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Studies on Genetic Variability, Heritability, Correlation and Path Analysis in Greengram [*Vigna radiata* (L.) Wilczek]

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Authors' contributions

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

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ABSTRACT

Mungbean (*Vigna radiata* (L.) Wilczek) is an important pulse crop cultivated across Asia and other regions, valued for its high protein content and adaptability to various climates. This study aimed to assess the genetic variability, heritability, and genetic advance of 11 agronomic traits in mungbean,

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using 10 genotypes crossed in a half-diallel design, and 45 F_1 hybrids formed. Field trials were conducted in randomized block design with three replications during Kharif 2023 at the Crop Research Centre, Meerut, India. Observations were recorded for traits including plant height, pods per plant, 100-seed weight, and seed yield. High genotypic and phenotypic coefficients of variation were observed for the number of pods per plant, while traits like seed yield and protein content showed moderate to low variability. Heritability was high for most traits, indicating strong genetic control, with genetic advance highest for the number of pods per plant. Genotypic correlation and path coefficient analysis revealed positive correlations between seed yield and key traits such as 100-seed weight and pod length. These findings provide valuable insights for the selection of high-yielding mungbean genotypes in breeding programs.

Keywords: Mungbean; variability; correlation; path coefficient analysis; GCV and PCV.

1. INTRODUCTION

Mungbean (*Vigna radiata* (L.) Wilczek) is sometimes referred to as greengram. This ancient, well-known pulse crop, which is diploid and has 2n=2x=22 chromosomes, is a member of the Papilionoideae family and is native to South East Asia [1]. *Vigna radiata* is divided into three subgroups: Vigna radiata subsp. radiata, which is cultivated, and Vigna radiata subsp. sublobata, which is wild (*Vigna radiata subsp. glabra*). It is a little green bean with a circular form that is native to India and is widely grown throughout Asia, including Bangladesh, India, Thailand, Laos, Vietnam, Cambodia, Indonesia, Malaysia, and South China. One of the most popular edible legumes cultivated in Asia is mungbean, which has a significant impact on both human diets and agricultural cultivation systems.

As a short-day plant, greengrams thrive best in warm, subtropical climates with an average temperature of 22 to 35 ºC and an annual rainfall of 60 to 100 cm. These regions are best suited for crop production when the mean sea level is between 1800 and 2000 meters. Sandy loam or deeply well-drained soils were necessary for its cultivation. Mungbean is an annual plant that is either upright or suberect, has branches, and tends to twine in the top branches. It typically reaches a height of 40 to 120 cm [2]. The trifoliate leaf arrangement has big, oval, fully or sparingly lobed, membranous leaflets with hairs on both sides. The length of the pods varies from 10 to 15 cm; they are usually cylindrical, straight, or slightly curved, and the seeds are tiny, globular, or oblong, usually green but sometimes speckled with yellow-brown.

Worldwide, Mungbean is a crop with a short growing season that is commonly cultivated in temperate, subtropical, and tropical climates. Its cultivation is appropriate for a variety of cropping systems, the majority of which are dominated by staple food crops like wheat and rice. These crops are widely grown in many Asian nations, sub-Saharan Africa, arid regions of southern Europe, warmer parts of Canada, and the United States [3-6]. Mungbean, one of the pulses that can withstand mild drought and heat stress, is important for rainfed agriculture in arid and semi-arid regions [7].

Mungbean is an annual crop that is highly branched, measured 60-76 cm tall [8], with a slight tendency to twine in upper branches. The central stem of this crop is roughly erect, but the side branches are semi-erect. Mungbean can be consumed as whole seed, dal, or sprouted form, as it is a source of high-quality protein which is an excellent complement to rice in respect to balanced human nutrition.

It contributes significantly to diets in terms of proteins (240 g/kg), carbs (630 g/kg), and a variety of micronutrients [3]. Of the 20–24 percent protein found in mungbean, the two main types are albumin and globulin, which make up almost 60% and 25% of the protein, respectively. Aside from that, it is frequently prescribed for Beriberi and is a rich source of vitamin B.

2. MATERIALS AND METHODS

Materials for the present investigation comprised ten genotypes of mungbean *viz.,* PM-3, PM-5, PM-9, PM-4, WHM-16, IPM-0219, PUSA-9531, SMM 15-72, Indor Moong and MH-521collected from the department of Genetics and Plant Breeding. All the possible 45 F_1's hybrids, excluding reciprocals made among these ten parents during *kharif* season 2022. The research centre situated at an elevation of about 237 meters above mean sea level 29º01' N latitude and 77º45' E longitude, representing the North

Western Plain Zone. Parents and crosses were sown at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut during the season of *Kharif* 2023. Seed of each of the parents and F_1's sown by hand dibbling method in two rows plot. The rows had 3 m long and spaced 30 cm apart. The plant to plant spacing maintained at 10 cm, and all the recommended agronomic inputs and practices were followed during the season to raise the healthy crops.

Observations recorded on five randomly selected competitive plants from each parent and F_1's populations in each replication for 11 characters namely, days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, pod length (cm), number of pods per plant, number of seeds per pod, protein content (%), 100 seed weight (gm), harvest index (%) and seed yield per plant (gm). The selected plants were tagged and properly labelled to record the observations.

Heritability was calculated using the formula suggested by Crumpacker and Allard [9] based on the component analysis. The genetic advance was calculated using the formula given by Robinson et al. [10], estimation of correlation coefficients by Searle [11], path coefficient analysis by Dewey and Lu. [12] and genotypic coefficient of variation by Fisher, [13]. These observations were collected in a data book as raw data and analysed through R Language software and Dos Box.

3. RESULTS AND DISCUSSION

3.1 Variability, Heritability and Genetic Advance as a Percentage of Mean

3.1.1 Genotypic Coefficient of Variation (GCV)

High percentage of genotypic coefficient of variation (more than 25%) was recorded for number of pods/plant (27.78) and moderate percentage of genotypic coefficient of variation (10-25%) was recorded for number of primary branches/plant (12.61) and 100 seed weight (g) (11.59). Plant Height (cm) (9.72), days to maturity (9.05), number of pods per plant 8.45, pod length (cm) (7.22), harvest index (%) (6.80), seed yield/plant (g) (5.96) and protein content (%) (4.86) showed low genotypic coefficient of variation (<10%). The higher and moderate GCV indicating that more variability and scope for selection in improving these characters. Similar results were found by Rahim et al., [14] Surashe et al. [15] Priya et al. [16].

3.1.2 Phenotypic Coefficient of Variation (PCV)

Phenotypic coefficient of variation (PCV) had generally higher than their corresponding genotypic coefficient of variation for all of the characters studied, indicated that these traits are more influenced by environmental factors. The high percentage of phenotypic coefficient of variation (more than 25%) was recorded for number of pods/plant (28.11) and moderate percentage of phenotypic coefficient of variation (10-25%) was recorded for number of primary branches/plant (12.96) and 100 seed weight (g) (12.37). Plant height (cm) (9.91), days to maturity (9.31), number of pods per plant (9.60), pod length (cm) (8.05), seed yield/plant (g) (8.35) harvest index (%) (7.13) and protein content (%) (5.40) showed low phenotypic coefficient of variation (<10%). Similar observations were also reported by Payasi [17] Anand et al. [18] Kumar et al. [19] Kumar, [20].

3.2 Heritability (h^2)

High heritability (> 60%) was found for all the characters *i.e*., number of pods/plant (97.64), plant height (cm) (96.08), number of primary branches/plant (94.64), days to maturity (94.57), days to 50% flowering (94.53), harvest index (%) (91.19), 100 seed weight (g) (87.78), protein content (%) (80.87), pod length (cm) (80.42) and number of pods per plant (77.53) except seed yield/plant (g) (50.98) which showed the moderate heritability. Similar observations were also reported by Babu et al. [21] Yoseph et al. [22] Saravanan et al. [23].

3.3 Genetic Advance (GA)

Expected genetic advance expressed as a percentage of mean was observed high (> 20%) for number of pods/plant (56.55), number of primary branches per plant (25.28), days to 50% flowering (23.15) and 100 seed weight (g) (22.36), whereas moderate genetic advance as percentage of mean (10-20%) expressed for days to maturity (18.13), number of pods per plant (15.33), pod length (cm) (13.34), harvest index (%) (13.39) and low for seed yield/plant (g) (8.77) and protein content (%) (9.00). These characters have also been reported earlier by Asari et al. [24] Majhi et al. [25] Singh et al. [26] Mundiyara et al. [27]. This indicated that these traits were highly heritable and selection of high performing genotypes is possible to improve these attributes.

3.4 Genotypic Correlation Coefficient

The genotypic correlation coefficient (Table 2) revealed that seed yield per plant was highly significant positively correlated with 100 seed weight (g) (0.681**), number of seeds per pod (0.567**), pod length (cm) (0.553**), plant height (cm) (0.383**) and number of primary branches per plant (0.373**). It was found significant positively correlated with number of pods per plant (0.171*). The positive but non-significant correlation was observed for days to 50% flowering 0.139, harvest index (%) 0.131, protein content (%) 0.069 and days to maturity 0. 054. These results are similar to earlier reports of Khalid et al. [28] Kumar et al. [29] Kadam et al. [30] Khan et al. [31].

3.5 Path Coefficient Analysis (Direct and Indirect Effects)

The yield contributing characters were considered in path coefficient analysis to estimate their direct and indirect effect on seed yield. In the research study, path analysis has proved very useful and it is used as a tool to partition the observed correlation coefficient into a series of direct and indirect effects of yield components on yield in 45 genotypes and the results are presented in Table 3.

3.5.1 Direct effect

The genotypic path coefficient analysis revealed maximum positive direct effect was depicted by 100 seed weight g (0.5269), pod length cm (0.4312), number of pods per plant (0.2608), plant height cm (0.2485), protein content % (0.2064), number of primary branches per plant (0.0845), days to maturity (0.0602), harvest index % (0.0719) and days to 50% flowering (0.0793). However, negative direct effect was observed for nmber of pods/plant (-0.4391). These results were similar to earlier reported by Kumar et al., [32] Manivelan et al., [33] Ahmad and Belwal, [34] Dash et al., [35] Joshi et al., [36].

3.5.2 Indirect effect

Days to 50% flowering expressed indirect and positive effect by protein content (%), number of primary branches/plant, plant height cm, 100 seed weight (g), and harvest index %. Days to maturity was affected indirectly and positively by the number of pods per plant, 100 seed weight, protein content, number of primary branches per plant, plant height, and pod length. Plant height showed an indirect and positive effect by pod length, the number of pods per plant, harvest index, 100 seed weight, days to maturity, days to 50% flowering, and the number of primary branches per plant. Number of primary branches per plant revealed an indirect and positive effect by 100 seed weight, the number of pods per plant, pod length, days to 50% flowering, days to maturity, and plant height. Pod length was affected indirectly and positively by plant height, the number of pods per plant, 100 seed weight, the number of primary branches per plant, and days to maturity. Number of pods per plant showed an indirect and positive effect by days to 50% flowering and harvest index. Similar observations were also reported by Ramakrishnan et al., [37] Kumar et al., [38] Khatik et al., [39] Kumar et al., [20]

Table 1. Phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance as % of mean in Greengram

Sl. No.	Genotypes	GCV(%)	PCV(%)	Heritability (%)	Genetic Advance	Genetic Advance as % of mean
1.	Days to 50% flowering	11.56	11.89	94.53	8.50	23.15
2.	Days to maturity	9.05	9.31	94.57	11.91	18.13
3.	Plant height (cm)	9.72	9.91	96.08	9.21	19.62
4.	Number of primary branches/plant	12.61	12.96	94.64	1.02	25.28
5.	Pod length (cm)	7.22	8.05	80.42	1.02	13.34
6.	Number of pods/plant	27.78	28.11	97.64	15.40	56.55
7.	No of seeds/pod	8.45	9.60	77.53	1.61	15.33
8.	Protein content (%)	4.86	5.40	80.87	2.11	9.00
9.	100 Seed weight (g)	11.59	12.37	87.78	0.73	22.36
10.	Harvest index (%)	6.80	7.13	91.19	3.94	13.39
11.	Seed yield/plant (g)	5.96	8.35	50.98	0.74	8.77

Table 2. Estimates of Genotypic correlation coefficients for different traits in Greengram

Parent/Hybrids	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of primary branches per plant	Pod length (cm)	Number of pods per plant	Number of seeds/pod	Protein content (%)	100 Seed weight (g)	Harvest index (%)	Seed yield/plant (g)
Days to 50% flowering	1.000	-0.195*	0.024	0.103	-0.188*	-0.324**	-0.193*	0.119	0.036	0.022	0.139
Days to maturity		1.000	0.046	0.094	0.043	0.425**	0.172*	0.165*	0.167*	-0.133	0.054
Plant height (cm)			1.000	0.010	0.448**	0.274**	0.129	-0.090	0.063	0.124	0.383**
Number of pri. Branch/plant				1.000	0.189*	0.328**	0.367**	-0.113	0.509**	-0.089	0.373**
Pod length (cm)					1.000	0.430**	0.247**	-0.060	0.275**	-0.058	0.553**
Number of pods/plant						1.000	0.365**	0.147	0.421**	-0.244**	0.171*
Number of seeds/pod							1.000	-0.078	0.613**	-0.038	0.567**
Protein content (%)								1.000	-0.031	0.002	0.069
100 Seed weight (g)									1.000	-0.049	0.681**
Harvest index (%)										1.000	0.131
Seed yield/plant (g)											1.000

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

Table 3. Estimates of (Genotypic) direct and indirect effects of different characters on yield per plant in Greengram

Parent/Hybrids	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of primary Branch/plant	Pod length (cm)	Number of pods/plant	Number of seeds/pod	Protein content (%)	100 Seed weight (g)	Harvest index (%)	Seed yield/plant (g)
Days to 50% flowering	**0.0793**	-0.0118	0.0061	0.0087	-0.0811	0.1424	-0.0505	0.0247	0.0188	0.0016	0.139
Days to maturity	-0.0155	**0.0602**	0.0115	0.0080	0.0185	-0.1866	0.0448	0.0340	0.0881	-0.0096	0.054
Plant height (cm)	0.0019	0.0028	**0.2485**	0.0008	0.1931	-0.1203	0.0337	-0.0186	0.0330	0.0089	0.383**
Number of primary Branches/plant	0.0081	0.0057	0.0024	**0.0845**	0.0813	-0.1440	0.0956	-0.0234	0.2682	-0.0064	0.373**
Pod length (cm)	-0.0149	0.0026	0.1113	0.0159	**0.4312**	-0.1889	0.0646	-0.0124	0.1452	-0.0041	0.553**
Number of pods/plant	-0.0257	0.0256	0.0681	0.0277	0.1855	**-0.4391**	0.0951	0.0303	0.2220	-0.0176	0.171*
Number of seeds/pod	-0.0153	0.0103	0.0321	0.0310	0.1067	-0.1601	**0.2608**	-0.0162	0.3228	-0.0028	0.567**
Protein content (%)	0.0095	0.0099	-0.0224	-0.0096	-0.0260	-0.0644	-0.0204	**0.2064**	-0.0166	0.0001	0.069
100 Seed weight (g)	0.0028	0.0101	0.0156	0.0430	0.1188	-0.1850	0.1598	-0.0065	**0.5269**	-0.0036	0.681**
Harvest index (%)	0.0017	-0.0080	0.0308	-0.0075	-0.0248	0.1072	-0.0100	0.0004	-0.0260	**0.0719**	0.131

Residual values = 0.0164

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

Number of seeds per pod expressed indirect and positive effects by 100 seed weight, the number of primary branches per plant, the number of pods per plant, pod length, days to maturity, and plant height. Protein content was revealed to have an indirect and positive effect by days to maturity, the number of pods per plant, days to 50% flowering, and harvest index.100 seed weight was affected indirectly and positively by plant height, days to 50% flowering, and protein content. Harvest index showed an indirect and positive effect by plant height (cm) (0.0089), days to 50% flowering (0.0016), and protein content (%) (0.0001). These findings are by the results obtained in mungbean by Kumar et al. [40] Azam et al. [41] Satyanarayana et al. [42] Kumar et al. [43] Thonta [44] Srivastava et al. [45].

4. CONCLUSION

This study provides significant insights into the genetic variability, heritability, and genetic advancement of various agronomic traits in mungbean. The high heritability observed for most traits, including plant height, number of pods per plant, and 100-seed weight, suggests strong genetic control and potential for effective selection in breeding programs. The genotypic and phenotypic coefficients of variation indicated substantial variability for traits like the number of pods per plant, highlighting these as critical targets for genetic improvement. Positive correlations between seed yield and traits such as 100-seed weight and pod length further emphasize their importance in enhancing mungbean productivity. Overall, the findings underscore the potential for developing high-yielding mungbean varieties through strategic selection and breeding, contributing to improved dietary protein intake and sustainable agriculture in diverse climatic regions.

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 no competing interests exist.

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