013), Soehendi and Srinives 2005) [9]. The highest was observed for MML-7 (9.90 g) while the lowest was observed in MML-8 (7.74 g). The parent MML-7 was statistically with respect to the other nine parents. Among the crosses, the mean was recorded to be 10.48 g with the highest being recorded in cross MML-13 x MML-4 (11.64 g) and low yield being observed in HYM-1 x MML-10 (9.35 g). It was found that the cross MML-13 x MML-4 was statistically highly significant among 21 crosses. A perusal of mean value of yield and yield contributing characters revealed that among the parents MML-13 x MML-4 (11.64 g) exhibited maximum value of seed yield per plant mungbean along with other yield contributing characters *viz.,* seed index (3.26 g) also studied by Tyagi *et al*., 2006 [15]. On the basis of per se performance for seed yield per plant, five best high yielding identified hybrid are MML-13 x MML-4 (11.64 g), HYM-2 x MML-4 (11.55 g) MML-13 x MML-10 (11.46 g), MML-12 x MML-4 (11.36 g) and MML-8 x MML-4 (11.31 g) supported by Turner, 1953, Sujatha *et al.*, 2011 [14, 12].

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