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Estimation of Genetic Parameters for Yield Traits in Greengram (*Vigna radiata* (L.) Wilczek) Mutants under EMS Mutagenesis of M3 Generation

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***Abstract* – The current study was carried out with mutants of greengram (WGG-42) genotype collected from from ICAR-CRIDA, Santoshnagar, Hyderabad and the work was done at the Center for Plant Molecular Biology at Osmania University in Hyderabad and the Department of Genetics and Plant Breeding at Acharya N.G. Ranga Agricultural University in Lam, Guntur, Andhra Pradesh. The aim of the study is to analyse genetic parameter for yield characters in M3 generation. The results showed the correlation analysis revealed that number of secondary branches per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, and 100-seed weight exhibited strong positive associations with seed yield, indicating their direct contribution to productivity. The results also showed the estimates of heritability and genetic advance showed that plant height, number of primary and secondary branches per plant, number of pods per plant, number of seeds per plant, and seed yield per plant recorded high heritability coupled with high genetic advance, suggesting the predominance of additive gene action. These traits offer substantial scope for improvement through direct selection in mutant populations. In contrast, traits such as 100-seed weight and days to maturity exhibited moderate heritability with low to moderate genetic advance, implying the influence of non-additive gene effects and environmental factors, thereby requiring recurrent selection or hybridization strategies for effective improvement. The study confirmed that EMS-induced mutagenesis is an effective approach for generating genetic variability in green gram. The M_3 generation mutants displayed significant variability with promising heritable traits for yield enhancement.**

***Keywords* – Green Gram, Correlation, Genetic Advance and Heritability.**

I. Introduction

Greengram, also known as mungbean (*Vigna radiata* (L.) Wilczek), is one of the most important pulse crops cultivated across tropical and subtropical regions of Asia, Africa, and parts of South America. It belongs to the family Fabaceae and is valued for its high nutritional content, short life cycle, and ability to enrich soil fertility through biological nitrogen fixation. The seeds contain approximately 24-26% protein, 1-1.5% fat, 60–65% carbohydrates, and are rich in essential amino acids such as lysine and leucine, making them a key dietary component in vegetarian populations (Kaur et al., 2023). A key objective of mutation breeding is to enhance genetic variability-the raw material for selection and crop improvement. Quantitative genetic parameters such as genotypic and phenotypic coefficients of variation (GCV, PCV), heritability, and genetic advance provide insights into the extent of variability and the potential for selection in mutant populations (Falconer & Mackay, 2023). High heritability coupled with high genetic advance indicates additive gene action and suggests that selection would be effective for the trait (Basavaraj et al., 2022). Moreover, correlation studies among traits help in understanding the interrelationships between yield and its contributing components, guiding breeders to select indirectly for yield improvement through easily measurable traits (Chaudhary et al., 2024).

II. Material and Methods

The present investigation was carried out at the Department of Genetics and Plant Breeding, Acharya N.G. Ranga Agricultural University, Lam, Guntur, Andhra Pradesh and Centre for Plant Molecular Biology, Osmania University, Hyderabad during Sept, 2025 to Dec, 2025. The greengram (*Vigna radiata* (L.) Wilczek) genotype-WGG-42, obtained from ICAR-CRIDA, Santoshnagar, Hyderabad and the ethyl methane sulphonate (EMS) was obtained from HIMEDIA Laboratory limited, Mumbai, India, was used as chemical mutagen to induce the blackgram seeds. The aim of the study is to analyses genetic parameter for yield characters in M3 generation.

Phenotypic and genotypic correlations were worked out using the formulae suggested by Johnson et al. (1955). Significance of correlation coefficients was tested by comparing phenotypic and genotypic correlation coefficients with the correlation table values given by Fisher and Yates (1963) at (n-2) degrees of freedom where 'n' denotes the number of paired observations used in the calculation. Phenotypic and genotypic coefficients of variation were calculated based on the method advocated by Burton (1952). Categorisation of the range of variation was followed as proposed by Sivasubramanian and Menon (1973). Heritability in broad sense was estimated as per Allard (1960) and expressed in percentage. Genetic advance was estimated by the method suggested by Johnson et al. (1955). Genetic advance was expressed as percentage of mean by using the following formula as given by Johnson et al. (1955).

III. Results and Discussions

3.1. *Correlation Analysis*

The phenotypic correlation coefficients among yield and yield-related traits in M_3 generation of greengram mutants are presented in Table 1.

Table 1. Phenotypic correlation for seed yield and yield contributing traits in greengram mutants in M3 generations.

	Pl. Ht (cm)	No. of P. Br./Pl	No. of S. Br./Pl	Days to F. Ini.	Days to P.M	No. L/Pl	No. Cl/Pl	No. P/Cl	No. P/Pl	No. S/PD	No S/Pl	100 S. Wt (g)
No. of P.Br./Pl	0.963**											
No. of S.Br./Pl	0.881**	0.908**										
Days to F. Ini.	-0.891**	-0.936**	-0.872**									
Days to P.M.	-0.892**	-0.893**	-0.881**	0.873**								
No. L/Pl	0.970**	0.979**	0.864**	-0.933**	-0.893**							
No. Cl/Pl	0.914**	0.942**	0.881**	-0.912**	-0.832**	0.927**						
No. P/Cl	0.855**	0.881**	0.860**	-0.824**	-0.824**	0.847**	0.861**					
No. P/Pl	0.906**	0.932**	0.903**	-0.898**	-0.848**	0.903**	0.980**	0.926**				
No. S/PD	0.847**	0.812**	0.752**	-0.715**	-0.812**	0.782**	0.813**	0.755**	0.821**			
No S/Pl	0.895**	0.912**	0.894**	-0.867**	-0.840**	0.874**	0.967**	0.906**	0.991**	0.872**		
100 S. Wt(g)	0.731**	0.747**	0.811**	-0.753**	-0.679**	0.670**	0.780**	0.767**	0.823**	0.629**	0.815**	

	Pl. Ht (cm)	No. of P. Br./Pl	No. of S. Br./Pl	Days to F. Ini.	Days to P.M	No. L/Pl	No. Cl/Pl	No. P/Cl	No. P/Pl	No. S/PD	No S/Pl	100 S. Wt (g)
S.Y. (g)/Pl	0.882**	0.897**	0.899**	-0.860**	-0.834**	0.854**	0.959**	0.896**	0.987**	0.857**	0.997**	0.846**

*Significant at 0.05% and ** 0.01 % level.

Pl. Ht (cm)-Plant Height (cm); No. of P.Br./Pl- Number of Primary Branches per Plant; No. of S.Br./Pl- Number of Secondary Branches per Plant; Days to F. Ini. - Days to Flower Initiation; Days to P.M - Days to Pod Maturity; No. L/Pl- Number of Leaves per plant; No. Cl/Pl- Number of Clusters per plant; No. P/Cl- Number of Pods per Cluster; No. P/Pl- Number of Pods per Plant; No. S/PD-Number of Seeds per Pod; No S/Pl- Number of Seeds per Plant; S.Y(g)/Pl- Seed Yield (g/pl); 100 S. Wt(g)-100 Seed Weight (g).

Seed yield per plant exhibited highly significant and positive phenotypic correlations with plant height (r = 0.882**), number of primary branches per plant (r = 0.897**), number of secondary branches per plant (r = 0.899**), number of leaves per plant (r = 0.854**), number of clusters per plant (r = 0.959**), number of pods per cluster (r = 0.896**), number of pods per plant (r = 0.987**), number of seeds per pod (r = 0.857**), number of seeds per plant (r = 0.997**), and 100-seed weight (r = 0.846**). It was negatively phenotypic correlated with days to flowering (r = –0.860**) and days to maturity (r = –0.834**).

Correlation studies provide insight into the degree and direction of association among different yield and yield-contributing traits, which helps in formulating effective selection strategies for yield improvement. Both phenotypic and genotypic correlations were estimated among various traits in Greengram (*Vigna radiata* L.) mutants of the M_3 generation.

Table 2. Phenotypic and Genotypic correlation for seed yield in greengram mutants in M3 generations.

Characters	Seed Yield (g/pl)	
	Phenotypic Correlation	Genotypic Correlation
Pl. Ht(cm)	0.882**	0.912**
No. of P.Br./Pl	0.897**	0.930**
No. of S.Br./Pl	0.899**	1.000**
Days to F.Ini.	-0.860**	-0.912**
Days to P.M	-0.834**	-0.930**
No. L/Pl	0.854**	0.910**
No. Cl/Pl	0.959**	0.994**
No. P/Cl	0.896**	0.967**
No. P/Pl	0.987**	0.996**
No. S/PD	0.857**	0.947**
No S/Pl	0.997**	0.999**
100 S. Wt(g)	0.846**	1.006**

*Significant at 0.05% and ** 0.01 % level.

3.1.1. *Phenotypic Correlation*

The phenotypic correlation coefficients among different characters (Table …) revealed that seed yield per pl-

-ant showed a highly significant and positive association with most of the yield-contributing traits such as number of primary branches per plant (r = 0.930**), number of secondary branches per plant (r = 1.000**), number of leaves per plant (r = 0.910**), number of clusters per plant (r = 0.994**), number of pods per cluster (r = 0.967**), number of pods per plant (r = 0.996**), number of seeds per pod (r = 0.947**), number of seeds per plant (r = 0.999**), and 100-seed weight (r = 1.006**). This indicates that these traits are major determinants of yield and may be simultaneously improved through selection.

On the contrary, days to flowering initiation (r = -0.912**) and days to physiological maturity (r = -0.930**) exhibited a significant negative correlation with seed yield per plant. This suggests that early flowering and early maturity are advantageous traits for yield improvement, especially under short-duration cropping systems or stress environments.

The strong and significant positive correlations among number of clusters per plant, number of pods per plant, and seed yield imply that these traits are interdependent and contribute synergistically to productivity. Similar findings were reported by Gadakh et al. (2013), Konda et al. (2019), and Dudhe et al. (2021), who observed a positive association of branching and pod-bearing traits with seed yield in Vigna radiata.

3.1.2. *Genotypic correlation*

The genotypic correlation coefficients among yield and yield-related traits in M_3 generation of greengram mutants are presented in Table 2.

Table 3. Genotypic correlation for seed yield and yield contributing traits in greengram mutants in M3 generation.

	Pl. Ht(cm)	No. of P. Br./Pl	No. of S.Br./Pl	Days to F. Ini.	Days to P.M.	No. L/Pl	No. Cl/Pl	No. P/Cl	No. P/Pl	No. S/PD	No S/Pl	100 S. Wt (g)
No. of P. Br./Pl	0.979**											
No. of S. Br./Pl	0.952**	0.952**										
Days to F. Ini.	-0.903**	-0.958**	-0.946**									
Days to P.M.	-0.972**	-0.995**	-0.988**	0.965**								
No. L/Pl	0.988**	0.999**	0.947**	-0.944**	-0.993**							
No. Cl/Pl	0.953**	0.979**	1.006**	-0.952**	-0.981**	0.957**						
No. P/Cl	0.916**	0.962**	0.954**	-0.898**	-0.949**	0.949**	0.991**					
No. P/Pl	0.923**	0.953**	0.994**	-0.927**	-0.948**	0.932**	0.998**	0.989**				
No. S/PD	1.028**	1.000**	1.019**	-0.905**	-1.002**	1.010**	0.989**	0.968**	0.964**			
No S/Pl	0.925**	0.944**	1.001**	-0.915**	-0.941**	0.925**	0.998**	0.982**	1.000**	0.956**		
100 S. Wt(g)	0.897**	0.929**	1.007**	-0.984**	-0.947**	0.911**	1.015**	0.894**	0.994**	0.941**	1.002**	
S.Y. (g)/Pl	0.912**	0.930**	1.000**	-0.912**	-0.930**	0.910**	0.994**	0.967**	0.996**	0.947**	0.999**	1.006**

*Significant at 0.05% and ** 0.01 % level.

Pl. Ht(cm)- Plant Height (cm); v No. of P.Br./Pl- Number of Primary Branches per Plant; No. of S.Br./Pl- Number of Secondary Branches per Plant; Days to F.Ini.- Days to Flower Initiation; Days to P.M- Days to Pod Maturity; No. L/Pl- Number of Leaves per plant; No. Cl/Pl- Number of Clusters per plant; No. P/Cl- Number of Pods per Cluster; No. P/Pl- Number of Pods per Plant; No. S/PD- Number of Seeds per Pod; No S/Pl- Number of Seeds per Plant; S.Y(g)/Pl- Seed Yield (g/pl); 100 S. Wt(g)- 100 Seed Weight (g).

Seed yield per plant showed highly significant and positive genotypic correlations with almost all yield-related traits such as plant height (r = 0.912**), number of primary branches (r = 0.930**), number of secondary branches (r = 1.000**), number of leaves (r = 0.910**), number of clusters (r = 0.994**), number of pods per cluster (r = 0.967**), number of pods per plant (r = 0.996**), number of seeds per pod (r = 0.947**), number of seeds per plant (r = 0.999**), and 100-seed weight (r = 1.006**). It was negatively genotypic correlated with days to flowering (r = –0.912**) and days to maturity (r = –0.930**).

The genotypic correlation coefficients were generally higher in magnitude than their corresponding phenotypic correlations, indicating that the observed associations are primarily genetic rather than environment--tal. This also suggests that environmental influence had a minimal effect on the expression of these traits.

At the genotypic level, seed yield per plant was highly and positively correlated with number of primary branches per plant ($r_{(g)}$ = 0.930**), secondary branches ($r_{(g)}$ = 1.000**), number of leaves ($r_{(g)}$ = 0.910**), clusters per plant ($r_{(g)}$ = 0.994**), pods per cluster ($r_{(g)}$ = 0.967**), pods per plant ($r_{(g)}$ = 0.996**), seeds per pod ($r_{(g)}$ = 0.947**), seeds per plant ($r_{(g)}$ = 0.999**), and 100-seed weight ($r_{(g)}$ = 1.006**).

These strong associations imply that these yield components are governed by closely linked or pleiotropic genes.

Negative and significant genotypic correlations were observed for days to flowering initiation ($r_{(g)}$ = -0.912**) and days to maturity ($r_{(g)}$ = -0.930**) with seed yield per plant, similar to phenotypic correlations. This reinforces the idea that early-flowering and early-maturing mutants possess greater yield potential, likely due to better partitioning of assimilates towards reproductive structures.

The close correspondence between phenotypic and genotypic correlation values for most of the traits suggests that the environmental influence was minimal, indicating that selection based on phenotype for these traits would be effective and reliable.

Comparable observations were made by Kumar et al. (2022) and Kumari et al. (2023) in *Vigna radiata*, who also reported higher genotypic correlations than phenotypic ones for yield-contributing traits such as number of branches, pods, and seed weight.

Evaluation of heritability (narrow sense), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and genetic advance (GA) in the M_3 generation of greengram mutants revealed several important insights for breeding and selection.

3.2. *Estimation of Heritability and Genetic Advance*

The estimates of heritability (narrow sense), genetic advance (GA), genotypic coefficient of variation (GCV), and phenotypic coefficient of variation (PCV) for various quantitative traits in greengram (*Vigna radiata* L.) mutants of the M_3 generation are presented in Table 3.

Table 4. Estimation of heritability, Genotypic and Phenotypic Coefficient of Variations, Genetic Advance and Genetic Advance Value % means for yield and yield related traits in greengram mutant in M3 generation.

S. No	Characters	Heritability (%)	Genotypic Coefficient of Variations	Phenotypic Coefficient of Variations	Genetic Advance	Genetic Advance Value % Means
1	Pl. Ht(cm)	99.14	34.297	34.445	31.733	70.347

S. No	Characters	Heritability (%)	Genotypic Coefficient of Variations	Phenotypic Coefficient of Variations	Genetic Advance	Genetic Advance Value % Means
2	No. of P.Br./Pl	97.864	39.19	39.615	5.513	79.864
3	No. of S.Br./Pl	87.011	28.637	30.7	1.563	55.028
4	Days to F.Ini.	98.022	10.679	10.786	11.674	21.78
5	Days to P.M	85.276	5.02	5.436	8.738	9.549
6	No. L/Pl	97.275	34.035	34.508	11.643	69.149
7	No. Cl/Pl	93.48	30.803	31.859	2.536	61.35
8	No. P/Cl	86.61	20.091	21.589	1.289	38.518
9	No. P/Pl	97.306	47.662	48.317	14.013	96.852
10	No. S/PD	68.639	8.456	10.207	1.36	14.432
11	No S/Pl	94.627	53.833	55.34	152.105	107.876
12	100 S. Wt(g)	64.931	3.679	4.566	0.207	6.107
13	S.Y(g)/Pl	94.393	57.454	59.136	5.58	114.99

Pl. Ht(cm)- Plant Height (cm); No. of P.Br./Pl- Number of Primary Branches per Plant; No. of S.Br./Pl- Number of Secondary Branches per Plant; Days to F.Ini.- Days to Flower Initiation; Days to P.M- Days to Pod Maturity; No. L/Pl- Number of Leaves per plant; No. Cl/Pl- Number of Clusters per plant; No. P/Cl- Number of Pods per Cluster; No. P/Pl- Number of Pods per Plant; No. S/PD- Number of Seeds per Pod; No S/Pl- Number of Seeds per Plant; S.Y(g)/Pl- Seed Yield (g/pl); 100 S. Wt(g)- 100 Seed Weight (g).

High heritability coupled with high genetic advance was observed for plant height, number of primary and secondary branches per plant, number of pods per plant, number of seeds per plant, and seed yield per plant, which indicates that these traits are predominantly controlled by additive gene effects. Therefore, selection based on these traits would be effective for yield improvement in greengram mutants.

In contrast, traits with moderate heritability and low genetic advance such as 100-seed weight and days to maturity suggest the influence of non-additive gene action or environmental factors, requiring further selection cycles or hybridization for improvement.

Table 5. High Heritability and High Genetic Advance Traits in greengram mutants in M3 generation.

S. No	Characters	Heritability (%)	Genotypic Coefficient of Variations	Phenotypic Coefficient of Variations	Genetic Advance	Genetic Advance Value % Means
1	Pl. Ht (cm)	99.14	34.297	34.445	31.733	70.347
2	No. of P.Br./Pl	97.864	39.19	39.615	5.513	79.864
3	Days to F.Ini.	98.022	10.679	10.786	11.674	21.78
4	No. L/Pl	97.275	34.035	34.508	11.643	69.149
5	No. P/Pl	97.306	47.662	48.317	14.013	96.852

Pl. Ht(cm)- Plant Height (cm); No. of P.Br./Pl- Number of Primary Branches per Plant; Days to F. Ini.- Days to Flower Initiation; No. L/Pl- Number of Leaves per plant; No. P/Pl- Number of Pods per Plant.

Traits such as plant height (99.14 %), number of primary branches per plant (97.86 %), number of leaves per plant (97.27 %) and number of pods per plant (97.30 %) exhibited very high heritability associated with high genetic advance as percent of mean (GAM) (70.347 %, 79.864 %, 69.149 %, 96.852 % respectively). This combination is indicative of predominantly additive gene action, minimal environmental influence and good scope for improvement through selection.

Similar trends have been reported in recent studies on mungbean/greengram, where high heritability along with high expected genetic gain suggested that direct selection would be effective.

Therefore, for these traits in the mutant population, early generation selection can be reliably deployed. The high GCV and PCV for these traits further reflect ample variability in the population. For example, seeds per plant had GCV ~53.83 % and PCV ~55.34 %, with GAM ~107.876 %, pointing to a broad developmental baseline and high selection potential.

3.2.1. *Moderate to Low Heritability & Genetic Advance Traits*

In contrast, traits such as 100-seed weight (heritability ~64.93 %, GAM ~6.11 %), days to physiological maturity (heritability ~85.28 %, GAM ~9.55 %) and number of seeds per pod (heritability ~68.64 %, GAM ~14.43 %) exhibited moderate to low genetic advance despite moderate to high heritability. This suggests that although the traits are inheritable, additive genetic variance is limited or the trait is under considerable environmental or non-additive genetic control (Khan et al., 2023). In such cases, selection may be less efficient and may require heterosis breeding or recurrent selection to exploit non-additive variance.

3.3. *Relationship between GCV and PCV*

Across traits, PCV values were marginally higher than GCV values which implies some environmental influence, but the gap was not very wide for most traits. For traits with very high heritability and high genetic advance, the narrow gap between GCV and PCV suggests that environment played a minor role and the observed variation is largely genetic. This pattern is in line with observations in recent legume-mutant studies (Singh & Roy, 2021) where GCV/PCV differences were small for traits with high heritability.

3.4. *Implications for Breeding in Greengram Mutants*

Because of the high heritability and genetic advance demonstrated by the key yield-contributing traits (pods per plant, seeds per plant, primary branches, leaves), these should be prioritized in selection programs aimed at improving yield in M_3 generation mutants. The strong genetic control implies that phenotype-based selection would likely be effective and can lead to stable improvement. Conversely, traits with low genetic advance (e.g., 100-seed weight) may need to be improved by other methods-for example through hybridization or multiple cycles of selection to accumulate favorable alleles.

Even though many traits show favorable genetic parameters, it is advisable to validate these findings across environments (multi-location trials) because the current estimates are from a single context (M_3 generation mutants). Gene × environment interactions could still influence expression, especially for traits with moderate heritability. Also, studying the nature of gene action (additive vs dominance) via combining ability or molecular marker-based analysis can further guide breeding strategy (Patel et al., 2024). Some research works have been carried out in black gram using gamma rays, combinations with EMS other chemical alkalizing agents to increase the yield and yield contributing traits and good results have been reported. Induced mutations are highly used to create genetic variability with desirable agronomical characters in the plants like black gram as these are self pollinated crops having less chance of genetic variability (Wani, 2021; Raina et al., 2019; Goyal et al., 2019; Laskar et al., 2018)). Similarly in other crops like chickpea (Raina et al 2019), lentil (Laskar et al 2018), mungbean (Singh, 2009), blackgram (Sonu Goyal et al 2020).

IV. Conclusion

The present investigation demonstrated that EMS-induced mutagenesis effectively generated substantial genetic variability in greengram, providing valuable scope for yield improvement. Traits such as plant height, number of primary and secondary branches per plant, number of pods per plant, number of seeds per plant, and seed yield per plant exhibited high heritability coupled with high genetic advance, indicating the predominance of additive gene action and the effectiveness of direct selection. Among these, number of pods per plant and seeds per plant emerged as reliable selection indices for enhancing productivity in advanced mutant generations. Conversely, traits like 100-seed weight and days to maturity, which showed moderate heritability with comparatively lower genetic advance, appear to be influenced by non-additive gene effects and environmental factors, suggesting the need for prolonged selection or hybridization strategies.

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