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QUANTITATIVE TRAIT ANALYSIS FOR GENETIC VARIABILITY AND HERITABILITY IN CHICKPEA (*Cicer arietinum* L.) GERMPLASM

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ABSTRACT

The present investigation entitled "Quantitative Trait Analysis for Genetic Variability and Heritability in Chickpea (*Cicer arietinum* L.) Germplasm" was conducted during Rabi 2024–25 at the Crop Research Centre, Department of Genetics and Plant Breeding, School of Agriculture, ITM University Gwalior. The experimental material comprised 50 chickpea genotypes along with 3 check varieties obtained from Indian Institute of Pulses Research and evaluated in an augmented design. Observations were recorded for nine quantitative traits to estimate genetic variability, heritability and genetic advance. Analysis of variance revealed significant differences among genotypes for all traits except number of seeds per pod, indicating substantial genetic variability. High genotypic and phenotypic coefficients of variation were observed for yield per plant (36.75 and 37.51), number of pods per plant (29.81 and 31.07), and seeds per plant (28.05 and 31.38). High heritability coupled with high genetic advance as percent of mean was recorded for yield per plant (96.01% and 74.29%), number of pods per plant (92.01% and 58.98%), plant height (97.59% and 43.96%), seeds per plant (79.91% and 51.73%), and 100-seed weight (97.14% and 44.91%), indicating the predominance of additive gene action and effectiveness of direct selection for these traits. The mean performance for yield per plant was 9.63 g, ranging from 3.34 to 18.78 g. The study indicated the presence of sufficient genetic variability among chickpea genotypes, suggesting that traits such as yield per plant, pods per plant, seeds per plant and 100-seed weight may be effectively utilized in chickpea improvement programmes.

Keywords **:** Chickpea; genetic variability, heritability; genetic advance; augmented design.

Introduction

Chickpea (*Cicer arietinum* L.) is one of the most important grain legume crops belonging to the family Fabaceae and subfamily Papilionoideae. It is a self-pollinated diploid species with chromosome number 2n = 2x = 16 (Singh *et al.*, 2022). The crop is believed to have originated in the Fertile Crescent and is presently cultivated in more than 50 countries across Asia, Africa, Australia, and the Mediterranean region (Varshney *et al.*, 2021). Chickpea flowers are papilionaceous, bisexual and predominantly self-pollinated, with flower colour varying from white to pink or purple depending on the genotype (Jain *et al.*, 2025).

Globally, chickpea occupies approximately 17.8 million hectares with an annual production of about 17.2 million tonnes and an average productivity of 967 kg ha^{-1} (FAOSTAT, 2024). India is the largest producer and consumer of chickpea, contributing nearly 70 per cent of the world's production (Kumar *et al.*, 2023). In India, chickpea is cultivated over an area of about 10.9 million hectares with a production of 13.5 million tonnes and productivity of around 1238 kg ha^{-1} (Directorate of Economics and Statistics, 2024). Among Indian states, Madhya Pradesh ranks first in area and production of chickpea with nearly 3.4 million hectares under cultivation and production exceeding 4.5 million tonnes annually (Government of Madhya Pradesh, 2024). The crop plays an important role in the pulse-based cropping systems of central India due to its adaptability to residual soil moisture conditions and low input requirements (Yadav *et al.*, 2024).

Chickpea seeds are highly nutritious and serve as an economical source of protein for the vegetarian population. The seeds contain about 18–24% protein, 50–60% carbohydrates, 4–5% fat, and appreciable amounts of minerals such as calcium, iron, phosphorus, magnesium and zinc (Jukanti *et al.,* 2012). Chickpea also contains essential amino acids, dietary fibre and vitamins, making it an important component of nutritional security and sustainable agriculture (Merga & Haji, 2019).

Despite its importance, chickpea productivity remains relatively low due to narrow genetic variability, susceptibility to biotic and abiotic stresses, and poor adaptability of existing cultivars (Varshney *et al.*, 2021). Genetic variability is the basic requirement for any crop improvement programme because effective selection depends upon the extent of heritable variation present in the population (Johnson *et al.*, 1955). Estimation of heritability along with genetic advance helps in understanding the nature of gene action and the effectiveness of selection for yield and related traits (Burton & DeVane, 1953). Therefore, the present investigation was undertaken to assess genetic variability, heritability and genetic advance among chickpea genotypes in order to identify promising traits and superior genotypes for future breeding programmes.

Materials and Methods

Experimental Site

The present investigation entitled "Quantitative Trait Analysis for Genetic Variability and Heritability in Chickpea (*Cicer arietinum* L.) Germplasm" was conducted during the Rabi season of 2024–25 at the Crop Research Centre, Department of Genetics and Plant Breeding, School of Agriculture, ITM University Gwalior. The experimental farm is situated in Gwalior district of Madhya Pradesh, India, which falls under the semi-arid agro-climatic zone characterized by moderate winter temperatures and low rainfall during the crop season.

Experimental Material

The experimental material comprised 50 diverse chickpea genotypes along with 3 standard check varieties obtained from Indian Institute of Pulses Research, Kanpur, U.P. The genotypes were evaluated to study the extent of genetic variability and the inheritance pattern of yield and yield-attributing traits in chickpea.

Experimental Design and Crop Management

The experiment was laid out in an Augmented Block Design (Federer, 1956), which is commonly employed for the evaluation of a large number of genotypes with limited seed quantity. The genotypes were grown under recommended agronomic practices to ensure a healthy crop stand throughout the growing season. Necessary plant protection measures were undertaken as and when required.

Meteorological Conditions During Crop Season

The meteorological data recorded during the crop growth period indicated that the maximum temperature ranged from 20.1°C to 35.0°C, while the minimum temperature varied between 4.2°C and 14.8°C. Relative humidity during morning hours ranged from 78.6 to 95.1 per cent and evening humidity varied from 33.7 to 58.1 per cent. Total rainfall received during the crop season was scanty, with occasional rainfall events recorded during late December and February. Sunshine hours ranged from 1.11 to 7.55 hours per day, whereas evaporation varied between 0.9 and 7.2 mm. These climatic conditions were generally favorable for the successful growth and development of chickpea during the Rabi season.

Observations Recorded

Observations were recorded on nine quantitative characters from randomly selected competitive plants in each genotype. The traits studied were: Days to 50% flowering, Days to maturity, Number of primary branches per plant, Plant height (cm), Number of pods per plant, Number of seeds per pod, Seeds per plant, 100-seed weight (g), Yield per plant (g).

Statistical Analysis

The statistical software used for the analysis was R Studio (Popat *et al.,* 2020) and Agri analyze (Popat *et al.,* 2024). Analysis of variance (ANOVA) was carried out following the procedure suggested by Federer (1956) for augmented designs to determine the significance of variation among genotypes. Descriptive statistics including mean, range, and coefficient of variation (CV) were estimated for all characters.

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were computed according to the method suggested by Burton and DeVane (1953). Broad-sense heritability (H^2bs) was estimated following the method proposed by Hanson *et al.* (1956), while genetic advance as per cent of mean (GAM) was calculated using the procedure described by Johnson *et al.* (1955). These parameters were used to assess the magnitude of variability and the effectiveness of selection for yield and its component traits in chickpea genotypes.

Result and Discussion

Analysis of variance (ANOVA)

The analysis of variance (ANOVA) revealed highly significant differences among chickpea genotypes for most of the quantitative traits studied, indicating the presence of substantial genetic variability among the experimental material (Table:1). Significant treatment mean squares were observed for days to 50% flowering (156.40**), days to maturity (166.64**), number of primary branches per plant (1.48**), plant height (158.23**), number of pods per plant (150.64**), seeds per plant (348.91**), 100-seed weight (20.47**) and yield per plant (19.99**). However, number of seeds per pod (0.04ns) showed non-significant variation, indicating comparatively narrow variability for this trait.

The significant variation observed for flowering and maturity traits indicated the existence of early and late maturing genotypes, which may be useful for breeding programmes aimed at developing climate-resilient varieties. Similar significant variability for phenological traits in chickpea was also reported by Jain *et al.* (2023) and Arbissie *et al.* (2025), who observed wide differences among chickpea genotypes for days to flowering and maturity under diverse environments.

Among growth characters, plant height and number of primary branches per plant exhibited highly significant differences among genotypes. The treatment mean square for plant height (158.23**) suggested considerable diversity in plant architecture. Similar findings were reported by Rehman *et al.* (2023) and Negusse *et al.* (2025), who reported significant genetic variation for plant height and branching traits in chickpea germplasm.

Yield contributing traits also showed substantial variability. Number of pods per plant (150.64**) and seeds per plant (348.91**) recorded highly significant mean square values, indicating the presence of exploitable genetic variability for yield improvement. Likewise, 100-seed weight (20.47**) and yield per plant (19.99**) were highly significant, suggesting the effectiveness of selection for these traits. Similar results were reported by Akbar *et al.* (2025), who observed strong genetic control and high variability for yield and yield-associated traits in chickpea genotypes. Earlier studies by Sharma *et al.* (2021) and Nikita and Lal (2022) also confirmed significant variability for pods per plant, seed weight and grain yield in chickpea.

The non-significant variation observed for seeds per pod indicated limited genetic diversity for this trait under the present experimental conditions. Similar observations were also reported in previous chickpea studies where seeds per pod exhibited comparatively lower variability than other yield components (Jha *et al.*, 2012; Meena *et al.*, 2021).

Parameters of Variability

Mean and CV

The descriptive statistics for nine quantitative traits in chickpea genotypes revealed the presence of considerable variability among the evaluated genotypes, indicating ample scope for selection and genetic improvement. Days to 50% flowering ranged from 47.33 to 85.33 days with a mean value of 72.64 days and a low coefficient of variation (CV) of 2.03%, whereas days to maturity varied from 96.60 to 140.61 days with a mean of 123.66 days and CV of 1.93%. The existence of variability for flowering and maturity traits indicated the availability of both early and late maturing genotypes, which may be useful for breeding programmes under varying agro-climatic conditions. Similar findings were reported by Jain *et al.* (2023) and Yadav *et al.* (2024), who observed substantial variability for phenological traits in chickpea under late-sown conditions.

Number of primary branches per plant ranged from 0.95 to 5.74 with a mean of 2.72 and CV of 9.23%, while plant height varied from 30.42 to 84.57 cm with a mean value of 50.11 cm and CV of 3.41%. Similar variability for plant architecture traits was also observed by Akbar *et al.* (2025) and Zhang *et al.* (2025), suggesting the existence of diverse genotypes suitable for crop improvement programmes.

Yield contributing traits exhibited comparatively higher variability. Number of pods per plant ranged from 18.97 to 67.95 with a mean of 34.19 and CV of 8.20%, whereas seeds per plant recorded the highest CV (13.23%) with values ranging from 22.78 to 89.25. The 100-seed weight varied from 11.27 to 29.37 g with a mean of 18.47 g, while yield per plant ranged from 3.34 to 18.78 g with a mean of 9.63 g and CV of 6.78%. These findings indicate substantial variability for yield and associated traits, which may be effectively utilized through selection breeding. Similar observations were reported by Yadav *et al.* (2024), Akbar *et al.* (2025), and recent chickpea variability studies conducted under diverse environments.

Genotypic Coefficient of Variation (GCV), Phenotypic Coefficient of Variation (PCV), Heritability in Broad Sense (H^2BS) and Genetic Advance as Percent of Mean (GAM)

The estimates of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (h²BS), and genetic advance as percent of mean (GAM) revealed substantial variability among the chickpea genotypes for most of the traits studied. In all characters, PCV values were slightly higher than GCV values, indicating limited environmental influence on trait expression and predominance of genetic factors. Similar observations were reported in recent chickpea studies by Akbar *et al.* (2025) and Yadav *et al.* (2024).

High GCV and PCV were observed for yield per plant (36.75 and 37.51), number of pods per plant (29.81 and 31.07), and seeds per plant (28.05 and 31.38), indicating the presence of wide genetic variability for these traits. Moderate GCV and PCV were recorded for plant height and 100-seed weight, whereas low estimates were observed for days to maturity and number of seeds per pod. Similar findings were also reported by Deb and Hasan (2024) and recent variability studies in chickpea germplasm.

Broad-sense heritability estimates ranged from medium to high. High heritability was observed for days to 50% flowering (97.36%), plant height (97.59%), 100-seed weight (97.14%), yield per plant (96.01%), days to maturity (93.14%), and number of pods per plant (92.01%). High heritability coupled with high GAM was recorded for yield per plant (74.29), number of pods per plant (58.98), seeds per plant (51.73), plant height (43.96), and 100-seed weight (44.91), suggesting the predominance of additive gene action and effectiveness of direct selection for these traits. Similar results were reported by recent studies in chickpea which emphasized that traits with high heritability and high genetic advance can be effectively improved through simple selection methods.

In contrast, number of seeds per pod exhibited medium heritability (41.23%) along with low GAM (9.72%), indicating greater environmental influence and non-additive gene action for this trait. Similar observations were reported by Rasheed *et al.* (2024) and Jain *et al.* (2025).

Conclusion

The present investigation revealed substantial genetic variability among the chickpea genotypes for most of the quantitative traits studied. High heritability coupled with high genetic advance was observed for yield per plant, number of pods per plant, seeds per plant, plant height, and 100-seed weight, indicating the predominance of additive gene action and effectiveness of direct selection for these traits. Therefore, these characters can be considered important selection criteria for developing high-yielding chickpea varieties. The identified variability among genotypes provides valuable genetic resources for future chickpea improvement and breeding programmes.

Table 1 : Analysis of Variance for Quantitative Traits in Chickpea Genotypes

Source	Df	Days to 50% flowering	Days to Maturity	No. of Primary Branches	Plant Height	No. of Pods per Plant	No. of Seeds per Pod	Seeds per Plant	100 Seed Weight	Yield per Plant
Block (ignoring Treatments)	4	105.18	126.94	0.19	51.46	101.42	0.01	272.05	13.66	4.71
Treatment (eliminating Blocks)	52	156.40**	166.64**	1.48**	158.23**	150.64**	0.04ns	348.91**	20.47**	19.99**
Treatment: Check	2	1225.87**	1215.91**	14.61**	1239.40**	209.85**	0.19**	1037.16**	49.90**	11.37**
Treatment: Test and Test vs. Check	50	113.62**	124.67**	0.96**	114.98**	148.28**	0.03ns	321.38**	19.29**	20.34**
Residuals	8	2.03	5.45	0.08	2.88	9.02	0.02	53.41	0.49	0.52
Std. Error	–	1.80	2.95	0.88	3.80	0.17	9.24	0.35	2.15	0.91
CD at 5%	–	4.16	6.81	2.04	8.76	0.39	21.32	0.81	4.95	2.10

ns = Non-significant (P > 0.05); *= Significant at 5% level (P ≤ 0.05);** = Significant at 1% level (P ≤ 0.01).

Table 2: Mean, Range and C.V. for quantitative traits in Chickpea genotypes

Trait	Mean	Min	Max	CV
Days to 50% flowering	72.64	47.33	85.33	2.03
Days to Maturity	123.66	96.6	140.61	1.93
No. of Primary Branches	2.72	0.95	5.74	9.23
Plant Height	50.11	30.42	84.57	3.41
No. of pods per plant	34.19	18.97	67.95	8.2
No. of Seeds per pod	1.53	1.19	1.92	8.7
Seeds per plant	51.97	22.78	89.25	13.23
100 seed weight	18.47	11.27	29.37	3.66
yield per plant	9.63	3.34	18.78	6.78

Table 3: GCV and PCV for quantitative traits in groundnut genotypes.

Trait	GCV	PCV	hBS	hBS. category	GAM	GAM. category
Days to 50% flowering	11.93	12.09	97.36	High	24.29	High
Days to Maturity	6.95	7.2	93.14	High	13.84	Medium
No. of Primary Branches	18.36	21.01	76.38	High	33.1	High
Plant Height	21.57	21.84	97.59	High	43.96	High
No. of pods per plant	29.81	31.07	92.01	High	58.98	High
No. of Seeds per pod	7.34	11.43	41.23	Medium	9.72	Low
Seeds per plant	28.05	31.38	79.91	High	51.73	High
100 seed weight	22.08	22.41	97.14	High	44.91	High
yield per plant	36.75	37.51	96.01	High	74.29	High

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