COMBINING ABILITY ANALYSIS OF BLACKGRAM

R. Elangaimannan, M. Venkatesan* and P. Karthikeyan
Department of Genetics and Plant Breeding
Faculty of Agriculture, Annamalai University
Annamalai Nagar, Tamilnadu

ABSTRACT

An investigation was carried out at Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University to evaluate the parents (lines and testers) and their hybrids in blackgram for seed yield and its component traits with an objective of developing superior hybrids for recombination breeding and to understand the nature of gene action for ten productive traits. Line x Tester mating design was adapted using seven lines and three testers and twenty one hybrids. The ratio of GCA/SCA variance revealed the predominance of non-additive gene action for all the characters studied. The lines which recorded high seed yield per plant viz., L1 (2KU-53) and L4 (VBG 05-014) were good general combiners for many of the traits studied. The testers which showed high seed yield per plant viz., T3 (VBN-5) and T1 (T9) were good general combiners for many of the traits studied. Evaluation based on high per se performance, favourable gca effects and tester non significant sca effects of hybrids resulted in the identification of L1 x T3 (2KU-53 x VBN-5) and L6 x T3 (VBG-05-014 x VBN-5) for recombination breeding.

Key words: Blackgram, *per se* performance, gca and sca effects, recombination breeding

INTRODUCTION

Black gram (*Vigna mungo* L. Hepper.) 2n = 22 family Fabaceae is an important pulse crop originated in India. Pulses are the major source of dietary protein for the vegetarian people. They are rich in protein content than cereals and other crops. In pulses, the protein content ranges from 20-40 percent as compared to 8-12 percent in cereals. Pulses are rich in lysine content with an average of 65 ± 7 mg/g of protein as compared to 29 ± 7 mg/g in cereals. It showed that pulses have 2-3 times more lysine content than cereals. In developing countries, pulses serve as major source of protein when compared to greater dependence of animal protein (56%) in developing countries. People in developing countries get only 12 percent protein from animal sources, whereas, 80 percent protein requirement comes from plant sources, mainly pulses. However in India, the net availability of pulses per day declined to 31.2g/day in 2007 when compared to 41.6 g in 1991 and 51.2 g in 1971 as against the recommended dietary allowance of 50g/day. Therefore, the only practical means of solving the protein malnutrition problem is to increase greatly the production of the pulse crops. The pulse crops, in general, give lower yield level than cereal crops. Norman E. Boarlaug (1973) claims that the pulses remain at low yield level and production is either static or dropping and hence he called them a 'slow runners'. This is due to fact that pulses have been mostly grown in poor soils and rainfed condition.

However, for nutritional security and sustainable agriculture, pulses play a significant role. Pulses occupy 68.82 million hectares and contribute 57.57 million tonnes to the world food basket. India ranks first in area and production of pulse crops and it shares 35.20 percent area and 27.65 per cent of global production. However, in India, area under pulses had dropped from 23.6 million hectares in 1961-61 to 20.5 million hectares in 2007-08. The production also had dropped from 13.35 million tonnes in 1999-2000 to 556 kg/ha in 2007-08. This sudden decline was due to both biotic and abiotic factors and lack of suitable varieties and genotypes with adaption to local conditions. This calls for constant integrated efforts to increase the production of pulse crop.

MATERIALS AND METHODS

The present investigation was carried out at the Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalainagar, Tamil Nadu. The experimental materials for the study consisted of seven lines and three testers obtained from Indian Institute of pulses Research, Kanpur, National Pulses Research Centre, Vamban, Tamilnadu Rice Research Institute (TRRI) Aduthurai and Plant Breeding Farm Annamalai University. The details of the selected parental materials for the study are furnished in Table 1. The testers used in the study were agronomically well adapted to this region.

Table -1. Blackgram genotypes utilized for the study

Lines	Testers
2KU-53 (L_1) VBG04-0012 (L_2) PS-1 (L_3) AUB-08-13 (L_4) RGRU-448 (L_5) VBG-05-014 (L_6) RU-08-702 (L_7)	T9 (T_1) ADT3 (T_2) VBN5 (T_3)

The seven lines (female parents) and three testers (male parents) were raised in three rows of 5 metre length, with a spacing of 30 x 15 cm at Plant Breeding Farm. Each of the seven lines was crossed with each of the three testers and a total of 21 cross combinations were obtained by following the method of Line x Tester analysis (Kempthorne, 1957). The 10 genotypes (seven lines and three testers) and 21 crosses were raised in a randomized block design with three replications. Each genotype was accommodated in a single row of 2m length with a spacing of 30 x 10 cm. An uniform population of twenty plants per replication was maintained in each genotype. The recommended agronomic practices were followed throughout the crop period. Observations were recorded for ten traits *viz.*, Days to first flowering, Plant height (cm), Number of branches per plant, Number of clusters per plant, Number of pods per cluster, Number of pods per plant, Number of seeds per pod, Pod length (cm), 100 Seed weight (g) and Seed yield per plant (g) in five randomly selected plants.

Scoring based on combining ability effects

The parents or cross combinations which showed significant positive *gca* or *sca* effects were given the score +1. The parents or cross combinations which recorded significantly negative *gca* or *sca* effects were given the score -1. The parents or cross combinations which registered non-significant *gca* or *sca* were given the score 0. For days to first flowering and plant height, negative significant *gca* or *sca* effects were given the score +1 and positive significant *gca* or *sca* effects were given the score -1. The genotype, which exhibited +1 was considered as good combiner. The genotype, which scored -1 was considered as poor combiner. The genotype, which scored 0, was considered as an average combiner.

Statistical Analysis

The estimation of mean, variance and standard error was worked out by adopting the standard methods of Panse and Sukhatme (1964). The test of significance was carried out by referring to the 'F' table given by Snedecor (1961). Line x tester analysis was carried out to test parents and hybrids based on their general and specific combining ability respectively. The general combining ability effects of the parents and specific combining ability effects of the crosses were worked out as suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

The analysis of variance revealed that the lines, testers, Line x Tester and parents Vs crosses differed among them for most of the characters studied. This indicated the presence of high genetic variability in the reference population. Therefore, further analysis of combining ability is appropriate. The estimate of components of variance provides an idea about additive and non additive (dominant) types of gene action (Baker, 1978). Panse (1942) suggested that if additive variance is greater than non additive variance, the chance of fixing superior genotypes in the early segregating generations would be greater and if non additive gene action is predominant selection has to be postponed to later generations. The estimate of dominance genetic variance (SCA) was greater than additive genetic variance (GCA) for most of the traits were controlled by non additive gene action. To exploit the dominance gene action of these traits, heterosis breeding or hybridization followed by selection in later generation is recommended for the improvement of blackgram. Rajanbabu(1997), Vaithiyalingam *et al*. (2002), Chand and Raghunadha Rao (2002) and Srividhya *et al.* (2005) observed predominance of the non-additive gene action in controlling these traits.

Evaluation of parents

Choice of parents is the basic need and it plays a major role in any breeding programme that was the pre-requisite for the breeders in crop improvement as they are expected to produce desirable segregants (Gilbert, 1958). Among the testers, T_3 and T_1 and among lines, L_4 followed by L_5 and L_7 expressed maximum mean seed yield per plant along with contributing characters (Table 2). Hence, these parents could be recommended to utilize as donors in cross breeding programme and crosses involving them will be expected to throw desirable segregants for seed yield. The general combining ability is defined as the average performance of a strain in a series of cross combinations. Singh and Harisingh (1985) and Tiwari *et al*. (1993) had also suggested that parents having high gca effects(Table 3) could produce transgressive segregants in F_2 or later generations. Among the lines, L_1 (+7), L_5 (+5), L_6 (+4), L_2 (+3), and L_4 (+1) were identified as good general combiners. Among testers, T_3 (+8) and T_1 (+3) were found as good general combiners, based on overall general combining ability (Table 4) and the crosses involving those parents results in the identification of superior segregants for favorable traits. Based on mean, gca and scoring, it can be concluded that single plant did not possess all the desirable attributes and the parents show diversity in the dispersion of characters.

Relationship of parents based on mean and *gca* effects

Combination of *per se* performance and *gca* effects will result in the selection of parents with good reservoir of superior genes. According to Sharma and Chauhan (1985), the *per se* performance and *gca* effects of the parents were directly related to each other. Majumder and Bhowal (1988) also reported parallelism between *per se* performance and *gca* effects for improvement of any character. The contribution of parents to hybrid performance was accomplished by comparing the *gca* effects. The lines and testers which recorded high seed yield per plant *viz*., L_1, L_2, T_1 and T_3 were good general combiners for three, two, five and six out of ten characters studied respectively. The parent T_2 exhibited significant *gca* effect for almost all the traits including seed yield per plant. The T_3 showed significant *gca* effect for most of the traits including seed yield per plant except days to first flowering and plant height. The line L_1 registered significant *gca* effect for plant height, 100 seed weight and seed yield per plant. The other line L_5 exhibited significant *gca* effect for the traits number of branches per plant and seed yield per plant. The high performance coupled with high *gca* effects in the parents T_3, T_1, L_1, and L_5 indicated that these genotypes have enormous amount of additive genetic variability for the above mentioned traits (Table 5). Thus, it can be concluded that crosses involving the above mentioned parent would result in the identification of superior segregants for seed yield.

Evaluation of Hybrids

Twenty one hybrids were synthesized following the line x tester mating design by using seven lines and three testers. They were evaluated for their *per se* performance and *sca* effects. Since *per se* performance is realized values, it is employed as the first criterion for selecting superior hybrids. In the present investigation, the hybrids namely, L_1 x T_3, L_6 x T_3, L_2 x T_1, L_2 x T_3 and L_4 x T_1 exhibited maximum significant mean seed yield per plant out of twenty one hybrids studied (Table 6). The above said five hybrids also registered higher significant mean value for number of branches, number of clusters, number of pods per plant and 100 seed weight coupled with moderate number of days to first flowering and number of pods per cluster. The hybrids L_6 x T_3 and L_2 x T_3 also showed less plant height. It is understood that earliness coupled with higher seed yield could well be achieved. Black gram breeders can also reduce the plant height and increase the number of branches, clusters, pods per plant and 100 seed weight and can develop early but high yielding short plant type.

The specific combining ability is defined as average performance of specific cross combination expressed as deviation from the population mean. Specific combining ability is the deviation from the performance predicted on the basis of general combining ability (Allard 1960). According to Sprague and Tatum (1942), the specific combining ability is controlled by non additive gene action. Usually, positive and significant *sca* effects (Table 7) were taken however, in case of days to first flowering and plant height significantly negative *sca* effects is favourable as it indicates earliness. Among 21 hybrids, the following cross combinations namely, L_2 x T_3 (+8), L_4 x T_2 (+6), L_1 x T_3 (+5), L_3 x T_3 (+4), L_3 x T_2 (+3) and L_6 x T_3 (+3) were identified as good specific combiners, based on overall specific combining ability effects (Table 8). Above cross combinations also had at least one good general combiner, based on overall *gca*. Among the hybrids which displayed high mean seed yield per plant, L1 x T_3, L_6 x T_3, and L_2 x T_1 were found to posses high significant *sca* effects for seed yield per plant. These cross combinations had at least one parent with high significant *gca* effects for seed yield per plant. Hence, the crosses L1 x T3 (2KU-53 x VBN-5) and L6 x T3 (VBG-05-014 x VBN-5) were found to have superior mean, non-significant sca effects with significant gca effects for seed yield per plant. Hence these hybrids can be effectively utilized for recombination breeding programme.

Table 2. Mean Performance of parents for different traits of Blackgram

Parents/ Hybrids	Days to first flowering	. Plant height (cm)	Number of branches per plant	Number of clusters per plant	. Number of pods per cluster	Number of pods per plant	Number of seeds per pod	Pod length (cm)	100 Seed weight (g)	Seed yield per plant (g)
L_1	32.60	33.60**	4.00	6.60	5.20	28.60	4.20	4.81*	4.02	8.96
L_2	32.60	34.80	4.60	7.60	4.80	28.40	4.60	5.12*	4.61	9.25
L_3	32.27	37.40	4.73	8.40**	5.67**	29.40	6.17**	4.94*	4.52	9.08
L_4	33.07	33.50**	4.60	8.50**	5.00	30.60**	5.30	4.74	5.05**	9.74*
L_5	33.33	35.60	4.80	7.40	4.60	31.40**	6.80**	4.55	4.76	9.61*
L_6	32.47	32.60**	4.60	7.30	5.33	30.40*	3.87	4.44	4.69	9.41
L_7	31.47**	35.87	5.40*	8.70**	5.07	29.20	6.13**	4.66	3.96	9.51
T_1	31.60*	34.60**	5.13	7.60	5.07	31.13	5.4	4.94	4.85**	9.81
T_2	31.60*	36.60	4.47	7.93	5.40*	30.87	5.13	5.01	4.81**	9.66
T_3	31.60*	35.50	4.60	8.10	4.60	31.4	6.40**	5.16*	4.91**	9.86

Table 3. General combining ability effects of parents for different traits of Blackgram

Parents	Days to first flowering	Plant height (cm)	Number of branches per plant	Number of clusters per plant	. Number of pods per cluster	Number of pods per plant	Number of seeds per pod	Pod length (cm)	100 Seed weight (g)	Seed yield per plant (g)
L_1	-0.84**	-1.24**	0.46**	0.27**	-0.00	0.15	0.51**	-0.01	0.19**	0.33**
L_2	1.09**	0.27**	0.23**	0.23*	0.23**	0.44**	-0.03	-0.20**	-.03**	0.98**
L_3	1.07**	1.14**	-0.31**	0.23*	-0.01	-0.60**	-0.40**	0.08**	-.08**	-0.42**
L_4	-0.26**	0.83**	-0.41**	-0.30**	0.04	0.57**	0.16	-0.02*	0.03**	0.10**
L_5	-1.17**	-0.17	0.59**	-0.27**	-0.21**	0.67**	-0.11	-0.11**	-.03**	0.72**
L_6	-0.04	-1.23**	0.06	-0.35**	-0.18*	0.52**	-0.23*	0.12**	0.05**	0.45**
L_7	0.16	0.40**	-0.61**	0.19*	0.14	0.64**	0.10	0.14**	-.12**	-0.72**
T_1	-0.17**	0.02	-0.17**	-0.19**	0.06	0.59**	-0.14*	-0.06**	-.03**	0.95**
T_2	0.84**	2.20**	-0.33**	-0.46**	0.54**	1.50**	-0.14**	-0.15**	-.06**	1.50**
T_3	0.67**	-2.22**	0.51**	0.65**	0.48**	0.90**	0.55**	0.22**	0.09**	0.56**

Table 4. Scoring of parents based on *gca* effects for all the ten characters

Parents	Days to first flowering	Plant height	Number of branches per plant	Number of clusters per plant	Number pods per cluster	Number of pods per Plant	Number of seed per pod	Pod length	100 seed weight	Seed yield per plant	**Total score**
L_1	0	+1	+1	+1	0	+1	+1	0	+1	+1	**+7**
L_2	-1	-1	+1	+1	+1	+1	0	0	0	+1	**+3**
L_3	-1	-1	0	+1	0	-1	-1	+1	0	-1	**+3**
L_4	0	-1	0	0	0	+1	+1	0	+1	+1	**+3**
L_5	+1	+1	+1	0	0	+1	0	0	0	+1	**+5**
L_6	0	+1	0	0	0	+1	-1	+1	+1	+1	**+4**
L_7	0	-1	-1	+1	+1	+1	+1	+1	0	-1	**+2**
T_1	+1	0	-1	0	+1	+1	0	0	0	+1	**+3**
T_2	-1	-1	-1	-1	+1	+1	0	-1	0	+1	**+2**
T_3	-1	+1	+1	+1	+1	+1	+1	+1	+1	+1	**+8**

Table 5. Relationship between *per se* performance and *gca* effects of parents

SL.NO	Characters	*Per se* Performance	*gca* effects	**Common parent**
1	Days to first flowering	L_7 T_1 L_3 T_3	T_1 L_5 L_1 L_4	**T_1**
2	Plant height	L_6 L_4 L_1 T_1	T_3 L_1 L_6 L_5	**L_1 & L_6**
3	Number of branches per plant	L_7 T_1 T_3 L_5	T_3 L_5 L_1	**T_3 & L_5**
4	Number of clusters per plant	T_3 T_2 L_7 L_4	T_3 L_1 L_2 L_3	**T_3**
5	Number of pods per cluster	T_2 T_1 L_3 L_6	T_2 T_3 L_2 L_4	**T_2**
6	Number of pods per plant	T_3 L_5 L_4 T_1	T_2 T_3 L_5 L_7	**T_3 & L_5**
7	Number of seed per pod	T_3 T_1 L_5 L_3	T_3 L_1 L_4 L_7	**T_3**
8	Pod length	T_3 T_2 L_2 L_3	T_3 L_7 L_6	**T_3**
9	100 seed weight	L_4 T_3 L_5 L_6	T_3 L_1 L_6	**L_6**
10	Seed yield per plant	T_3 T_1 L_4 L_5	T_2 T_1 L_2 L_5	**T_1 & L_5**

Table 6. Mean Performance of hybrids for different traits of Blackgram

Hybrids	Days to first flowering	. Plant height (cm)	Number of branches per plant	Number of clusters per plant	. Number of pods per cluster	Number of pods per plant	Number of seeds per pod	Pod length (cm)	100 Seed weight (g)	Seed yield per plant (g)
L_1 X T_1	30.40**	32.20**	4.60	6.80	5.40**	30.33	5.4	4.76	5.11**	11.78**
L_1 X T_2	32.20	34.60	4.00	7.00	4.13	28.8	5.2	4.68	5.07**	9.02
L_1 X T_3	32.40	31.73**	6.20**	9.60**	5.20	33.40**	6.23**	5.30**	5.02**	12.56**
L_2X T_1	29.00**	33.40	5.13*	7.40	5.30*	31.40*	5.07	4.68	4.88	12.44**
L_2 X T_2	34.60	35.80	4.40	7.27	4.00	29.4	4.53	4.48	4.74	10.61
L_2 X T_3	31.00	29.60**	4.60	8.60**	6.13**	32.60**	5.60*	5.04**	5.14**	12.26**
L_3 X T_1	34.20	32.57**	3.80	7.73	4.70	31.30*	4.4	4.84	4.74	10.02
L_3 X T_2	31.60	38.60	3.30	7.20	4.60	27.2	4.5	5.05**	4.87	9.22
L_3 X T_3	32.13	32.37**	5.40**	8.33**	5.40**	31.80**	5.2	5.12**	5.02**	11.88**
L_4 X T_1	31.20	34.40	3.40	7.63	4.90	31.80**	4.13	4.94	4.86	12.25**
L_4 X T_2	32.60	37.60	4.40	6.43	4.90	30.4	4.2	4.94	5.10**	9.55
L_4 X T_3	30.13**	30.60**	4.40	7.60	5.07	31.60**	7.43**	4.84	4.97*	10.88
L_5 X T_1	29.80**	32.87*	4.80	7.00	5.10	30.27	5.1	4.66	5.04**	11.65**
L_5 X T_2	31.73	33.60	5.30**	7.80	3.80	29.6	4.2	4.56	4.68	8.64
L_5 X T_3	29.67**	33.13	5.10*	6.97	5.20	30.2	5.67*	5.24**	5.04**	9.92
L_6 X T_1	30.80*	35.13	3.60	6.60	4.67	32.13**	5.1	5.04**	4.93	12.14**
L_6 X T_2	33.4	31.83**	4.40	7.40	4.40	27.6	5.1	4.78	5.06**	9.09
L_6 X T_3	30.40**	29.47**	5.60**	7.53	5.13	30.8	5.1	5.34**	5.36**	12.48**
L_7 X T_1	31.00	33.17	4.80	8.20**	4.77	31.80**	5.87**	5.14**	4.88	11.87**
L_7 X T_2	30.80*	37.00	3.20	6.37	4.80	31.40*	4.87	4.93	4.76	8.88
L_7 X T_3	33.40	31.13**	3.60	8.57**	5.60**	30.8	4.87	5.14**	4.86	9.47

Table 7. Specific combining ability effects of hybrids for different traits of Blackgram

Hybrids	Days to first flowering	. Plant height (cm)	Number of branches per plant	Number of clusters per plant	. Number of pods per cluster	Number of pods per plant	Number of seeds per pod	Pod length (cm)	100 Seed weight (g)	Seed yield per plant (g)
L_1 X T_1	-0.16	0.05	-0.16	-0.81**	0.43**	-1.10**	-0.07	-0.09**	0	-0.29
L_1 X T_2	0.62**	0.26	-0.60**	-0.34*	-0.24	-0.55*	0	-0.08**	-0.02*	-.60**
L_1 X T_3	-.46**	-0.31	0.76**	1.15**	-0.19	1.65**	0.07	0.17**	0.02*	0.88*
L_2X T_1	-0.09	-0.26	0.60**	-0.17	0.09	-0.33	0.14	0.01	-0.01	0.17
L_2 X T_2	1.09**	-0.05	0.02	-0.03	-0.61**	-0.24	-0.13	-0.10**	-.12**	0.34*
L_2 X T_3	-1.00**	0.31	0.62**	0.2	0.51	0.56	-0.02	0.09**	0.13*	0.07
L_3 X T_1	1.73**	-.96**	-0.19	0.17	-0.26*	0.61**	-0.16	-0.10**	-.10**	-.30**
L_3 X T_2	-1.89**	1.88**	-0.53**	-0.1	0.24	-1.40**	0.21	0.20**	0.05*	0.35*
L_3 X T_3	0.16	0.08	0.73**	-0.07	0.02	0.80**	-0.05	-0.10**	0.05*	0.95*
L_4 X T_1	0.06	0.18	-0.49**	0.60**	-0.12	-0.06	-0.98**	0.10**	-.09**	0.41*
L_4 X T_2	0.44**	1.20**	0.67**	-0.33*	0.48**	0.63**	-0.65**	0.19**	0.18*	0.16
L_4 X T_3	-0.51**	-.38**	-0.17	-0.27	-0.37**	-0.57*	1.63**	-0.28**	-.10**	-.57**
L_5 X T_1	-0.43**	-0.35*	-0.09	-0.07	0.34*	-0.35	0.25	-0.10**	0.15*	0.64*
L_5 X T_2	0.49**	-.80**	0.57**	1.00**	-0.36**	1.07**	-0.38*	-0.11**	-.18**	0.07
L_5 X T_3	-0.06	2.16**	-0.47**	-0.93**	0.02	-0.73**	0.13	0.20**	0.03*	-.71**
L_6 X T_1	-0.56**	2.97**	-0.76**	-0.39*	-0.13	1.36**	0.01	0.05**	-.04**	-0.04
L_6 X T_2	1.02**	-.52**	0.2	0.68**	0.2	-1.08**	0.87**	-0.12**	0.11*	-.64**
L_6 X T_3	-0.46**	-.45**	0.56**	-0.29	-0.08	-0.28	0.88**	0.07**	0.08*	0.69*
L_7 X T_1	-0.56**	-.62**	1.11**	0.68**	-0.35**	-0.13	0.81**	0.13**	0.08*	0.85*
L_7 X T_2	-1.78**	1.03**	-0.33*	-0.89**	0.28*	1.56**	0.07	0.02	-0.02	0.31*
L_7 X T_3	2.34**	-0.41*	-0.77**	0.21	0.07	1.44**	-0.88**	-0.15**	-.06**	-.16**

Table 8. Scoring based on *sca* effects for all the ten characters

Cross Combinations	Days to first flowering	Plant height	Number of branches per plant	Number of clusters per plant	Number pods per Clusters	Number of pods per plant	Number of seeds per pod	Pod length	100 seed weight	Seed yield per plant	Total score
L_1 x T_1	0	0	0	0	+1	-1	0	0	0	0	0
L_1 x T_2	+1	+1	-1	0	0	-1	0	0	0	-1	-1
L_1 x T_3	-1	0	+1	+1	0	+1	0	+1	+1	+1	+5
L_2 x T_1	+1	0	+1	0	0	-1	-1	+1	0	+1	+2
L_2 x T_2	-1	0	0	0	-1	0	0	0	0	+1	-1
L_2 x T_3	0	+1	+1	+1	+1	+1	0	+1	+1	+1	+8
L_3 x T_1	+1	-1	0	+1	-1	+1	-1	0	0	-1	-1
L_3 x T_2	-1	+1	-1	0	+1	-1	+1	+1	+1	+1	+3
L_3 x T_3	0	0	+1	0	0	+1	0	0	+1	+1	+4
L_4 x T_1	0	+1	-1	+1	0	0	-1	+1	0	+1	-2
L_4 x T_2	+1	+1	+1	-1	+1	+1	-1	+1	+1	+1	+6
L_4 x T_3	-1	-1	0	0	-1	-1	+1	0	0	-1	-4
L_5 x T_1	-1	-1	0	0	+1	0	+1	0	+1	+1	+2
L_5 x T_2	0	-1	+1	+1	-1	+1	-1	0	-1	0	-1
L_5 x T_3	0	+1	-1	-1	0	-1	0	+1	+1	-1	0
L_6 x T_1	-1	+1	-1	-1	0	+1	0	+1	0	0	0
L_6 x T_2	+1	-1	+1	+1	+1	-1	+1	0	+1	-1	+3
L_6 x T_3	-1	-1	+1	0	0	0	+1	+1	+1	+1	+3
L_7 x T_1	-1	-1	+1	+1	-1	0	+1	+1	+1	+1	+3
L_7 x T_2	-1	+1	-1	-1	+1	+1	0	+1	0	+1	+2
L_7 x T_3	+1	-1	-1	+1	0	+1	-1	0	0	-1	-1

References

1. Allard R.W. 1960. Principles of plant Breeding wiley and song. Ine., New York London.

2. Baker,R.G. 1978. Issues in diallel analysis. **Crop Sci.,** 18:533-536.

3. Chand, P., and C. Raghunadha Rao. 2002 Studies on gene action in a biparental cross in black gram (*Vigna mungo* (L) Hepper). **Indian J. Genet.,62**(4):347-348

4. Gilbert, N. E. G. 1958. Diallel cross in plant breeding. **Heredity,** 12:477-498.

5. Kempthorne, O. 1957. An introduction to genetic statistics . **John Wiley and Sons Inc .,** New York

6. Majumder, P. K and J. G. Bhowal. 1988. Combining ability in a few varieties of *T.aestivum, T. compactum* and *T. Sphaercoccum*. **Indian J. Genet., 48**(1):43-48

7. Norman E. Boarlaug. 1973. Building a protein revolution on grain legumes . Max.Milner (Eds.).In: **Nutritional improvement of food legumes by Breeding protein Advisory Group of United Nation**.PP. 7-11

8. Panse, V.G. 1942. Genetics of quantitative characters in relation to plant breeding. Indian J.Genet.,M2: 318-327.

9. Panse, V.G. and P.V. Sukhatme, 1964. Statistical Methods for Agricultural Workers . Indian Council of Agricultural Research, New Delhi, p.359

10. Rajan babu, V. 1997. Heterosis and combining ability in black gram (*Vigna mungo* (L) Hepper). **M.Sc ., (Ag) Thesis** Tamil Nadu Agric. Univ., Coimbatore.

11. Sharma, R.L. and B.P.S. Chauhan. 1985. Combining ability in sesame. **Indian J. Genet.,**45(1):45-59

12. Singh B.B and Harisingh. 1985. Heterosis and combining ability for kernel size in Rice . **Indian J. Genet., 45(2)**:181-185

13. Snedecor, G.W. 1961. Statistical Analysis 5th ed. Iowa State University Press , Ames

14. Sprague, G. F and L.A. Tatum. 1942. General vs specific combining ability in single crosses of corn**. J.Am.Soc.Agron.,** 34:923-932

15. Srividhya *et al.* 2005. components of genetic variation in biparental progenies of black gram (*Vigna mungo* (L) Hepper). **Legume Res .,** 28(4):291-293

16. Tiwari *et al*. 1993. Combining ability studies in mungbean (*Vigna radiata* (L). Wilczek). **Indian J. Genet.,** 53(4):395-398

17. Vaithiyalingam *et al*. 2002. Combining ability studies in black gram (*Vigna mungo* (L) Hepper). **Crop Res .,** 24(1):81-85