International Journal of Plant & Soil Science

Volume 37, Issue 9, Page 95-105, 2025; Article no.IJPSS.142177
ISSN: 2320-7035

Heterosis and Combining Ability Analysis of Mungbean (*Vigna radiata* L. Wilczek) Genotypes for Yield and Its Attributing Traits

Yogendra Singh [a*], Sarvendra Kumar [a], Vijay Kumar Yadav [a], Shweta Yadav [a], CL Maurya [a], Kanhaiya Lal [b] and Anuj Mishra [a]

[a] Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (UP), 208002, India.
[b] Kamla Nehru Institute of Physical and Social Sciences, Sultanpur (UP), 228118, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2025/v37i95689

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/142177

Original Research Article

Received: 08/06/2025
Published: 23/08/2025

ABSTRACT

India is the world's largest producer and consumer of pulses, accounting for 36.8% of the global cultivated area, 24.2% of global production, and 27% of global consumption. The paper aims to conduct heterosis and combining ability analysis of mungbean genotypes for yield and its its attributing traits. An experiment consisting of 75 genotypes (21 parents + 54 F_1s) was conducted in a randomised block design with three replications during *Kharif* 2022 at Student's Instructional Farm, C. S. Azad University of Agriculture and Technology, Kanpur, to assess the Heterosis and Combining Ability of different mungbean genotypes. The analysis indicates that the variance due to

---

Corresponding author: E-mail: yogendrasinghpatel95@gmail.com;

Cite as: *Singh, Yogendra, Sarvendra Kumar, Vijay Kumar Yadav, Shweta Yadav, CL Maurya, Kanhaiya Lal, and Anuj Mishra. 2025. "Heterosis and Combining Ability Analysis of Mungbean (Vigna Radiata L. Wilczek) Genotypes for Yield and Its Attributing Traits". International Journal of Plant & Soil Science 37 (9):95-105. https://doi.org/10.9734/ijpss/2025/v37i95689.*

lines was significant for pod length (cm) and biological yield per plant (g). Additionally, the variance due to testers was significant for several traits, including days to 50% flowering, number of pod clusters per plant, number of pods per plant, pod length (cm), number of seeds per pod, 100 seed weight (g), and biological yield per plant (g). The mean sum of squares resulting from their interaction was significant for all traits studied. The significant and positive GCA effects for grain per plant were exhibited by three lines, *viz.,* KM 2364, IPM 604 and NM 1705. The present investigation revealed that the seven cross combinations *viz*, KM 2448 x IPM 02-3, KM 2448 x KM 2195, KM 2449 x KM 2195, IPM 208 x PDM 139, IPM 604 x IPM 02-3, SML 1839 x PDM 139, and PUSA 2071 x IPM 02-3, were good specific combiners for seed yield per plant. In the present investigation, KM 2364 x PDM 139, having per se performance as well as the highest economic heterosis (27.18 %) for yield, also revealed significant desirable heterotic effects for days to maturity, plant height, and harvest index. Similarly, the other best hybrid, PUSA 2072 x KM 2195, showing high per se coupled with high magnitude of economic heterosis (26.80%), also showed significant useful heterosis for days to maturity, plant height and harvest index. The present investigation revealed that the seven cross combinations viz; KM 2448 x IPM 02-3, KM 2448 x KM 2195, KM 2449 x KM 2195, IPM 208 x PDM 139, IPM 604 x IPM 02-3, SML 1839 x PDM 139, and PUSA 2071 x IPM 02-3 were good specific combiners for seed yield per plant.

Keywords: Pulses; mungbean; heterosis; combining ability; genotypes.

1. INTRODUCTION

Pulses are grown all throughout the world, with Asia, especially India, accounting for over half of global production. Pulses are produced and exported by over 173 nations, with India, Canada, China, Myanmar, and Nigeria among the top producers. More than 80% of the pulses grown in Canada are exported, making it a significant producer and exporter of pulses worldwide (Gurusamy et al., 2022). India is the world's largest producer and consumer of pulses, accounting for 36.8% of the global cultivated area, 24.2% of global production, and 27% of global consumption. The country produces approximately 80% of the world's pigeon pea, 65% of chickpea, 37% of lentil, and 65– 70% of mung bean/urad bean. Pulses, known for their high grain protein content, are a crucial component of India's predominantly vegetarian diet. Despite the nutritional benefits of pulses, their production is hindered by competition with wheat, rice and other rabicrops, resulting in decreased per capita availability. Pulses also play a crucial role in improving soil biodiversity and can contribute to sustainable agricultural practices. As dietary preferences shift towards vegetarianism and veganism, pulses are recognised as a low-carbon food option for the future (Agarwal et al., 2024; Gunathunga et al., 2024). They play a vital role in addressing protein deficiency and malnutrition, especially among the underprivileged. Mungbean (*Vigna radiata* L. Wilczek), also known as green gram, is a warm-season annual legume characterised by rapid growth. It has a short life span of 75–90 days and a small genome of 579 Mb, with a diploid chromosome number of 2n=2x=22 (Arumuganathan and Earle, 1991; Kang et al., 2014; Liu et al., 2016). Mungbean cultivation can enhance the chemical, biological and physical qualities of soil by biologically fixing atmospheric nitrogen (Mundiyara et al., 2024). To design an efficient breeding program, understanding the nature of gene action governing yield and its components is essential. Gene effect studies aid in selecting superior parents and determining specific combining ability (SCA) effects for superior hybrids. This information also helps estimate the magnitude of heterosis. The choice of breeding procedures depends on the type of gene action influencing yield and its component traits, which is evaluated through genetic variance components—additive and dominance variance.

2. MATERIALS AND METHODS

The present investigation entitled “Heterosis and Combining Ability Analysis of Mungbean Genotypes for Yield and its Attributing Traits” was carried out at Students’ Instructional Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur- 208 002 (U.P.) during *Kharif* 2022.

Geographically, the research farm is situated at 26.28 °N latitude, 80.20 °E longitude and about 126 meters above sea level, lying in the lower Ganges-Yamuna doab at the bank of the Ganges River. This place falls in the Central Plain zone of Agro-ecological sub-region (ICAR) and Upper

Gangetic Plain Zone of Agro-Climatic zone (Planning Commission).

The soil type of this site is deep, loamy, with proper irrigation and drainage facilities, which is favourable for raising a good crop. The soil type is sandy loam. The annual rainfall is about 1270 mm. The climate of the district Kanpur is semi-arid with a hot summer and a cold winter.

In this experiment there were 21 parents out of which 18 (KM 2364, KM 2419, KM 2438, KM 2439, KM 2448, KM 2449, KM 2450, KM 2452, HUM 230, IPM 208, IPM 325, IPM 604, SML 1839, SML 1723, PUSA 2071, PUSA 2072, NM 1705, NM 1903) were used as lines and 3 (PDM 139, IPM 02-3 and KM 2195) used as tester.

All 18 lines and 3 testers were grown at the student instructional farm (SIF) during *Kharif* season 2021 for making crosses in line x tester mating design, and resultant seeds of 54 hybrids, as well as 21 parental lines, were harvested separately.

The final trial comprising 75 treatments (21 parents + 54 F_1s) was conducted in a randomised block design with three replications during *Kharif* 2022 at Student's Instructional Farm, C. S. Azad University of Agriculture and Technology, Kanpur. Each parent and F_1 was grown in a single row plot.

3. RESULTS AND DISCUSSION

The analysis of variance for combining ability, utilising a Line × Tester mating design for thirteen traits, is detailed in Table 1. The variance from crosses was divided into components attributable to lines, testers, and their interaction. The analysis indicates that the variance due to lines was significant for pod length (cm) and biological yield per plant (g). Additionally, the variance due to testers was significant for several traits, including days to 50% flowering, number of pod clusters per plant, number of pods per plant, pod length (cm), number of seeds per pod, 100 seed weight (g), and biological yield per plant (g). The mean sum of squares resulting from their interaction was significant for all traits studied.

The significant mean sum of squares for lines, testers, and their interaction suggests that both general combining ability (gca) and specific combining ability (sca) variances play a crucial role in the inheritance of all the characters analysed. These findings align with the research conducted by Chavan et al. (2019), Mohan and Sheeba (2019), Narasimhulu et al. (2016) and Kakde et al. (2019).

The analysis of combining ability serves as an effective method for assessing the genetic potential of parent plants and their hybrids, facilitating their use in breeding programs. This approach also yields insights into the gene effects that govern the inheritance of various traits, which is crucial for formulating appropriate breeding strategies. Numerous studies have highlighted the importance of selecting parents based on combining ability during hybridisation programs for mungbean, as documented in the literature. Among the various methods for conducting combining ability analysis, the line × tester analysis (Kempthorne, 1957) has been extensively employed to evaluate germplasm and identify promising donor parents and their hybrids for breeding initiatives across multiple crops, including mungbean. Similar findings have been reported by Katiyar et al. (2015), Surashe et al. (2017), Kumar et al. (2018), and Kohakade et al. (2021).

The success of any plant breeding program is significantly influenced by the careful selection of parent plants. Relying solely on the individual performance of parents may not be adequate for producing heterotic hybrids. Understanding general combining ability (GCA) in conjunction with high individual performance can facilitate the identification of potential parents that possess a rich pool of superior genes (Singh and Harisingh, 1985). Chandra et al. (1969) recommended combining ability studies as a criterion for parent selection. GCA is primarily associated with the additive effects of genes, making it a reliable and effective method for selection (Sprague and Tatum, 1942). The GCA of parents for a specific trait is likely to influence the specific combining ability (SCA) of particular cross combinations due to interaction effects. Therefore, selecting parents based on GCA effects is crucial in plant breeding programs.

To demonstrate the genetic potential of parents for hybridisation, the GCA effects of 21 parents (comprising 18 lines and 3 testers) across thirteen traits were evaluated. The GCA estimates for all traits presented in Table 1 indicated that none of the parents excelled as good general combiners for all traits.

Table 1. Analysis of variance for combining ability for thirteen traits in mungbean

Traits	**Source**				**Variance**				
	Line [17]	**Tester [2]**	**Line x Tester [34]**	**Error [148]**	**σ^2L**	**σ^2T**	**σ^2GCA**	**σ^2SCA**	**σ^2GCA** **σ^2SCA**
Days to 50% flowering	3.57	29.93**	3.14**	0.64	0.05	0.50	0.01	3.86	0.003
Days to maturity	13.58	2.04	7.95**	1.67	0.63	-0.11	-0.02	2.06	-0.010
Plant height (cm)	14.32	8.63	18.38**	6.95	-0.45	-0.18	-0.02	2.27	-0.009
Number of primary branches per plant	0.40	0.05	0.25*	0.16	0.02	-0.00	0.00	0.02	0.000
Number of pod clusters per plant	2.87	23.04**	2.12**	0.41	0.08	0.39	0.01	2.98	0.003
Number of pods per plant	56.76	398.32**	40.91**	1.56	1.76	6.618	0.20	54.59	0.004
Pod length (cm)	2.74*	14.68*	1.31**	0.30	0.16	0.25	0.01	1.98	0.005
Number of seeds per pod	2.14	17.95**	1.65**	0.40	0.05	0.30	0.01	2.28	0.004
100 seed weight (g)	0.16	0.74*	0.20**	0.08	-0.00	0.01	9.18	0.10	91.800
Biological yield per plant (g)	8.03**	3.48*	6.73**	0.69	0.14	-0.06	0.00	1.80	0.000
Harvest index (%)	41.13	50.00	56.86**	18.78	-1.75	-0.22	-0.06	9.63	-0.006
Seed yield per plant (g)	1.84	1.42	2.02**	0.61	-0.19	-0.01	-0.00	0.38	0.000
Protein content (%)	0.95	0.91	0.80**	0.31	0.02	0.00	0.00	0.19	0.000

**, ** Significant at 5 % and 1 % level of significance, respectively*

The significant and positive GCA effects for grain per plant were exhibited by three lines, *viz.,* KM 2364, IPM 604 and NM 1705. The genotype, IPM 604 was good general combiner for days to maturity, number of pod clusters per plant, number of pods per plant, pod length, number of seeds per pod, biological yield per plant and protein content, genotype NM 1705 for days to maturity, number of pod clusters per plant, number of pods per plant, pod length and biological yield per plant. KM 2364 was average general combiner for number of primary branches per plant, biological yield per plant and harvest index, similarly, IPM 604 was average general combiner for plant height, number of primary branches per plant and 100 seed weight, and NM 1705 was average general combiner for days to 50% flowering, plant height, number of seeds per pod, 100 seed weight, harvest index and protein content. These suggested that these genotypes could be a better choice for developing early maturity as well as yield enhancement in mungbean.

The available literature, Mishra et al. (2024), Rather (2023), Azam et al. (2022), Kohakade et al. (2021), Rathod et al. (2020), Nath et al. (2019) and Samantaray et al. (2018) also reported significant and positive GCA effects for seed yield and yield components in different genotypes of mung bean.

The three lines mentioned above demonstrate positive and significant general combining ability (GCA) effects for seed yield per plant and other key traits discussed in the preceding paragraphs. These lines could be valuable candidates for hybridization or multiple crossing programs aimed at producing high-yielding varieties or transgressive segregants in mungbean development.

The promising F_1 hybrids showing substantial significant combining ability (SCA) effects in a favourable direction could be integrated into future mungbean enhancement programs. The general and specific combining abilities are linked to interaction effects, likely resulting from dominance and epistatic components of genetic variation that are inherently non-fixable. The advantages of the notable and positive sca effects in a desirable direction are detailed in Table 2.

The present investigation revealed that the seven cross combinations *viz*; KM 2448 x IPM 02-3, KM 2448 x KM 2195, KM 2449 x KM 2195, IPM 208 x PDM 139, IPM 604 x IPM 02-3, SML 1839 x PDM 139, and PUSA 2071 x IPM 02-3 were good specific combiners for seed yield per plant. Along with seed yield per plant cross combinations; KM 2448 x IPM 02-3 was also good specific combiner for number of pods per plant and biological yield per plant, KM 2448 x KM 2195 for number of pods per plant and pod length, IPM 208 x PDM 139 for days to maturity, pod length and number of seeds per pod, IPM 604 x IPM 02-3 for days to maturity, SML 1839 x PDM 139 for days to flowering and biological yield per plant, PUSA 2071 x IPM 02-3 for number of seeds per pod, 100 seed weight and harvest index. The specific combining ability (SCA) effect of crosses serves as a valuable estimate for identifying optimal cross combinations. A high SCA indicates a strong heterotic response; however, this does not necessarily correlate with superior hybrid performance.

It is evident that cross combinations exhibiting high SCA estimates for seed yield per plant consistently show positive SCA effects for one or more traits associated with yield. Grafius (1959) suggested that there may not be distinct genes solely responsible for yield, as yield is likely the outcome of complex interactions among various genetic components contributing to different yield traits. Similar results for other cross combinations were observed by Latha et al. (2018), Samantaray et al. (2018), Nath et al. (2019), Rathod et al. (2020), Kohakade et al. (2021), Azam et al. (2022), Rather (2023) and Mishra et al. (2024).

Overall, the crosses that demonstrated significant specific combining ability (sca) effects were consistently linked to improved performance for the respective traits. An examination of Table 2 indicated that effective specific combiners included parent combinations of low x low, average x high, average x low, low x high, and high x high general combining ability effects. These results suggest that the most effective cross combinations do not solely arise from high x high general combiners; they can also emerge from various other parental pairings. Nevertheless, in most instances, the crosses with elevated sca effects typically featured one or both parents as strong general combiners for the traits being analysed. These findings align with previous research of Latha et al. (2018), Samantaray et al. (2018), Nath et al. (2019), Rathod et al. (2020), Kohakade et al. (2021), Azam et al. (2022), Rather (2023) and Mishra et al. (2024).

Table 2. Best specific combiners in relation to the mean performance of the crosses

S. No.	Characters	Crosses with significant effects	Per se performance	SCA	GCA effects of its parents
01	Days to 50% flowering	KM 2438 x IPM 02-3	40.33	-1.198*	P x A
		KM 2439 x IPM 02-3	39.67	-0.975*	A x A
		HUM 230 x PDM 139	40.00	-2.216**	P x P
		IPM 208 x KM 2195	39.67	-1.364**	A x P
		SML 1839 x PDM 139	41.67	-1.327**	A x P
		PUSA 2072 x IPM 02-3	41.67	-1.198*	P x A
		NM 1705 x PDM 139	42.67	-1.327**	A x P
02	Days to maturity	KM 2419 x PDM 139	66.00	-3.364**	G x A
		KM 2448 x PDM 139	62.33	-1.698*	P x A
		KM 2450 x IPM 02-3	63.00	-2.642**	G x P
		HUM 230 x PDM 139	58.00	-1.809*	P x A
		IPM 208 x PDM 139	65.33	-1.809*	P x A
		IPM 604 x IPM 02-3	61.33	-1.531*	G x P
03	Plant height (cm)	KM 2364 x PDM 139	34.47	-4.031**	G x P
		KM 2448 x PDM 139	39.83	-3.753*	P x P
		IPM 208 x KM 2195	39.40	-8.618**	G x A
04	Number of primary branches per plant	KM 2439 x PDM 139	1.67	0.53*	P x A
05	Number of pod clusters per plant	KM 2364 x IPM 02-3	10.00	1.191**	P x P
		KM 2419 x PDM 139	10.33	1.117**	P x P
		KM 2450 x KM 2195	9.33	1.469**	A x G
		HUM 230 x PDM 139	10.00	0.784*	P x P
		IPM 325 x IPM 02-3	9.00	0.747*	P x P
		SML 1839 x KM 2195	10.00	1.136**	P x G
		PUSA 2071 x PDM 139	12.00	0.784*	P x P
		NM 1705 x PDM 139	10.67	0.784*	G x P
06	Number of pods per plant	KM 2364 x IPM 02-3	30.33	7.272**	P x P
		KM 2419 x PDM 139	30.00	3.753**	G x P
		KM 2438 x IPM 02-3	22.00	4.605**	G x P
		KM 2439 x PDM 139	23.00	1.642*	G x P
		KM 2448 x IPM 02-3	24.00	2.827**	G x P

S. No.	Characters	Crosses with significant effects	Per se performance	SCA	GCA effects of its parents
		KM 2448 x KM 2195	23.00	1.753*	G x G
		KM 2449 x IPM 02-3	31.67	1.716*	A x P
		KM 2450 x IPM 02-3	25.00	3.383**	A x P
		KM 2450 x KM 2195	31.00	2.975**	A x G
		KM 2452 x KM 2195	27.00	1.753*	P x G
		HUM 230 x PDM 139	28.67	4.975**	A x P
		IPM 325 x PDM 139	20.00	2.086**	P x P
		IPM 604 x PDM 139	19.67	2.086**	G x P
		SML 1839 x KM 2195	30.00	5.975**	P x G
		PUSA 2071 x PDM 139	33.00	1.753*	P x P
		PUSA 2072 x KM 2195	32.33	3.753**	P x G
		NM 1705 x PDM 139	33.67	2.309**	G x P
07	Pod length	KM 2448 x KM 2195	8.03	1.062**	P x G
		IPM 208 x PDM 139	9.03	1.305**	P x P
08	Number of seeds per pod	KM 2419 x IPM 02-3	7.20	0.847*	G x P
		KM 2438 x IPM 02-3	8.67	0.747*	P x P
		IPM 325 x KM 2195	10.00	1.19**	P x G
		PUSA 2071 x IPM 02-3	9.33	1.025**	A x P
		PUSA 2072 x PDM 139	9.63	1.052**	A x P
09	100 seed weight	KM 2364 x KM 2195	3.99	0.515**	P x G
		PUSA 2071 x IPM 02-3	4.27	0.570**	P x P
		NM 1903 x IPM 02-3	4.10	0.437**	A x P
10	Biological yield per plant	KM 2364 x PDM 139	20.83	1.144*	A x P
		KM 2364 x KM 2195	18.63	1.079*	A x A
		KM 2438 x IPM 02-3	18.50	3.955**	A x G
		KM 2448 x IPM 02-3	18.87	1.144*	A x G
		KM 2452 x IPM 02-3	20.83	1.266**	P x G
		IPM 325 x KM 2195	20.83	1.257**	P x A
		IPM 604 x PDM 139	17.97	1.099*	G x P
		SML 1839 x PDM 139	21.27	3.133**	A x P
		PUSA 2072 x KM 2195	20.73	1.612**	P x A

S. No.	Characters	Crosses with significant effects	Per se performance	SCA	GCA effects of its parents
		NM 1705 x PDM 139	18.93	1.133*	G x P
11	Harvest index	KM 2438 x KM 2195	52.67	7.301**	A x A
		IPM 208 x PDM 139	43.21	8.503**	P x A
		PUSA 2071 x IPM 02-3	53.65	5.438*	P x P
12	Seed yield per plant	KM 2448 x IPM 02-3	9.57	0.978*	P x P
		KM 2448 x KM 2195	9.63	1.021*	P x A
		KM 2449 x KM 2195	9.63	0.921*	P x A
		IPM 208 x PDM 139	8.77	1.479**	P x A
		IPM 604 x IPM 02-3	10.53	2.556**	G x P
		SML 1839 x PDM 139	10.47	1.335**	P x A
		PUSA 2071 x IPM 02-3	9.90	1.223**	A x P
13	Protein content	KM 2364 x IPM 02-3	22.43	0.919**	P x A
		KM 2439 x IPM 02-3	22.37	0.697*	A x A
		KM 2450 x PDM 139	23.03	0.641*	P x P
		KM 2452 x KM 2195	22.73	0.84**	P x A

A = Average, P = Poor, G = Good

Heterosis can be defined as the superiority or inferiority of the F1s over the mid-parents, better parents and best commercial/standard variety. In this study, heterosis was evaluated against the standard check variety, Shikha.

Enhancing grain yield in mungbean primarily relies on traditional breeding techniques that leverage additive genetic variance. Given that a significant amount of non-allelic genetic variance for yield and other traits has been documented (Khattak et al., 2002; Singh et al., 2006), exploring alternative breeding strategies such as heterosis breeding could further enhance mungbean productivity in our nation. For successful large-scale application of heterosis breeding, it is essential to first identify promising cross combinations that can achieve over 20% economic heterosis, making them viable for commercial use.

Typically, the crosses that demonstrated the highest estimates of yield heterosis also displayed significant heterosis for one or more yield components. In the present investigation, KM 2364 x PDM 139, having per se performance as well as the highest economic heterosis (27.18 %) for yield, also revealed significant desirable heterotic effects for days to maturity, plant height, and harvest index. Similarly, the other best hybrid, PUSA 2072 x KM 2195, showing high per se coupled with high magnitude of economic heterosis (26.80%), also showed significant useful heterosis for days to maturity, plant height and harvest index. In addition, a few crosses *viz*. KM 2448 x PDM 139, KM 2449 x IPM 02-3, IPM 208 x KM 2195, IPM 325 x KM 2195, SML 1723 x IPM 02-3, SML 1723 x KM 2195 and NM 1903 x IPM 02-3 showing high/moderate economic heterosis for seed yield and its components. In such crosses, intensive selection should be practised in large segregating populations for isolating several high-yielding homozygous lines.

The presence of a significant degree of heterosis in both directions for all examined traits suggests a strong potential for isolating hybrids that exhibit high heterosis in a favourable direction for these traits. This scenario is highly advantageous for developing heterotic hybrids that can be utilised as breeding materials. Previous studies, including those by Hange et al. (2020), Kakde et al. (2019), Mohan and Sheeba (2019), Dhurai et al. (2016), and Tantasawat et al. (2015), have also reported a broad range of heterosis in both directions, along with sufficiently high estimates in the desirable direction for grain yield per plant and other traits in mungbean.

The crosses that demonstrated significant and positive heterosis for grain yield per plant also showed notable and positive estimates of heterosis for several key yield components, particularly for days to maturity, plant height, number of pod clusters per plant, number of seeds per pod, 100-seed weight, biological yield per plant, and harvest index. These findings support the conclusions of earlier researchers that the heterosis observed for grain yield per plant is largely attributed to the heterosis of its yield components. Numerous studies in the literature have indicated that the high positive heterosis for seed yield in mungbean is linked to heterosis in several important yield components, as noted by Hange et al. (2020), Kakde et al. (2019), Mohan and Sheeba (2019), Dhurai et al. (2016), Tantasawat et al. (2015), and Patil et al. (2014).

4. CONCLUSION

The present investigation revealed that the seven cross combinations viz; KM 2448 x IPM 02-3, KM 2448 x KM 2195, KM 2449 x KM 2195, IPM 208 x PDM 139, IPM 604 x IPM 02-3, SML 1839 x PDM 139, and PUSA 2071 x IPM 02-3 were good specific combiners for seed yield per plant. Along with seed yield per plant cross combinations; KM 2448 x IPM 02-3 was also good specific combiner for number of pods per plant and biological yield per plant, KM 2448 x KM 2195 for number of pods per plant and pod length, IPM 208 x PDM 139 for days to maturity, pod length and number of seeds per pod, IPM 604 x IPM 02-3 for days to maturity, SML 1839 x PDM 139 for days to flowering and biological yield per plant, PUSA 2071 x IPM 02-3 for number of seeds per pod, 100 seed weight and harvest index.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Agarwal, D., Devra, S. J., & R., R. S. (2024). Pulses in India: Comprehensive analysis of production, challenges, and strategic vision for 2030. *Journal of Experimental Agriculture International, 46*(11), 293–304.

Arumuganathan, K., & Earle, E. D. (1991). Nuclear DNA content of some important plant species. *Plant Molecular Biology Reporter, 9*, 208–218.

Azam, M. G., Sarker, U., Hossain, M. A., Iqbal, M. S., Islam, M. R., Hossain, M. F., Ercisli, S., Kul, R., Assouguem, A., Al-Huqail, A. A., & Mohamed, R. H. H. (2022). Genetic analysis in grain legumes (*Vigna radiata* (L.) Wilczek) for yield improvement and identifying heterotic hybrids. *Plants, 11*(13), 1774.

Chandra, S., Sindhu, G. S., & Arora, N. D. (1969). Line x Tester studies on some male sterile and pollinator parents in forage sorghum. *Indian Journal of Agricultural Sciences, 39*, 690–698.

Chavan, S. B., Patil, D. K., & Pawan, V. S. (2019). Heterosis study for grain yield and yield contributing characters in mungbean. *Journal of Pharmacognosy and Phytochemistry, 8*(6), 1880–1886.

Dhurai, S. Y., Singh, M. N., & Saroj, S. K. (2016). Heterosis and inbreeding depression for yield and its components in mungbean (*Vigna radiata* (L.) Wilczek). *The Bioscan, 11*(2), 1053–1057.

Grafius, J. E. (1959). Heterosis in barley. *Agronomy Journal, 5*, 551–554.

Gunathunga, C., Senanayake, S., Jayasinghe, M. A., Brennan, C. S., Truong, T., Marapana, U., & Chandrapala, J. (2024). Germination effects on nutritional quality: A comprehensive review of selected cereals and pulses changes. *Journal of Food Composition and Analysis, 128*, 106024.

Gurusamy, S., Vidhya, C. S., Khasherao, B. Y., & Shanmugam, A. (2022). Pulses for health and their varied ways of processing and consumption in India – A review. *Applied Food Research, 2*(2), 100171.

Hange, S. R., Shinde, S. R., & Pawar, V. S. (2020). Heterosis studies in green gram (*Vigna radiata* L. Wilczek) for earliness, grain yield and yield contributing character. *International Journal of Chemical Studies, 8*(4), 4028–4031.

Kakde, S. S., Gawate, A. B., & Mandge, S. V. (2019). Heterosis for yield and component traits and seed yield in mungbean (*Vigna radiata* L. Wilczek). *Journal of Pharmacognosy and Phytochemistry, 8*(2), 296–300.

Kang, Y. J., Kim, S. K., Kim, M. Y., Lestari, P., Kim, K. H., Ha, B. K., Jun, T. H., Hwang, W. J., Lee, T., Lee, J., & Shim, S. (2014). Genome sequence of mungbean and insights into evolution within *Vigna* species. *Nature Communications, 5*(1), 5443.

Katiyar, D., Hemantaranjan, A., & Singh, B. (2015). Chitosan as a promising natural compound to enhance potential physiological responses in plant: A review. *Indian Journal of Plant Physiology, 20*(1), 1–9.

Kempthorne, O. (1957). The contributions of statistics to agronomy. *Advances in Agronomy, 9*, 177–204.

Khattak, G. S. S., Haq, M. A., Ashraf, A., Khan, A. J., & Zamir, R. (2002). Genetic architecture of secondary yield components in mungbean (*Vigna radiata* (L.) Wilczek). *Breeding Science, 52*, 235–241.

Kohakade, S. N., Kute, N. S., Karvar, S. H., Jadhav, G. N., & Shinde, G. C. (2021). Heterosis studies for yield and yield components in greengram (*Vigna radiata* L. Wilczek). *Journal of Pharmacognosy and Phytochemistry, 10*(1), 529–533.

Kumar, A., Sharma, N. K., Kumar, R., Sanadya, S. K., & Sahoo, S. (2018). Correlation and path analysis for seed yield and components traits in mungbean under arid environment. *International Journal of Chemical Studies, 6*(4), 1679–1681.

Latha, V. S., Eswari, K. B., & Kumar, S. S. (2018). Combining ability analysis for seed yield and its component characters in greengram (*Vigna radiata* L. Wilczek). *International Journal of Chemical Studies, 6*(2), 237–242.

Liu, M. S., Kuo, T. C. Y., Ko, C. Y., Wu, D. C., Li, K. Y., Lin, W. J., Lin, C. P., Wang, Y. W., Schafleitner, R., Lo, H. F., & Chen, C. Y. (2016). Genomic and transcriptomic comparison of nucleotide variations for insights into bruchid resistance of mungbean (*Vigna radiata* [L.] R. Wilczek). *BMC Plant Biology, 16*, 1–16.

Mishra, A., Mishra, T. K., Satpathy, T., & Pradhan, B. (2024). Combining ability studies for seed yield and its quantitative traits in F2 crosses of mungbean (*Vigna radiata* Wilczek). *Legume Research, 47*(11), 1864–1868.

Mohan, S., & Sheeba, A. (2019). Heterosis and combining ability analysis for yield and yield related traits in greeng (*Vigna radiata* L.). *Electronic Journal of Plant Breeding, 10*(3), 1255–1261.

Mundiyara, R., Yadav, G. L., Bajiya, R., Singh, I., & Panday, S. (2024). Genetic variability, character association and path analysis for various characters in mungbean (*Vigna radiata* (L.) Wilczek). *Journal of Experimental Agriculture International, 46*(7), 299–307.

Narasimhulu, R., Naidu, N. V., Reddy, K. H. P., & Naidu, G. M. (2016). Combining ability and heterosis for yield and its attributes in greengram (*Vigna radiata* L. Wilczek). *Electronic Journal of Plant Breeding, 7*(3), 784–793.

Nath, A., Maloo, S. R., Nath, S., & Yadav, G. S. (2019). Combining ability analysis for seed protein and methionine content in greengram (*Vigna radiata* L. Wilczek). *Indian Journal of Agricultural Research, 52*(1), 34–39.

Patil, A. B., Desai, N. C., Chuahan, D. A., & Chougule, G. R. (2014). Heterosis for seed yield and yield attributing traits in mungbean (*Vigna radiata* L. Wilczek). *Bioinfolet, 11*(2a), 386–390.

Rather, M. I. (2023). *Genetic diversity studies and identification of Cercospora leaf spot and MYMV resistant genotypes in mungbean (Vigna radiata L.)* [Doctoral dissertation, SKUAST Kashmir].

Rathod, V., Pithia, M. S., & Solanki, H. V. (2020). Combining ability analysis for yield and yield components in mungbean (*Vigna radiata* L. Wilczek). *Legume Research, 43*(1), 151–154.

Samantaray, J., Das, T. R., & Baisakh, B. (2018). Combining ability and gene action for yield traits in greengram (*Vigna radiata* L. Wilczek). *Electronic Journal of Plant Breeding, 9*(2), 583–588.

Singh, I., Gill, M. S., & Bains, T. S. (2006). Generation mean analysis for yield attributing traits in mungbean (*Vigna radiata* (L.) Wilczek). *Indian Journal of Genetics and Plant Breeding, 66*(1), 47–48.

Singh, R. A., & Harisingh. (1985). Combining ability and heterosis for seed yield and its component characters in Indian mustard sown early and late. *Indian Journal of Agricultural Sciences, 55*(5), 309–315.

Sprague, G. P., & Tatum, L. A. (1942). General vs. specific combining ability in single crosses of corn. *Journal of the American Society of Agronomy, 34*, 923–932.

Surashe, S. M., Patil, D. K., & Gite, V. K. (2017). Combining ability for yield and yield attributes characters in greengram (*Vigna radiata* (L.) Wilczek). *International Journal of Current Microbiology and Applied Sciences, 6*(11), 3552–3558.

Tantasawat, P. A., Khajudparn, P., Prajongjai, T., & Poolsawat, O. (2015). Heterosis for the improvement of yield in mungbean (*Vigna radiata* L. Wilczek). *Genetics and Molecular Research, 14*(3), 10444–10451.

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/142177