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COMBINING ABILITY AND GENE ACTION ANALYSIS USING LINE × TESTER IN GREEN GRAM (*VIGNA RADIATA* L.)

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ABSTRACT

The present investigation was carried out at the Department of Genetics and Plant Breeding, School of Agriculture, Lovely Professional University, Phagwara, Punjab (India). The present study was undertaken by comprising 9 females or lines *viz.*, MGG- 366, MGG- 295, WGG-37 (eksheela), TM-96-2, MGG-348, MGG-347, MGG-351, Moong Tilak, Tilak Gold and 4 males or testers include Rajendran G-65, WGG-42, LGG- 460, Banshi Moong and 1 check (SML 668). The inbred lines were collected from the KVK, Rudroor, Telangana and ARS, Sri Ganganagar as part of germplasm collection. Total 36 crosses which made by Line × Tester mating design during summer 2023. The hybrids (36) along with parents (13) and 1 check were grown and tested in RBD with three replications during summer, 2023. The characters or traits studied in this research are *viz;* Days to 50 per cent flowering, Days to maturity, Plant height (cm), Number of branches per plant, 100 seeds weight (g), Grain yield per plant (g), Number of seeds per pod, Length of the pod (cm), Number of clusters per plant, Number of pods per plant, Harvest Index (%). The study confirms that lines MGG 366, MGG 347, MGG 348, TM 96-2 and Moong Tilak and testers LGG 460, Rajendran G-65 are best for development of hybrids. The cross MGG-348 × LGG-460 is the most significant cross resulted as best for most of the traits due to its more specific combining ability of crosses involved. The additive effect (A) is highest for trait of days to maturity followed by days to fifty percent flowering and plant height. The dominance effect is said to be the prime desirable character for beneficial traits and this effect is highly recorded in the traits of days to maturity followed days to fifty percent flowering.
***Keywords*:** General combining ability, Specific combining ability, Gene action, Heritability, Additive effect

Introduction

Green gram (*Vigna radiata* L.) an important crop in the pulse category, is an annual legume belonging to Fabaceae family that is widely grown, with diploid chromosome 2n=2x=22 (Karpechenko, 1925). It can be be grown in various cropping systems. It is highly valued in India, particularly among the predominantly vegetarian population, as it provides a rich source of easily digestible and high-quality protein. Mungbean seeds contain approximately 59 to 65% carbohydrates, 22 to 28% total protein, 21 to 25% amino acids, 1.5 to 2.63% lipids, 1.0 to 1.5% fat, 3.5 to 4.5% fiber, and 4-5% ash, offering approximately 334 to 344 kcal of energy per serving (Srivastava and Ali, 2004). Mungbean serves as a vital protein source for India's vegetarian population. Moreover, it is recognized for its abundant folate and iron content, surpassing most other legumes (Keatinge *et al.*, 2011). Essential amino acids, such as phenylalanine, isoleucine, leucine, and lysine, are also present in significant amounts (Lambrides and Godwin, 2007).

India holds the distinction of being the largest producer of Mungbean, accounting for 65% of the global cultivation area and 54% of production (Kumari *et al.*, 2023). The crop occupies approximately 4.34 million hectares in India, resulting in a production of 2.12 million tonnes and a productivity rate of 489 kg per hectare (Anon., 2020). Greengram is a self-pollinated and short duration crop. It provides a high-quality protein supply (22-24%) and boosts the incomes of small-scale farmers (Rahim *et al.*, 2010). Mature grain has carbohydrates (62.6g), fibre (16.3g), fat (1.2g), protein (23.9g) and 347 calories per 100 grams (Majhi *et al.*, 2020).

Line × tester cross is a modified form of the top-cross proposed by Davis (1927) for inbred evaluation. The line × tester technique was developed by Kempthorne (1957). It is good approach for screening the germplasm on the basis of GCA and SCA variances, and effects. The total number of crosses to be made is equal to the product of the number of lines and the number of testers included in the study. The line × tester technique has been extensively used in almost all the major field crops to estimate GCA and SCA variances and effects and to understand the nature of gene action involved in the expression of various quantitative traits. This technique measures the GCA and SCA variances and effects and the genetic components of variance. It however, fails to detect and estimate the epistatic variance.

The success of mung bean breeding depends on the ability to further exploit the vast number of genes and gene recombination's in the gene pool that would produce higher heterosis. The magnitude of heterosis depends on the choice of appropriate parental lines. The line × tester technique has been extensively used in almost all the major field crops to estimate GCA and SCA variances and effects and to understand the nature of gene action involved in the expression of various quantitative traits. This technique measures the GCA and SCA variances and effects and the genetic components of variance. It however, fails to detect and estimate the epistatic variance. With these ideas an experiment was conducted to study the general and specific combining ability, nature and magnitude of gene action for seed yield and its component traits using Line × Tester Analysis in Green gram (*Vigna radiata* L.) in 2023 in plain zone of Punjab.

Materials and Methods

The present investigation was conducted during *summer* 2023 at Post Graduate Research Farm, School of Agriculture, LPU, Punjab. The crossing program was implemented during *summer* 2023. The experiment was laid out in Randomized Block Design with three replications. It comprising of 36 crosses, 9 females and 4 male parents and one check *viz.*, SML 668 were included. The inbred lines were collected from the KVK, Rudroor, Telangana and ARS, Sri Ganganagar.

Estimation of GCA and SCA effects

ANOVA for analysis of combining ability using Line x Tester method and test of significance for different genotypes was performed according to Kempthorne (1957).

The individual effects of General Combining Ability (GCA) and Specific Combining Ability (SCA) were estimated by calculating the two-way table of female and male parents, and then summing the values obtained over multiple replications.

(a) GCA effects of A^{th} line

$$Gi = \frac{xA}{Tr} - \frac{\sum x}{LTr}$$

(b) GCA effects of B^{th} tester

$$Gj = \frac{xB}{Lr} - \frac{\sum x}{LTr}$$

(c) SCA effects of AB^{th} cross

$$Sij = \frac{xAB}{r} - \frac{xA}{T} - \frac{xB}{Lr} + \frac{\sum x.}{LTr}$$

Where,

$\sum x.$ = total sum of all crosses, $xA.$ = total sum of A^{th} lines over all testers and replications

x_A = total of B^{th} tester over all lines and replications,

x_{AB} = AB^{th} line x tester combination total over all replications,

r = No. of replications, L *and* T = No. of of lines and testers.

Estimation of variances of GCA and SCA

Estimation of variance of GCA and SCA was calculated by formulae (Singh and Chaudhary, 1977).

$$\sigma 2GCA = \frac{(M.L + M.T - 2.M.L.T)}{r(L+T)}$$

$$\sigma 2SCA = \frac{(M.L.T - M.r)}{r(L+T)}$$

Where,

M.L = Mean squares of female lines, *M.T* = Mean squares of male testers, *M.L.T* = Mean squares of line x tester (cross), *L and T* = number of lines and testers, *r* = number of replications.

Contribution of line, testers and their interactions to total variance

Proportional contribution of line, testers and their interactions to total variance computed as per (Singh and Chaudhary, 1977).

$$Contribution\ of\ Line = \frac{S.S.(L)}{S.S\ (Crosses)} \text{ x } 100$$

$$Contribution\ of\ Tester = \frac{S.S.(T)}{S.S\ (Crosses)} \text{ x } 100$$

$$Contribution\ of\ Line\ x\ Tester = \frac{S.S\ (L\ x\ T)}{S.S\ (Crosses)} \text{ x } 100$$

Where,

S.S.L = sum squares of lines
S.S.T = sum squares of testers
S.S crosses = sum squares of crosses
S.S Line x Tester = sum squares of line × tester

Table 1: List of Genotypes and check used in crossing programme

Sr.	Genotypes	Source
Lines		
1	MGG- 366	KVK, Rudroor, Telangana
2	MGG- 295	KVK, Rudroor, Telangana
3	WGG-37 (Eksheela)	KVK, Rudroor, Telangana
4	TM- 96-2	KVK, Rudroor, Telangana
5	MGG-348	KVK, Rudroor, Telangana
6	MGG-347	KVK, Rudroor, Telangana
7	MGG-351	KVK, Rudroor, Telangana
8	Moong Tilak	ARS, Sri Ganganagar
9	Tilak Gold	ARS, Sri Ganganagar
Testers		
1	Rajendran G-65	KVK, Rudroor, Telangana
2	WGG-42	KVK, Rudroor, Telangana
3	LGG- 460	ARS, Sri Ganganagar
4	Banshi Moong	ARS, Sri Ganganagar

Results and Discussion

Analysis of variance for combining ability

The analysis of variance for combining ability for eleven different characters have been presented in Table 2. The highest variance is reported for the traits like days to maturity (1630.56), plant height (661.73), days to fifty percent flowering (604.77), harvest index (172.77) and all the subsequent mentioned traits are highly significant. The least but significant trait or character is number of seeds per pod (5.71). The highest variance is achieved by traits like days to fifty percent flowering (379.5), plant height (368.6) and the least variance is with the trait of number of branches per plant (2.75) and all the fore-mentioned traits except number of branches per plant are highly significant.

The crossing of lines and testers, the variance is clearly visible with all the characters involved and none of the characters or traits devoid of significance i.e., all the traits are under significant. Higher variance is achieved by days to maturity (83.53), days to fifty percent flowering (83.09), harvest index (47.21), number of pods per plant (45.45). the least variance is attained by length of pod (0.61) and number of branches per plant (0.61). The highest variance is attained by the trait days to maturity (27.32) and days to fifty percent flowering (26.98), harvest index (13.71), number of pods per plant (12.39) while the lowest variance is attained by length of pod (0.18). While all the characters taken for the study got the significance.

GCA and SCA effects for parents and their crosses

The estimates of general combining ability effects of parents and specific combining ability effects for the hybrids were presented in Table 3 and 4 respectively.

Days to 50 per cent flowering

The lowest GCA effect is attained by MGG 366 followed by MGG 348. Highest GCA among testers attained by Moong Tilak. Whereas, the lowest and negative GCA is attained by LGG 460. Whereas, of all the hybrids produced from the cross of lines and testers. The highest and positive SCA is achieved by WGG- 37 (eksheela)× LGG-460, TM-96-2 × LGG-460, MGG-348 × BANSHI MOONG. Where the lowest GCA is recorded by WGG- 37 (eksheela) × RAJENDRAN-G-65, TM-96-2 × BANSHI MOONG, MGG-348 × LGG-460 which were similarly reported by Yashpal *et al.* (2015) and Bhavani *et al.* (2016).

Days to Maturity

The lowest GCA effect is attained by MGG 347 followed by MGG 295. Highest GCA among testers attained by WGG 42. Whereas, the lowest and negative GCA is attained by LGG 460. The highest and positive SCA is achieved by MGG-366 × BANSHI MOONG, MOONG TILAK × LGG-460, MGG-348 × BANSHI MOONG. Where the lowest GCA is recorded by MGG- 295× LGG-460, MGG-348 × LGG-460, MOONG TILAK × WGG-42 which were similar to the reported values of Yashpal *et al.* (2015).

Plant height (cm)

The lowest negative GCA is attained by Moog Tilak followed by TM 96-2. In testers, the range of GCA is about -3.85 to 7.09. Highest GCA among testers attained by Rajendran G-65. Whereas, the lowest and negative GCA is attained by Banshi Moong. The highest and positive SCA is achieved by MGG-347× LGG-460, MGG 366 × RAJENDRAN- G-65. Where the lowest GCA is recorded by MGG-347 × RAJENDRAN-G-65, WGG- 37 (eksheela) × RAJENDRAN-G-65, MGG-348 × LGG-460 were similarly reported by Bhavani *et al.* (2016) and Mohan *et al*. (2019).

Number of branches per plant

Lowest negative GCA is attained by TM 96-2 followed by WGG 37. Highest GCA among testers attained by Banshi Moong. Whereas, the lowest and negative GCA is attained by LGG 460. The highest and positive SCA is achieved by MGG-347× BANSHI MOONG, WGG- 37 (eksheela) × BANSHI MOONG, MGG 366 × RAJENDRAN-G-65. Where the lowest GCA is recorded by TILAK GOLD × BANSHI MOONG which were similar to the reported values of Khaimichho *et al*. (2016) and Shalini *et al.* (2019).

Number of pods per plant

The highest positive GCA is attained by MGG 295 followed by MGG 347 whereas, the lowest negative GCA is attained by Moong Tilak. Highest GCA among testers attained by Rajendran G-65. Whereas, the lowest and negative GCA is attained by Banshi Moong. The highest and positive SCA is achieved by MGG-351 × RAJENDRAN-G-65. Where the lowest GCA is recorded by MGG-351 × LGG-460 which were similarly mentioned in findings of Narasimhulu *et al*. (2014) and Kumar *et al.* (2017).

100 seeds weight (g)

The lowest GCA is attained by MGG 347. In testers, the range of GCA is about -0.55 to 1.42. Highest GCA among testers attained by LGG 460. Whereas, the lowest and negative GCA is attained by WGG 42. The highest and positive SCA is achieved by MOONG TILAK × RAJENDRAN-G-65. Where the lowest GCA is recorded by MGG-348 × WGG-42 which were similar to the findings of Nath *et al*. (2018).

Grain yield per plant (g)

The lowest GCA is attained by Moong Tilak. In testers, the range of GCA is about -1,78 to 0.47. Highest GCA among testers attained by Rajendran G-65. Whereas, the lowest and negative GCA is attained by Banshi Moong. The highest and positive SCA is achieved by TILAK GOLD × RAJENDRAN-G-65. Where the lowest GCA is recorded by WGG- 37 (eksheela)× WGG-42 were reported similarly by Khaimichho *et al*. (2016) and Yashpal *et al.* (2015).

Number of seeds per pod

The highest positive GCA is attained by MGG 351 whereas, the lowest GCA is attained by MGG 347. In testers, the range of GCA is about -0.67 to 0.44. Highest GCA among testers attained by LGG 460. Whereas, the lowest and negative GCA is attained by Banshi Moong. The highest and positive SCA is achieved by TM-96-2 × RAJENDRAN-G-65. Where the lowest GCA is recorded by MGG-348 × BANSHI MOONG were reported similarly by Mukati *et al.* (2014) and Mohan *et al*. (2019).

Length of pod (cm)

The highest positive GCA is attained by MGG 348 whereas, the lowest GCA is attained by MGG 351. In testers, the range of GCA is about -0.50 to 1.04. Highest GCA among testers attained by LGG 460. Whereas, the lowest and negative GCA is attained by WGG 42. The highest and positive SCA is achieved by WGG- 37 (eksheela) × BANSHI MOONG. Where the lowest GCA is recorded by TM-96-2 × LGG-460 were reported similar by Debbarma *et al.* (2022) and Kumar *et al*. (2017).

Number of clusters per plant

The highest positive GCA is attained by Tilak Gold whereas, the lowest GCA is attained by Moong Tilak. In testers, the range of GCA is about -0.31 to 0.34. Highest GCA among testers attained by WGG 42. Whereas, the lowest and negative GCA is attained by Rajendran G-65. The highest and positive SCA is achieved by MGG-347× LGG-460. Where the lowest GCA is recorded by MOONG TILAK × WGG-42 were reported similarly by Mukati *et al*. (2014) and Shalini *et al.* (2019).

Harvest Index (%)

The highest positive GCA is attained by TM 96-2 whereas, the lowest GCA is attained by WGG 37. In testers or male parent, the range of GCA is about -3.14 to 2.55. Highest GCA among testers attained by Rajendran G-65. Whereas, the lowest and negative GCA is attained by WGG 42. The highest and positive SCA is achieved by WGG- 37 (eksheela) × RAJENDRAN-G-65, MGG-347 × WGG-42. Where the lowest GCA is recorded by TM-96-2 × RAJENDRAN-G-65 which were similarly reported by the findings of Bhavani, *et al.* (2016) and Kumar *et al*. (2017).

Gene action and Heritability

The value of the estimates of G.C.A. and S.C.A. variance, their A and D effects and percentages of the heritability in narrow sense along with nature of gene action were presented in Table 5. The variance due to G.C.A. effects were higher for days to maturity (46.61) followed by plant height (25.92), days to fifty percent flowering (25.13) whereas, the lowest G.C.A is attained by number of seeds per pod (0.18), number of clusters per plant (0.23), length of pod (0.43) and none of the traits shown the negative G.C.A effects. While the S.C.A effects of hybrids made by the crossing between nine lines and four testers showing the range of about 0.14 to 27.32, where the traits days to maturity (27.32) and days to fifty percent flowering (26.98) shows higher S.C.A effects and traits like number of branches per plant (0.14), length of pod (0.18), number of seeds per pod (0.31) shows lower S.C.A effects compared to rest of traits.

When it comes to the Additive (A), Dominant (D) and Epistasis (E) in this study additive effect (A) is predominantly higher in days to maturity (93.23) followed by days to fifty percent flowering (26.98) and thereby lowest in traits of number of branches per plant (0.16) followed by number of clusters per plant (0.46). The dominance effect (D) as an important parameter shows highest effect in traits of days to maturity (27.3), days to fifty percent flowering (26.98) while becoming lowest in the traits of number of branches per plant (0.14) followed by length of pod (0.18), number of seeds per pod (0.31). Whereas, the epistatic effects of traits considered shown higher in plant height (3.25) followed by number of seeds per pod (2.75), harvest index (2.04) and lowest in length of pod (0.02) followed by number of clusters per plant (0.07), number of seeds per pod (0.07).

Heritability (narrow sense) of the study provided better result in most of the characters and it recorded the highest in the traits of plant height (82.43) followed by days to maturity (77.00), days to fifty percent flowering (64.47) while it has recorded lowest in the traits of 100 seed weight (11.18) followed by number of clusters per plant (26.43). The ratio of gca and sca showed its significance in giving the gene action and the ratio is highest in plant height (3.33) and lowest in grain yield per plant (0.14). The traits thereby give the gene action of non-additive gene action for all the traits except days to maturity, plant height, length of pod.

Percentage contribution of females, males and female x male interaction

Percentage contribution of males, females and females x males to the sum of square of hybrids are presented in Table 6. The contribution of all the lines (female parent) and testers (male parent) were estimated under the present study gives the comprehensive involvement of both the parents under the different traits. The traits showing higher contribution of lines are number of branches per plant (56.71%) followed by plant height (51.47%), days to fifty percent flowering (44.36%) while lower contribution of lines in days to maturity (18.10%). The contribution of testers includes higher in the traits of days to maturity (58.09%) followed by length of pod (52.38%), plant height (34.65%) and the lowest is recorded in the traits of number of branches per plant (5.58) followed by number of clusters per plant (4.04%). While the contribution in female and male interaction gives higher in the traits of 100 seed weight (59.10%) followed by harvest index (54.43%), number of pods per plant (49.22%) whereas the lowest recorded in plant height (13.89%), followed by length of pod (18.08%).

Conclusion

The present study identified promising cross combinations with superior specific combining ability (sca) effects for key yield and related traits in mungbean. The cross MGG-348 × LGG-460 was most notable, excelling in 100-seed weight, grain yield per plant, number of pods per plant, and seeds per pod. MGG-348 × RAJENDRAN-G-65 showed superiority for earliness and maturity traits, while MGG-347 × WGG-42 and MGG-347 × LGG-460 were effective for plant height, pod length, clusters per plant, and maturity-related traits. In addition, MOONG TILAK × BANSHI MOONG and MGG-366 × WGG-42 exhibited desirable sca for seed weight, clusters per plant, and harvest index. Non-additive gene action predominantly governed yield traits, suggesting the potential of heterosis breeding for improvement. Heritability estimates indicated high heritability for plant height and lower values for 100-seed weight. These findings provide valuable direction for exploiting heterosis and guiding future breeding programs aimed at enhancing mungbean productivity.

Table 2 : Analysis of variance for combining ability

Sr. No	Source of variation	d.f.	Days to 50 per cent flowering	Days to Maturity	Plant height (cm)	Length of pod (cm)	Number of branches per plant	100 seed weight (g)	Grain yield per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Harvest index
1	**Females**	8	379.5**	190.56	368.6**	2.93**	2.75**	31.71	16.43	7.36	101.12	1.81	53.81
2	**Males**	3	604.77**	1630.56**	661.73**	13.87**	0.72	40.41	26.48*	2.13	105.43	5.71**	172.77*
3	**Female x Male**	24	83.09**	83.53**	33.15**	0.61**	0.61**	22.57**	7.90**	3.88**	45.45**	1.15**	47.21**
4	**Error**	70	2.14	1.56	9.77	0.06	0.19	0.45	1.30	0.22	8.27	0.21	6.11
5	**δ^2 GCA Lines**	8	31.44**	15.75	29.90**	0.24**	0.21**	2.61	1.26	0.59	7.74	0.13	3.97
6	**δ^2 GCA Tester**	3	22.32**	60.33**	24.15**	0.51**	0.02	1.48	0.93*	0.07	3.60	0.20**	6.17*
7	**δ^2 for L x T**	24	26.98**	27.32**	7.79**	0.18**	0.1393**	7.37**	2.20**	1.22**	12.39**	0.31**	13.71**

Table 3 : The estimates of the general combining ability effects for eleven characters in Green gram

Sr. No	Lines	Days to 50 per cent flowering	Days to Maturity	Plant height (cm)	Length of pod (cm)	Number of branches per plant	100 seed weight (g)	Grain yield per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Harvest index
1	**MGG 366**	-6.61 **	0.47	-0.47	-0.18 *	0.34**	1.06**	1.70 **	0.20	2.03*	0.27*	1.18
2	**MGG 295**	8.31**	-1.86 **	-0.26	0.05	0.42 **	0.62**	0.63	-0.66 **	3.53 **	0.26	3.01**
3	**WGG 37**	-3.19**	1.72**	3.56**	0.09	-0.50**	1.31**	-0.71*	-1.03**	-1.37	-0.05	-4.28**
4	**TM-96-2**	-2.86 **	0.89 *	-1.73	0.06	-0.77**	0.66**	-0.64	0.12	-1.65	-0.19	2.25**
5	**MGG- 348**	-5.36**	-1.69**	-1.82*	1.22**	0.48**	1.06**	1.59**	0.56**	0.76	-0.18	-0.89
6	**MGG- 347**	1.06*	-5.61**	11.89**	-0.19**	-0.02	0.01	-0.83*	0.59**	3.33**	-0.35**	-0.22
7	**MGG- 351**	9.56**	0.64	-0.25	-0.43**	-0.24	-0.32	0.54	0.08	-0.12	0.54**	0.31
8	**MOONG TILAK**	-0.86*	8.64**	-9.03**	-0.26**	-0.28*	-4.01**	-0.56	-1.09**	-5.84**	0.37**	-0.98
9	**TILAK GOLD**	-0.03	-3.19**	-1.86*	-0.35**	0.57**	-0.40*	-1.71**	1.22**	-0.66	-0.67**	-0.38
S.E.		**0.42**	**0.36**	**0.90**	**0.07**	**0.13**	**0.19**	**0.33**	**0.14**	**0.83**	**0.13**	**0.71**
C.D. 5%		**0.84**	**0.72**	**1.80**	**0.14**	**0.25**	**0.38**	**0.66**	**0.27**	**1.66**	**0.26**	**1.42**
C.D. 1%		**1.12**	**0.96**	**2.39**	**0.19**	**0.33**	**0.51**	**0.87**	**0.36**	**2.20**	**0.35**	**1.89**
10	**RAJENDRAN G-**	-1.06**	-3.65**	7.09**	-0.11**	-0.03	0.47**	-0.09	-0.31**	2.42**	0.24**	2.55**
11	**65 WGG- 42**	1.34**	10.13**	-0.37	-0.50**	-0.09	0.99**	-0.8**	0.34**	0.23	-0.07	-3.14**
12	**LGG- 460**	-5.81**	-7.94**	-2.88**	1.04**	-0.12	0.33**	1.42**	0.11	-0.26	0.44**	1.45**
13	**BANSHI MOONG**	5.53**	1.46**	-3.85**	-0.43**	0.24**	-1.78**	-0.55**	-0.15	-2.39**	-0.61**	-0.87*
S.E.		**0.28**	**0.24**	**0.60**	**0.05**	**0.08**	**0.13**	**0.22**	**0.09**	**0.55**	**0.09**	**0.48**
C.D. 5%		**0.56**	**0.48**	**1.20**	**0.09**	**0.17**	**0.26**	**0.44**	**0.18**	**1.10**	**0.18**	**0.95**
C.D. 1%		**0.75**	**0.64**	**1.59**	**0.13**	**0.22**	**0.34**	**0.58**	**0.24**	**1.47**	**0.23**	**1.26**

*, ** indicates at 5% and 1%level of significant, respectively

Table 4 : Estimates of specific combining ability effects for crosses in Green gram

Sr. No	Hybrids	Days to 50 percent flowering	Days to Maturity	Plant height (cm)	Length of pod (cm)	Number of branches per plant	100 seed weight (g)
1	MGG 366 × RAJENDRAN-G-65	5.65**	-3.77**	4.44*	-0.26	0.51*	-2.98**
2	MGG- 366× WGG- 42	3.57**	-6.5**	-0.60	-0.23	-0.54*	1.49**
3	MGG- 366×LGG- 460	-4.28**	1.53*	-3.31	0.72**	-0.20	3.19**
4	MGG-366 × BANSHI MOONG	-4.94**	8.79**	-0.53	-0.23	0.24	-1.70**
5	MGG-295× RAJENDRAN-G-65	1.40	3.56**	1.08	0.01	0.13	-0.75
6	MGG- 295 × WGG-42	2.99**	2.79**	-0.51	-0.03	0.02	-2.48**
7	MGG- 295× LGG-460	-6.86**	-7.5**	-3.30	0.26	-0.31	4.12**
8	MGG-295 × BANSHI MOONG	2.47**	1.12	2.73	-0.23	0.16	-0.89*
9	WGG-37(eksheela)× RAJENDRAN-G-65	-11.77**	-0.35	-5.45**	-0.59**	-0.52*	-0.27
10	WGG-37(eksheela)× WGG-42	0.82	-1.13	2.48	0.02	-0.16	-3.53**
11	WGG- 37 (eksheela)× LGG-460	6.97**	4.94**	3.48	-0.39**	-0.03	0.12

12	WGG- 37 (eksheela) × BANSHI MOONG	3.97**	-3.4**	-0.50	0.96**	0.71**	3.69**
13	TM-96-2 × RAJENDRAN-G-65	0.56	-1.85*	1.27	0.40**	-0.58*	2.17**
14	TM-96-2 × WGG-42	1.16	-0.63	-0.02	0.46**	0.54*	-0.37
15	TM-96-2 × LGG-460	6.31**	5.44**	-2.25	-0.92**	0.40	-2.63**
16	TM-96-2 × BANSHI MOONG	-8.03**	-2.9**	1.00	0.06	-0.36	0.84*
17	MGG-348× RAJENDRAN-G-65	2.73**	4.06**	1.708	0.64**	0.03	-2.59**
18	MGG-348 × WGG-42	0.32	3.29**	-0.42	-0.17	0.29	-0.49
19	MGG-348 × LGG-460	-7.19**	-7.3**	-1.38	0.05	0.15	2.83**
20	MGG-348 × BANSHI MOONG	4.14**	-0.05	0.09	-0.51**	-0.47	0.25
21	MGG-347× RAJENDRAN-G-65	0.98	-6.0**	-6.18**	-0.41**	-0.06	1.70**
22	MGG-347 × WGG-42	-2.09*	6.20**	-1.22	-0.12	-0.27	2.58**
23	MGG-347× LGG-460	2.06*	-3.1**	6.82**	0.53**	-0.50*	-3.31**
24	MGG-347× BANSHI MOONG	-0.94	2.87*	0.58	0.01	0.84**	-0.98*
25	MGG-351 × RAJENDRAN-G-65	3.15**	-1.9**	3.32	-0.01	0.16	-0.19
26	MGG-351 × WGG-42	-0.26	0.95	-1.95	0.14	-0.05	1.17**
27	MGG-351 × LGG-460	-5.78**	4.36**	-2.22	0.03	-0.12	0.27
28	MGG-351 × BANSHI MOONG	2.89**	-3.4**	0.85	-0.16	0.02	-1.24**
29	MOONG TILAK × RAJENDRAN-G-65	-2.10*	2.73**	-2.21	0.19	0.23	-2.20**
30	MOONG TILAK × WGG-42	-3.18**	-7.4**	4.23*	0.04	0.02	1.95**
31	MOONG TILAK × LGG-460	4.64**	7.03**	1.47	-0.20	0.22	-1.76**
32	MOONG TILAK × BANSHI MOONG	0.64	-2.4**	-3.49	-0.02	-0.47	2.01**
33	TILAK GOLD × RAJENDRAN-G-65	-0.60	3.56**	2.02	0.04	0.11	5.11**
34	TILAK GOLD × WGG-42	-3.34**	2.45**	-1.98	-0.10	0.16	-0.32
35	TILAK GOLD × LGG-460	4.14**	-5.5**	0.68	-0.08	0.39	-2.83**
36	TILAK GOLD × BANSHI MOONG	-0.19	-0.55	-0.72	0.13	-0.66*	-1.97**
S.E.		**0.84**	**0.72**	**1.80**	**0.14**	**0.25**	**0.39**
C.D. 5%		**1.68**	**1.44**	**3.61**	**0.29**	**0.50**	**0.77**
C.D. 1%		**2.24**	**1.91**	**4.78**	**0.38**	**0.67**	**1.02**

Table: 4 Estimates of specific combining ability effects for crosses in Green gram (Contd)…

Sr. No	**Hybrids**	**Grain yield per plant**	**Number of clusters per plant**	**Number of pods per plant**	**Number of seeds per pod**	**Harvest index**
1	MGG 366 × RAJENDRAN-G-65	-0.05	-2.06**	-1.44	-0.35	1.14
2	MGG- 366× WGG- 42	0.32	0.64*	1.43	-0.80**	3.11*
3	MGG- 366×LGG- 460	1.07	0.47	3.03	0.48	-0.72
4	MGG-366 × BANSHI MOONG	-1.34*	0.96**	-3.02	0.67*	-3.53*
5	MGG-295× RAJENDRAN-G-65	-1.51*	0.61*	-1.08	-0.44	1.81
6	MGG- 295 × WGG-42	-1.38*	0.30	1.02	-0.09	-0.77
7	MGG- 295× LGG-460	0.78	0.87**	2.11	0.52	0.37
8	MGG-295 × BANSHI MOONG	2.12**	-1.78**	-2.05	0.01	-1.41
9	WGG-37(eksheela)× RAJENDRAN-G-65	0.37	0.31	-1.24	-0.43	7.78**
10	WGG-37(eksheela)× WGG-42	0.23	1.00**	5.09**	0.18	2.85
11	WGG- 37 (eksheela)× LGG-460	-0.23	-2.27**	-4.52**	-0.30	-4.58**
12	WGG- 37 (eksheela) × BANSHI MOONG	-0.37	0.96**	0.66	0.55*	-6.05**
13	TM-96-2 × RAJENDRAN-G-65	0.29	-0.11	1.62	1.14**	-5.54**
14	TM-96-2 × WGG-42	0.19	-0.08	0.54	0.16	2.42
15	TM-96-2 × LGG-460	-1.23	-0.25	-4.23*	-0.39	0.40
16	TM-96-2 × BANSHI MOONG	0.75	0.44	2.06	-0.90**	2.71
17	MGG-348× RAJENDRAN-G-65	-0.90	-0.08	-3.33*	0.43	0.31
18	MGG-348 × WGG-42	-2.21**	1.01**	-1.87	-0.45	-1.02
19	MGG-348 × LGG-460	2.12**	-0.42	4.79**	0.93**	2.34
20	MGG-348 × BANSHI MOONG	1.10	-0.50	0.42	-0.91**	-1.63
21	MGG-347× RAJENDRAN-G-65	-1.01	-0.25	2.17	0.24	-7.35**
22	MGG-347 × WGG-42	1.12	-0.89**	-1.74	0.06	5.12**
23	MGG-347× LGG-460	-1.08	1.57**	4.61**	-0.09	-0.29
24	MGG-347× BANSHI MOONG	0.97	-0.44	-5.05**	-0.20	2.52
25	MGG-351 × RAJENDRAN-G-65	-1.16	0.17	6.25**	-0.45	-0.21
26	MGG-351 × WGG-42	0.63	0.59*	1.82	0.11	-2.53

27	MGG-351 × LGG-460	0.75	-0.44	-8.51**	0.32	2.11
28	MGG-351 × BANSHI MOONG	-0.21	-0.32	0.45	0.04	0.62
29	MOONG TILAK × RAJENDRAN-G-65	4.35**	0.91**	-1.75	-0.08	2.02
30	MOONG TILAK × WGG-42	-0.62	-2.34**	-2.94	0.25	-4.54**
31	MOONG TILAK × LGG-460	-1.66*	0.79**	1.70	-0.60*	-0.42
32	MOONG TILAK × BANSHI MOONG	-2.07**	0.65*	2.99	0.44	2.94*
33	TILAK GOLD × RAJENDRAN-G-65	-0.36	0.52	-1.20	-0.04	0.01
34	TILAK GOLD × WGG-42	1.72*	-0.25	-3.33*	0.60*	-4.63**
35	TILAK GOLD × LGG-460	-0.51	-0.32	-3.34*	-0.87**	0.81
36	TILAK GOLD × BANSHI MOONG	-0.85	0.04	3.54*	0.31	3.82**
S.E.		**0.66**	**0.27**	**1.66**	**0.27**	**1.428**
C.D. 5%		**1.31**	**0.54**	**3.31**	**0.53**	**2.85**
C.D. 1%		**1.75**	**0.72**	**4.40**	**0.70**	**3.78**

Table 5 : Gene action and heritability for eleven different characters in Green gram

Parameter	Days to 50 percent flowering	Days to Maturity	Plant height (cm)	Length of pod (cm)	Number of branches per plant	100 seed weight (g)	Grain yield per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Harvest index
δ^2gca	25.13	46.61	25.92	0.43	0.08	1.83	1.03	0.23	4.87	0.18	5.51
δ^2sca	26.98	27.32	7.79	0.18	0.14	7.37	2.2	1.22	12.39	0.31	13.72
δ^{2a}	50.25	93.23	51.84	0.85	0.16	3.65	2.07	0.46	9.74	0.36	10.99
δ^{2d}	26.98	27.3	7.79	0.18	0.14	7.37	2.19	1.22	12.39	0.31	13.73
δ^{2e}	0.71	0.52	3.25	0.02	0.06	0.14	0.43	0.07	2.75	0.07	2.04
h^2(ns) %	64.47	77.00	82.43	81.09	43.82	11.18	43.96	26.43	39.14	48.67	41.13
δ^2gca/δ^2sca	0.93	1.71	3.33	2.39	0.57	0.25	0.14	0.19	0.39	0.58	0.40
Nature	**Non-Additive**	**Additive**	**Additive**	**Additive**	**Non-Additive**	**Non-Additive**	**Non-Additive**	**Non-Additive**	**Non-Additive**	**Non-Additive**	**Non-Additive**

Table 6 : Percentage contributions of females, males and females x male interaction

Sr.	Traits	Females (%)	Males (%)	Hybrid (%)
1	Days to 50 per cent flowering	44.36 %	26.51 %	29.13 %
2	Days to Maturity	18.10 %	58.09 %	23.81 %
3	Plant height (cm)	51.47 %	34.65 %	13.89 %
4	Number of branches per plant	56.71 %	5.58 %	37.70 %
5	Number of pods per plant	36.50 %	14.27 %	49.22 %
6	100 seeds weight (g)	27.68 %	13.22 %	59.10 %
7	Grain yield per plant (g)	32.82 %	19.83 %	47.35 %
8	Number of seeds per pod	24.49 %	28.88 %	46.63 %
9	Length of pod (cm)	29.54 %	52.38 %	18.08 %
10	Number of clusters per plant	37.19 %	4.04 %	58.76 %
11	Harvest Index (%)	20.67 %	24.91 %	54.43 %

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