Received: 29 Mar 2023 | Revised: 13 Jun 2023 | Accepted: 14 Jun 2023

Electronic Journal of Plant Breeding

Research Article

Estimation of the genetic potential of parents and crosses for yield component traits in blackgram [*Vigna mungo* (L.) Hepper] through combining ability analysis

A. Surendhar[1], P. Jayamani[2]*, K. Iyanar[3], L. Karthiba[2] and P. S. Shanmugam[2]

[1]Department of Genetics and Plant Breeding, Centre for Plant Breeding and Genetics (CPBG), Tamil Nadu Agricultural University (TNAU), Coimbatore-641003
[2]Department of Pulses, CPBG, TNAU, Coimbatore-641003
[3]Department of Millets, CPBG, TNAU, Coimbatore-641003
***E-Mail:** jayamani1108@gmail.com

Abstract
Blackgram is the grain legume crop mainly grown in variable edaphic and weather conditions in India resulting in less productivity. However, the yield of blackgram can be improved by breeding methods involving potential parents by analysing the combining ability. A set of three female parents (CO 5, CO 6 and ADT 5) and six male parents (MASH 1008, VBN 6, VBN 8, VBN 9, VBN 10 and VBN 11) were used as parents. The crosses were synthesised in Line × Tester fashion and they were evaluated along with parents for ten quantitative characters. The gene action controlling the traits and combining ability of the parents and crosses were analysed. The preponderance of non-additive gene action was observed for all the traits studied. The parents, CO 5 and VBN 11 were found to have significant positive general combining ability effect (*gca*) for yield and its component traits. The crosses, CO 5 × VBN 8, CO 5 × VBN 11 and ADT 5 × VBN 10 showed a significant specific combining ability effect (*sca*) for single plant yield. Among the crosses, CO 5 × VBN 8 was identified as the best cross on the basis of *sca*, *per se* performance, *gca* status of parents and heterosis for yield and yield component traits. For single plant yield, CO 5 × VBN 11 performed well for all the above parameters. Hence, these two crosses could be exploited for recombination breeding to improve yield.

Keywords: Blackgram, combining ability, gene action and heterosis.

INTRODUCTION

Blackgram (*Vigna mungo* (L.) Hepper) is one of the important leguminous crops cultivated in Indian sub-continent, also known as mash, urdbean etc. Being a grain legume crop, rich in high-quality protein (20-26%) and is an important ingredient in Indian meals along with rice (Mehra *et al.,* 2016). India is the largest producer and consumer of blackgram in the world. It is suitable for growing in all the three seasons in India and produces 2.34 million tonnes annually from a 4.67 million hectare area with average productivity of 501 kg ha^{-1} (Anonymous, 2021). It is also grown in rice fallow conditions with minimum management practices. The productivity is low due to biotic and abiotic stresses and cultivation in marginal, dry and unproductive lands. However, productivity can be improved by developing suitable varieties with high yield potential. Combining ability analysis is the tool to select the best parents for hybridization to get the novel segregants in the recombination breeding (Fasahat *et al.,* 2016). With this idea, combining ability analysis was performed in blackgram for yield and its component traits through Line × Tester design to select the good parental lines and crosses for further improvement of blackgram.

MATERIALS AND METHODS

The present study includes nine varieties of blackgram collected from the Department of Pulses, TNAU were crossed in Line × Tester mating fashion during *summer*, 2022. The lines (female parents) *viz.,* CO 5, CO 6 and ADT 5 and testers (male parents) *viz.,* MASH 1008, VBN 6, VBN 8, VBN 9, VBN 10 and VBN 11 were selected for hybridization. The newly synthesized 18 crosses, nine parents and one check variety CO 7 were evaluated in randomized completely block design (Replicated twice) during *kharif*, 2022 in the experimental plot of Department of Pulses, TNAU, Coimbatore.

The quantitative traits *viz.,* plant height (cm), branches per plant, clusters per plant, pods per cluster, pods per plant, pod length (cm), seeds per pod, hundred seed weight (g) and single plant yield (g) were recorded on competitive plants from each replication. The trait days to 50 per cent flowering was recorded on a plot basis from each replication. The analysis of variance for combining ability through Line × Tester was carried out following the technique given by Kempthorne (1957). The degree of dominance was calculated by using the formula $(\sigma^2D/\sigma^2A)^{1/2}$ where σ^2D dominance or specific combining ability variance (SCA) and σ^2A is additive or general combining ability variance (GCA). The standard heterosis was calculated with the check variety CO 7. The correlation coefficient between single plant yield with other characters was calculated by the method proposed by Goulden (1952). The best crosses were selected on the basis of specific combining ability (*sca*) effects, *per se* performance, general combining ability (*gca*) status of parents and standard heterosis for the traits correlated with single plant yield.

RESULTS AND DISCUSSION

Analysis of variance for combining ability:In combining ability analysis, a significant variance was observed for crosses, lines, testers and their interactions for all the traits (**Table 1**). The significant variance in lines and tester indicated the existence of additive gene action and the significant variance in interaction indicated the prevalence of non-additive gene action. However, non-significant values were observed for pods per cluster in testers and also for interaction and single plant yield in testers. Patial *et al.* (2018) and Patial *et al.* (2022) observed significant variation in blackgram crosses for all the traits studied in the present study.

Gene action and proportional contribution to combining ability variances: The knowledge of the gene action of the traits is important to proceed with the suitable breeding programme. In this study, the estimates of SCA were found to be higher than GCA variances for all the quantitative traits and governing the predominance of non-additive gene action (**Table 2**). More than unity of degree of dominance in all the traits indicates the presence of over-dominance in expressing traits in the crosses. This non-additive nature of gene action in the traits *viz.,* days to 50 per cent flowering, plant height, branches per plant, clusters per plant, pods per cluster, pods per plant, pod length, seeds per pod, hundred seed weight and single plant yield were also reported by Gill *et al.* (2015) and Gill *et al.* (2020) in blackgram. However, Vadivel *et al.* (2022) reported a preponderance of additive gene action for all the yield-contributing traits except for pods per cluster in blackgram.

To the total estimates of combining ability variances, the contribution of lines ranged from 28.49 per cent in seeds per pod to 74.90 per cent in plant height. The contribution of testers ranged between 8.75 per cent (days to 50% flowering) and 46.58 per cent (seeds per pod). The lines contributed more towards the total variance than the testers which is evident in the more divergence among the lines. The per cent contribution of interaction was found between 15.62 per cent (plant height) and 40.32 per cent (branches per plant). It infers the presence of more genetic variation among the lines. The contribution of interaction was found to be higher than the contribution of testers in all the traits except for pod length, seeds per pod and hundred seed weight and could be due to the specific combining ability of the crosses. It again proves the prevalence of the non-additive components of gene action in the expression of these traits. However, the exploitation of non-additive gene action in a highly self-pollinated crop like blackgram is not possible through heterosis breeding. Hence, all these traits could be improved by pedigree breeding and bi-parental mating programmes. The preponderance of non-additive gene action due to a higher contribution of interaction than the tester to the total variance was also reported by Chakraborty *et al.* (2010) and Patial *et al.* (2022) in blackgram.

General combining ability of parents: The breeding programme involving hybridization needs good parents to create more variability and to get novel transgressive segregants. The general combining ability (*gca*) is predicted based on the average performance of the set of crosses involving the parents. Hence, the good parents are selected based on the *gca* effects which is due to the additive gene action and fixable (Sprague and Tatum, 1942). In the present study, line CO 5 and the tester VBN 11 had significant positive *gca* for single plant yield (**Fig. 1**). Negative *gca* is preferred for the trait days to 50 per cent flowering for earliness. For this trait, lines CO 6 and ADT 5 and the testers VBN 8 and VBN 9 were found to have significant negative *gca* effects. The line CO 5 showed significant positive *gca* for single plant yield along with significant positive *gca* in most of the traits *viz.,* plant height, pods per plant, clusters per plant, branches per plant, hundred seed weight, pods per cluster and pod length. In the same way, the tester VBN 11 showed significant positive *gca* for single plant yield with other yield contributing traits *viz.,* pods per plant, seeds per pod, hundred seed weight and pod length. As suggested by Griffing (1956), the crosses involving significant positive *gca* parents *viz.,* CO 5 and VBN 11

https://doi.org/10.37992/2023.1402.067

Table 1. Analysis of variance of combining ability for ten quantitative traits in blackgram

S.No.	Traits	Mean sum of squares					
		Replications	Crosses	Lines	Testers	L x T	Error
	df	1	17	2	5	10	17
1.	Days to 50 % flowering	0.25	19.89 **	123.08 **	5.91 **	6.25 **	0.25
2.	Plant height	4.91	143.78 **	915.42 **	46.35 **	38.18 **	1.67
3.	Branches per plant	0.19	0.71 **	2.88 **	0.28 *	0.48 **	0.08
4.	Clusters per plant	1.49	26.51 **	147.54 **	10.27 **	10.43 **	2.02
5.	Pods per cluster	0.15	0.24 *	0.93 **	0.14	0.14	0.09
6.	Pods per plant	4.95	112.25 **	491.20 **	71.96 **	56.61 **	11.50
7.	Pod length	0.10	0.19 **	0.67 **	0.25 **	0.07 *	0.02
8.	Seeds per pod	0.01	0.40 **	0.97 **	0.64 **	0.17 *	0.05
9.	Hundred seed weight	0.02	0.48 **	2.51 **	0.36 **	0.14 *	0.04
10.	Single plant yield	0.87	14.24 **	62.68 **	4.76	9.30 **	1.85

*Significance at P≤0.05; **Significance at P≤0.01

Table 2. Estimates of combining ability variances and proportionate of lines, testers and their interactions

S. No.	Traits	GCA	SCA	SCA / GCA	Degree of dominance	Proportional contribution (%)		
						Lines	Testers	Interaction
1.	Days to 50 % flowering	0.61	3.00	4.92	2.22	72.78	8.75	18.48
2.	Plant height	4.74	18.25	3.85	1.96	74.90	9.48	15.62
3.	Branches per plant	0.01	0.2	20.00	4.47	47.81	11.88	40.32
4.	Clusters per plant	0.72	4.20	5.83	2.42	65.47	11.39	23.14
5.	Pods per cluster	0.01	0.02	2.00	1.41	45.87	17.57	36.56
6.	Pods per plant	2.50	22.55	9.02	3.00	51.48	18.86	29.66
7.	Pod length	0.01	0.02	2.00	1.41	40.65	37.8	21.55
8.	Seeds per pod	0.01	0.05	5.00	2.24	28.49	46.58	24.94
9.	Hundred seed weight	0.01	0.04	4.00	2.00	60.68	21.84	17.48
10.	Single plant yield	0.22	3.72	16.91	4.11	51.77	9.83	38.41

will be productive for releasing ideal segregants by fixing novel additive genes. The research outcomes of Vadivel *et al.* (2022) also showed parents with significant positive *gca* for the number of branches per plant, pod length, number of seeds per pod, number of clusters per plant and hundred seed weight in blackgram.

Specific combining ability of crosses: In practice, the potential crosses are selected based on specific combining ability (*sca*). It is a deviation in the performance of the crosses from the predicted value derived from the *gca* of their parents (Allard, 1956). The mere selection of crosses based on the *per se* performance will not be productive. So, the genetically elite crosses should also have significant positive *sca* effects for the traits. Among the 18 crosses, only three crosses *viz.,* CO 5 × VBN 8, CO 5 × VBN 11 and ADT 5 × VBN 10 were found with significant positive *sca* for single plant yield (**Fig. 2**). Along with single plant yield, the cross CO 5 × VBN 8 showed a significant positive *sca* effect for plant height, branches per plant, cluster per plant and pods per plant (**Table 3**). Another significant positive *sca* cross CO 5 × VBN 11 for a single plant also showed significant negative *sca* for days to 50 per cent flowering. Furthermore, ADT 5 × VBN 10 was observed with significant positive *sca* for plant height, branches per plant and clusters per plant along with single plant yield (**Table 3**). Hence, the specific combiners CO 5 × VBN 8, CO 5 × VBN 11 and ADT 5 × VBN 10 could be utilized for pedigree breeding to improve the yield. Significant negative *sca* for days to 50 per cent flowering displayed by the crosses *viz.,* CO 5 × VBN 9, CO 5 × VBN 11, CO 6 × VBN 8, CO 6 × VBN 10, ADT 5 × MASH 1008 and ADT 5 × VBN 6. These six crosses could be used for isolating short-duration segregants and further development of varieties in blackgram. Gill *et al.* (2020) also reported the blackgram crosses with significant positive *sca* for single plant yield along with pods per plant, pod length, plant height, number of branches and

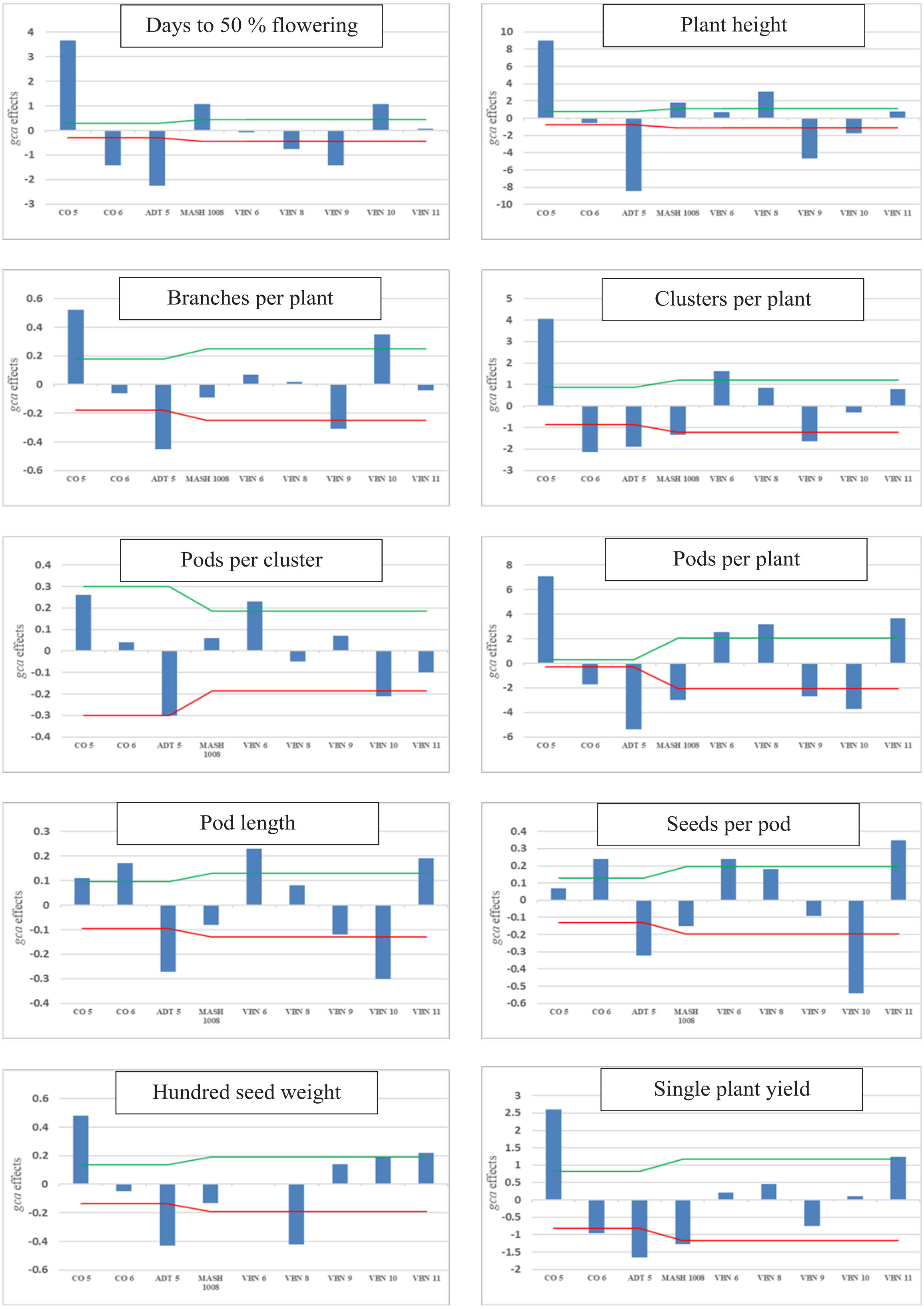

Fig. 1. General combining ability effects (*gca*) of parents for ten quantitative traits (Bars above the green line and below the red line are significantly positive and negative gca effects respectively)

https://doi.org/10.37992/2023.1402.067

hundred seed weight. Good specific combiners were reported by Boraiah *et al.* (2019) for the traits *viz*., pods per plant, pod length, seeds per pod, hundred seed weight along with single plant yield in blackgram.

Comparing significant positive sca crosses with per se performance, heterosis and gca status of parents in yield correlated traits **:** The good cross is selected based on several aspects *viz*., *sca*, *per se* performance, heterosis and *gca* status of the parents. In this study, highly correlated traits with single plant yield *viz.,* pods per plant (0.92), clusters per plant (0.91), plant height (0.70), hundred seed weight (0.67), branches per plant (0.61), days to 50 per cent flowering (0.52) and pod length (0.45) were considered for selection of crosses (**Table 3**). On viewing the performance of three good specific combiners (CO 5 × VBN 8, CO 5 × VBN 11 and ADT 5 × VBN 10) for single plant yield, two crosses namely CO 5 × VBN 8 and CO 5 × VBN 11 were excelled in *per se* performance for single plant yield (17.07 g and 17.40 g, respectively), standard heterosis over CO 7 (54.95% and 57.89%, respectively) and also had good parental *gca* combinations (**Table 3**). When both parents have significant positive *gca*, it is ascribed to additive gene action which is fixable. The cross combination should have a minimum one parent with significant positive *gca* to fix the additive genes in their progenies. The crosses *viz*., CO 5 × VBN 11 and CO 5 × VBN 8 had a minimum of one parent with significant positive *gca* for single plant yield and hence high yielding segregants will be expected through fixing of additive genes in segregating generations. The crosses with good performance were identified for the correlated traits with yield *viz.,* CO 6 × VBN 8 and ADT 5 × VBN 6 for days to 50 per cent flowering, CO 5 × MASH 1008, CO 5 × VBN 6 and CO 5 × VBN 8 for plant height, CO 5 × VBN 8 for branches per plant, CO 5 × VBN 6 and CO 5 × VBN 8 for clusters per plant, CO 5 × VBN 8 for pods per plant and CO 5 × VBN 10 for hundred seed weight. All the above crosses were found to have minimum one parent with significant positive *gca* for the respective traits. Considering the out performance of crosses in all the aspects mentioned in **Table 3**, CO 5 × VBN 8 was identified as the best cross for single plant yield along with plant height, branches per plant, clusters per plant and pods per plant. The performance of another cross, CO 5 × VBN 11 was found to be the best for single plant yield in all the aspects mentioned. Hence, these two crosses *viz,* CO 5 × VBN 8 and CO 5 × VBN 11 could be recommended for pedigree breeding programme. The results of Shalini and Lal (2019) supported these findings by reporting crosses with significant positive *sca*, involvement of good general combiner parents and heterosis for single plant yield,

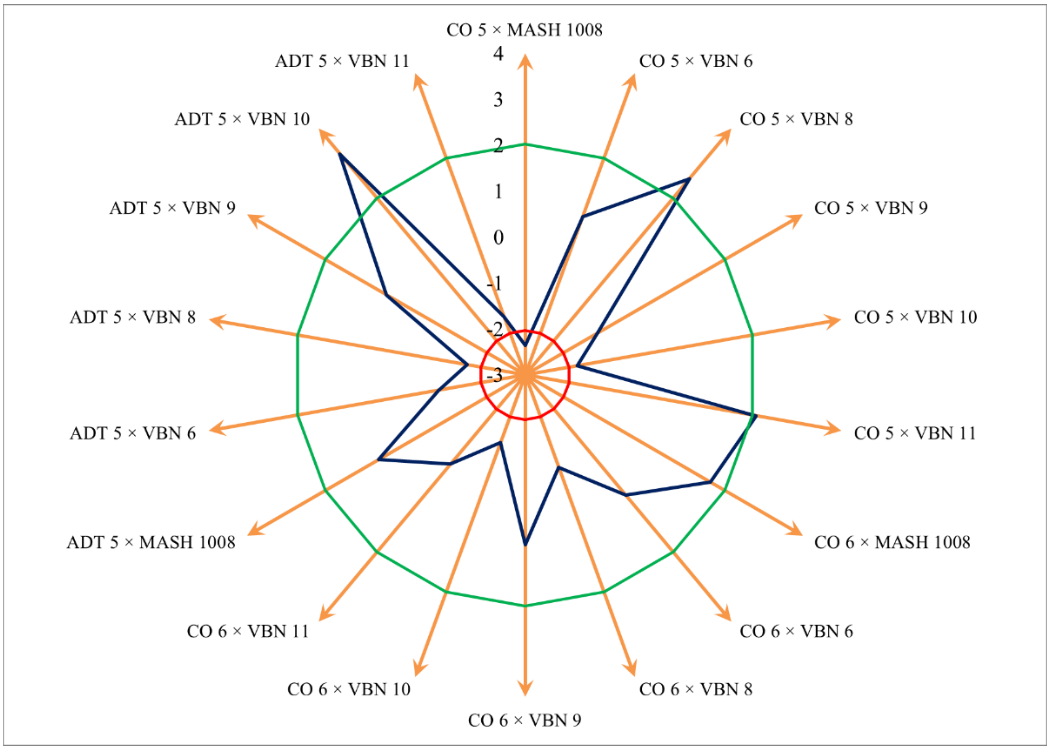

Fig. 2. Specific combining ability effects (*sca*) of crosses for single plant yield (Web line (blue) outside the green circle and inside the red circle are significantly positive and negative sca effects respectively)

Table 3. Comparison of *sca* of crosses with *per se* performance, standard heterosis and *gca* status of parents in yield correlated traits

S.No.	Traits	Correlation with single plant yield	Crosses with significant *sca* effects	*sca* effects	*Per se* performance	Standard heterosis over CO7 (%)	*gca* status of parents	Crosses excelled in all the categories
1.	Days to 50 % flowering	0.52 **	CO 5 × VBN 9 CO 5 × VBN 11 CO 6 × VBN 8 CO 6 × VBN 10 ADT 5 × MASH 1008 ADT 5 × VBN 6	-2.83 ** -1.83 ** -0.92 * -0.75 * -0.92 * -1.25 **	38.50 41.00 36.00 ** 38.00 * 37.00 ** 35.50 **	1.32 7.89 -5.26 ** 0.00 -2.63 -6.58 **	L × H L × H H × H H × L H × L H × M	CO 6 × VBN 8 ADT 5 × VBN 6
2.	Plant height (cm)	0.70 **	CO 5 × MASH 1008 CO 5 × VBN 6 CO 5 × VBN 8 CO 6 × VBN 10 CO 6 × VBN 11 ADT 5 × VBN 9 ADT 5 × VBN 10	4.18 ** 2.84 ** 5.10 ** 2.71 ** 2.65 * 4.45 ** 3.37 **	45.83 ** 43.33 ** 48.00 ** 31.25 33.67 * 22.17 24.00	47.85 ** 39.77 ** 54.84 ** 0.81 8.60 * -28.48 ** -22.58 **	H × H H × M H × H M × L M × M L × L L × L	CO 5 × MASH 1008 CO 5 × VBN 6 CO 5 × VBN 8
3.	Branches per plant	0.61 **	CO 5 × VBN 8 CO 6 × MASH 1008 ADT 5 × VBN 10	0.54 * 0.57 * 0.51 *	3.50 ** 2.84 2.84	75.00 ** 41.75 ** 41.75 **	H × M M × M L × H	CO 5 × VBN 8
4.	Clusters per plant	0.91 **	CO 5 × VBN 6 CO 5 × VBN 8 ADT 5 × VBN 10	2.79 * 2.57 * 2.34 *	16.83 ** 15.84 ** 8.50	146.23 ** 131.68 ** 24.36	H × H H × M L × M	CO 5 × VBN 6 CO 5 × VBN 8
5.	Pods per plant	0.92 **	CO 5 × VBN 8	7.86 **	65.17 **	43.22 **	H × H	CO 5 × VBN 8
6.	Pod length (cm)	0.45 **	ADT 5 × VBN 11	0.31 *	5.16	-0.39	L × H	-
7.	Hundred seed weight (g)	0.67 **	CO 5 × VBN 10	0.41 *	5.40 **	19.32 **	H × M	CO 5 × VBN 10
8.	Single plant yield (g)	1.00 **	CO 5 × VBN 8 CO 5 × VBN 11 ADT 5 × VBN 10	2.57 * 2.11 * 3.28 **	17.07 ** 17.40 ** 13.16	54.95 ** 57.89 ** 19.46	H × M H × H L × M	CO 5 × VBN 8 CO 5 × VBN 11

L (Low) - Significant negative *gca*; M (Medium) - Non-significant *gca*; H (High) - Significant positive *gca*;
*Significance at P≤0.05; **Significance at P≤0.01.

hundred seed weight and clusters per plant in blackgram. Patial *et al.* (2022) obtained good specific combiners in blackgram with high *per se* performance for plant height, branches per plant and single plant yield.

The estimates of significant SCA and GCA indicated the presence of both non-additive and additive genetic components for all the traits. More than unity of SCA/GCA ratio and significant positive *sca* effect of the crosses infers the preponderance of non-additive gene action controlling the traits. But the exploitation of this kind of gene action is not possible in blackgram. Hence, good specific combiners with high *per se* performance involving good general combiners for single plant yield and its correlated traits identified in the present study namely CO 5 × VBN 8 and CO 5 × VBN 11 are suggested for pedigree breeding, biparental mating and selection in the later generations to fix novel additive genes in their progenies.

ACKNOWLEDGEMENT

The authors are indebted to the Council for Scientific and Industrial Research (CSIR), Ministry of Science & Technology, Government of India for providing a research fellowship to the first author.

REFERENCES

Allard, R.W. 1956. Biometrical approach to plant breeding. *Proceedings of Symposium on Genetics and Plant Breeding. Broahave, Nat. Laboratory*, 66-68.

Anonymous. 2021. ANGRAU Blackgram Outlook Report-January to December 2021. *Acharya N.G. Ranga Agricultural University*, 1-6.

Boraiah, K. M., Byregowda, M., Keerthi, C. M., Vijayakumar, H. P., Ramesh, S. and Reena, M. 2019. Frequency of heterotic hybrids in relation to parental genetic divergence and general combining ability in blackgram [*Vigna mungo* (L.) Hepper]. *Legume Research: An International Journal*, **42**(5): 595-602. [Cross Ref]

Chakraborty, S., Kumar, H.B., Kumar, B.B., Pathak, D, Kalita, H. and Barman, B. 2010. Genetic parameters and combining ability effects of parents for seed yield and other quantitative traits in Blackgram [*Vigna mungo* (L.) Hepper]. *Notulae Scientia Biologicae,* **2**(2): 121-126. [Cross Ref]

Fasahat, P., Rajabi, A., Rad, J. M. and Derera, J. 2016. Principles and utilization of combining ability in plant breeding. *Biometrics & Biostatistics International Journal*, **4**(1): 1-24. [Cross Ref]

Gill, R. K., Bindra, S. and Tyagi, V. 2020. Estimation of combining ability of blackgram [*Vigna mungo* (L.) Hepper] genotypes for grain yield and component traits. *Agricultural Research Journal*, **57**(1): 18-22. [Cross Ref]

Gill, R.K., Singh, I., Kumar, A. and Singh, S. 2015. Assessment of combining ability for various quantitative traits in summer urdbean. *Electronic Journal of Plant Breeding,* **6**(2): 412-416.

Goulden, CH. 1952. "Methods of statistical analysis, Edition. 2." *John Wiley & Sons, Inc, New York,* P 467.

Griffing, B. R. U. C. E. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. *Australian journal of biological sciences*, **9**(4): 463-493. [Cross Ref]

Kempthorne, O. 1957. An introduction to Genetic Statistics. *John Wiley and Sons Inc, New York,* P 545.

Mehra, R., Tikle, A.N., Saxena, A., Munjal, A., Khandia, R. and Singh, M. 2016. Correlation, path-coefficient and genetic diversity in blackgram [*Vigna mungo* (L) Hepper]. *International Journal of Plant Sciences,* **7**(1):001-011.

Patial, R., Mittal, R. K. and Sood, V. K. 2018. Estimation of heterosis for seed yield and yield contributing traits in urdbean [*Vigna mungo* (L.) Hepper]. *International Journal of Chemical Studies*, **6**(5): 2385-2390.

Patial, R., Mittal, R. K., Sood, V. K. and Ahmed, S. 2022. Studies on combining ability for seed yield and its related traits in blackgram [*Vigna mungo* (L.) hepper]. *Legume Research: An International Journal,* **45**(3): 292-298.

Shalini, C. H. and Lal, G. M. 2019. Heterosis and combining ability studies for yield and yield components in blackgram [*Vigna mungo* (L.) Hepper] under different environmental conditions of Prayagraj region, India. *Journal of Pharmacognosy and Phytochemistry*, **8**(3): 3512-3516.

Sprague, G.F. and Tatum, L.A. 1942. General versus specific combining ability in single crosses of corn. *Journal of American Society of Agronomy*, **34**(10): 923-932. [Cross Ref]

Vadivel, K., Manivannan, N., Mahalingam, A., Satya, V. K. and Vanniarajan, C. 2022. Combining ability analysis for seed yield and component traits over season in Blackgram [*Vigna mungo* (L.) Hepper]. *Legume Research: An International Journal*, **45**(5): 545-550.