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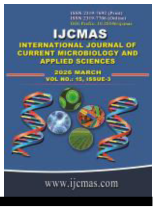

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Estimation of Genetic variability, Heritability, Genetic Advance and Character Association in Chickpea (*Cicer arietinum* L.) for Higher Grain Yield

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ABSTRACT

Grain yield in chickpea is crucial as it directly determines farmer income, food security, and market competitiveness. High-yielding varieties ensure efficient land use, support sustainable agriculture, and meet rising global demand for protein-rich pulses. Breeding programs strengthen yield stability under stress conditions and enhance resilience in diverse environments. In this study 36 chickpea genotypes were evaluated for Genetic variability, Heritability, Genetic Advance and Character Association. The chickpea genotypes were sown in, Augmented Block Design with four checks (in to 6 blocks) conducted at experimental farm of main campus of ICAR-Indian Institute of Pulses Research, Kanpur, 208024 Uttar Pradesh, India., during Rabi, season 2024-25. Phenotypic data were recorded for eight characters *viz.* days to 50% flowering, days to maturity, plant height, number of pods per plant, 100-grain weight, harvest index, grain yield per plant, and biological yield per plant. The highest value of PCV was observed for biological yield per plant (32.94) and GCV was recorded for grain yield per plant (26.98). High heritability coupled with high genetic advance were observed for grain yield per plant (73.71% & 47.78) respectively. Highly significant positive correlation for grain yield per plant with biological yield per plant (0.542**) and grain yield per plant with harvest index (0.448 **). Path analysis revealed that the highest positive and substantial direct effects on grain yield per plant were exerted by biological yield per plant (0.95). Thus, these component traits can be used in chickpea breeding programs for further improvement in grain yield.

Keywords

Genetic Variability, Correlation, Path Coefficient. Heritability and Genetic Advance

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Introduction

Pulses are nutrient-rich leguminous crops valued for their high protein, fibre, and essential micronutrients. They include Chickpea, Lentil, Mungbean, Pigeonpea, Fieldpea and others, serving as staple foods across Asia, Africa, and Latin America. Environmentally sustainable, pulses enrich soil fertility through nitrogen fixation, reducing dependence on chemical fertilizers. Their resilience to diverse climates and affordability make them vital for food security, balanced diets, and sustainable agricultural systems worldwide.

Chickpea (*Cicer arietinum L.*) is an annual legume belonging to the family Fabaceae, with 2n=2x=14 chromosomes. It is characterized by pinnate leaves, white to pink flowers, and pods containing one to three seeds. Two main types are recognized: Desi (small, angular, coloured seeds with rough coat) and Kabuli (larger, cream-colored, smooth seeds). The plant is self-pollinated, with a deep taproot system that enhances drought tolerance. Its symbiotic association with *Mesorhizobium* species enables biological nitrogen fixation, improving soil fertility.

Chickpea is among the earliest domesticated crops, with archaeological evidence tracing its origin to the Fertile Crescent about 7,000 years ago. From there, it spread to the Mediterranean basin, South Asia, and East Africa [*Abbo et al., 2003*]. Today, India is the largest producer and consumer, accounting for more than two-thirds of global production. Other major producers include Pakistan, Turkey, Ethiopia, and Australia. Its adaptability to semi-arid climates has facilitated cultivation across Asia, Africa, and Latin America [*FAO Stat 2024*].

Chickpea seeds are highly nutritious, providing approximately 20–22% protein, rich in essential amino acids such as lysine and arginine. They are also abundant in dietary fibre, complex carbohydrates, vitamins (particularly folate, vitamin B6), and minerals like iron, phosphorus, magnesium, and zinc. The seeds have a low glycemic index, making them suitable for diabetic diets. Their protein quality complements cereals, forming a balanced diet in vegetarian populations [*Jukanti et al., 2012*].

Chickpea serve diverse culinary and industrial purposes. In South Asia, they are consumed as whole seeds, split pulses (chana dal), or flour (besan) used in snacks and sweets. In Mediterranean cuisine, chickpeas are central to dishes like hummus and falafel. Beyond food, chickpea flour is used in gluten-free products, while roasted seeds are eaten as snacks. The crop also contributes to sustainable agriculture by enriching soil nitrogen. Additionally, chickpea residues serve as fodder, and its role in crop rotations enhances productivity in dryland farming systems.

Genetic variability, heritability, genetic advance, and character association are fundamental pillars in chickpea breeding. Genetic variability provides the raw material for selection, ensuring diverse traits for yield, stress tolerance, and adaptability. Heritability estimates help breeders understand the proportion of trait expression controlled by genetics versus environment, guiding reliable selection. Genetic advance complements heritability by predicting the expected improvement under selection pressure, thus indicating the efficiency of breeding programs. Character association, including correlation and path analysis, reveals interrelationships among traits such as yield, flowering time, and stress tolerance, enabling indirect selection strategies. Together, these parameters empower breeders to identify superior genotypes, design effective selection schemes, and accelerate genetic gains. Their integration ensures development of high-yielding, resilient chickpea varieties, supporting food security and sustainable agriculture [*Patel et al., 2025*].

Materials and Methods

This experiment was conducted with 40 chickpea genotypes (including checks) which was sown in Augmented Block Design [*Federer 1961*]. The 4 checks were eg. GNG 2207, BG 3043, GCP 105 and KPG 59 taken in the experiment and the bed size of experiment was 4 meter wide and 16 meter long and crop spacing was 30X10 cm row to row and plant to plant respectively. The whole experimental bed was divided in 6 blocks and each block comprised of 9 entries (5 test entries and 4 checks). The research trial was conducted at experimental farm of main campus of ICAR-Indian Institute of Pulses Research, Kanpur, 208024 Uttar Pradesh, India. In this experiment eight quantitative traits were taken for recording phenological data like Days to 50% flowering, Days to maturity, Plant height (cm), No. of pods per plant, 100-grain weight (g), Harvest index (%), Biological yield per plant and Grain yield per plant. Studied parameters are according to some earlier workers which are.

1. GCV & PCV was suggested by Burton and de Vane (1952)
2. Heritability was suggested by Hanson *et al.,* (1956)
3. Genetic Advance was suggested by Johnson *et al.,* (1955)
4. Correlation Coefficient was suggested by Al-ji-bouri *et al.,* (1958)
5. Path Coefficient was suggested by Dewey and Lu (1959)

Results and Discussion

The results obtained from different analysis are presented in the following sub-heads:

- ANOVA
- Genetic Variability, Heritability and Genetic Advance
- Character association (Correlation coefficient & Path coefficient)

ANOVA

ANOVA is vital in breeding experiments as it partitions variation among genotypes, environments, and their interactions. It identifies significant differences in trait performance, ensures reliability of replication, and guides selection decisions. By quantifying sources of variation, ANOVA strengthens genetic interpretation and supports precise, evidence-based crop improvement strategies.

Days to 50% flowering and days to maturity showed highly significant treatment differences, confirming strong genetic variability. Plant height exhibited moderate significance, with some blocks influenced, indicating partial environmental effects. Number of pods per plant revealed highly significant variation, especially between checks, highlighting strong genetic diversity. 100-seed weight showed significant treatment effects, suggesting stable genetic control. Harvest index was significant only in test vs. check comparisons, reflecting selective differences.

Biological yield per plant displayed significant treatment variation, while grain yield per plant showed highly significant differences, confirming strong genetic contribution. Overall, yield and pod traits emerged as key targets for effective selection, *see Table 01* [Gaur *et al.,* 2008].

Genetic Variability

Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV) measure variability among traits. PCV reflects total variation, including both genetic and environmental effects, while GCV isolates only genetic variation. When PCV and GCV values are close, it indicates minimal environmental influence, suggesting traits are largely governed by genetics. Heritability, expressed in broad sense, quantifies the proportion of phenotypic variance attributable to genetic factors. High heritability implies reliable transmission of traits across generations. However, heritability alone does not guarantee effective selection.

Genetic Advance, often expressed as a percentage of the mean, estimates expected improvement under selection pressure. Traits with high heritability coupled with high Genetic Advance are most amenable to selection, as they are controlled by additive gene action. Thus, the interplay of PCV, GCV, heritability, and Genetic Advance guides breeders in identifying traits with strong genetic control and high potential for crop improvement.

Days to 50% flowering showed very close PCV (4.93%) and GCV (4.78%) with high heritability (94.03%) and moderate Genetic Advance, indicating strong additive gene control and suitability for direct selection. Days to maturity also recorded high heritability (87.41%) with moderate Genetic Advance, suggesting reliable inheritance but slower improvement. Plant height exhibited wide variability (PCV 13.99%, GCV 9.77%) with moderate heritability (48.71%) and low Genetic Advance, reflecting environmental influence. Number of pods per plant had high PCV (30.37%) and GCV (25.67%), with heritability of 71.44% and moderate Genetic Advance, making it promising for selection. 100-grain weight showed moderate PCV and GCV, heritability of 45.97%, and moderate Genetic Advance, indicating stable inheritance yet limited Genetic Advance.

Harvest index and biological yield displayed moderate heritability (53.45% and 63.98%) with moderate Genetic Advance, suggesting partial additive control. Grain yield per plant recorded high PCV (31.42%), GCV (26.98%), heritability of 73.71%, and high Genetic Advance, highlighting it as a key trait for effective genetic improvement, *see Table 02* [*Bharath et al., 2025*].

Table.1 Analysis of variance (ANOVA) for the Augmented Block Design.

Source of Variation	**D.F.**	**Mean. Square**							
		D50%F	**DM**	**PHT**	**Pods/P**	**100-SW**	**HI**	**BYP**	**GYP**
Block (Ignoring treatments)	5	5.20 ^{ns}	146.81 *	157.34 ^{ns}	558.31 ^{ns}	84.33 ^{ns}	37.92 ^{ns}	471.59 ^{ns}	47.77 **
Treatment (Eliminating Block)	39	15.96 **	16.53 **	122.17 *	342.42 **	12.39 **	134.69 ^{ns}	244.97 *	26.57 *
Treatment: Check	3	25.59 **	16.59 *	13.60 ^{ns}	873.38 **	21.20 ^{ns}	33.50 ^{ns}	160.78 ^{ns}	15.24 ^{ns}
Treatment: Test and Test vs. Check	36	15.15 **	16.53 **	131.22 *	298.18 *	11.66 **	143.13 *	251.99 *	27.52 *
Residuals	15	0.93	3.13	55.05	107.68	10.72	63.75	91.19	8.80

Table.2 Range, mean, coefficient of variation and least significant differences for different character of Chickpea genotypes.

Characters	**Range**		**Mean Value**	**Coefficient of variation (%)**				**Genetic advance**	**Genetic advance (mean)**	**Heritability (%)**
	Min.	**Max.**		**PCV (%)**	**GCV (%)**	**CV (%)**	**LSD_1 5%**			
Days to 50% flowering	62.44	85.44	80.02	4.93	4.78	1.20	3.24	7.65	9.56	94.03
Days to maturity	119.31	146.94	137.37	3.63	3.39	1.29	5.96	8.98	6.54	87.41
Plant height (cm)	43.77	97.00	74.04	13.99	9.77	9.88	25.01	10.41	14.06	48.71
Number of pods plant^{-1}	34.13	121.68	63.93	30.37	25.67	15.97	34.97	28.61	44.76	71.44
100-grain weight (g)	12.32	26.92	18.64	23.89	16.20	18.11	11.03	4.22	22.66	45.97
Harvest index (%)	16.90	75.76	39.17	29.88	21.84	20.85	26.91	12.90	32.95	53.45
Biological yield plant^{-1}(g)	11.68	89.28	48.30	32.94	26.35	18.35	32.18	21.00	43.48	63.98
Grain yield per plant (g)	10.38	32.05	18.42	31.42	26.98	15.56	10.00	8.80	47.78	73.71

Table.3 Simple correlation coefficient between different characters in Chickpea genotypes.

Characters	**Days to 50% flowering**	**Days to maturity**	**Plant height**	**Number of pods plant^{-1}**	**100-grain weight (g)**	**Harvest index (%)**	**Biological yield plant^{-1}(g)**	**Grain yield per plant (g)**
Days to 50% flowering	1.000	0.324*	0.167	0.085	-0.056	-0.074	0.154	0.170
Days to maturity		1.000	0.347**	0.233	-0.365**	-0.048	0.357**	0.269*
Plant height (cm)			1.000	0.235	0.045	-0.195	0.345**	0.147
Number of pods plant^{-1}				1.000	-0.212	0.033	0.381**	0.435**
100-grain weight (g)			-		1.000	0.077	-0.307*	-0.182
Harvest index (%)						1.000	0.466**	0.448**
Biological yield plant^{-1}(g)						-	1.000	0.542**
Grain yield per plant (g)								1.000

Table.4 Simple Path coefficient between different characters of Chickpea genotypes towards yield.

Characters	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Number of pods plant^{-1}**	**100-grain weight (g)**	**Harvest index (%)**	**Biological yield plant^{-1}(g)**	**Grain yield per plant (g)**
Days to 50% flowering	**0.107**	-0.01905	-0.00305	-0.0483	-0.00216	-0.06570	0.14763	0.170
Days to maturity	0.03472	**-0.059**	-0.00635	0.01320	-0.01413	-0.04277	0.34268	0.269
Plant height (cm)	0.01785	-0.02037	**-0.018**	0.01333	-0.00173	-0.17419	0.33077	0.147
Number of pods plant^{-1}	0.00913	-0.01369	-0.00431	**0.057**	-0.00821	0.02966	0.36535	0.435
100-grain weight (g)	-0.00598	0.02145	0.00082	-0.01202	**0.039**	0.06910	-0.29458	-0.182
Harvest index (%)	-0.00789	0.00282	0.00358	0.00188	0.00300	**0.892**	-0.44733	0.448
Biological yield /plant	0.01648	-0.02099	-0.00632	0.02158	-0.01189	-0.41593	**0.959**	0.542

Fig. 01 Field view of Chickpea Breeding farm and our Experiment

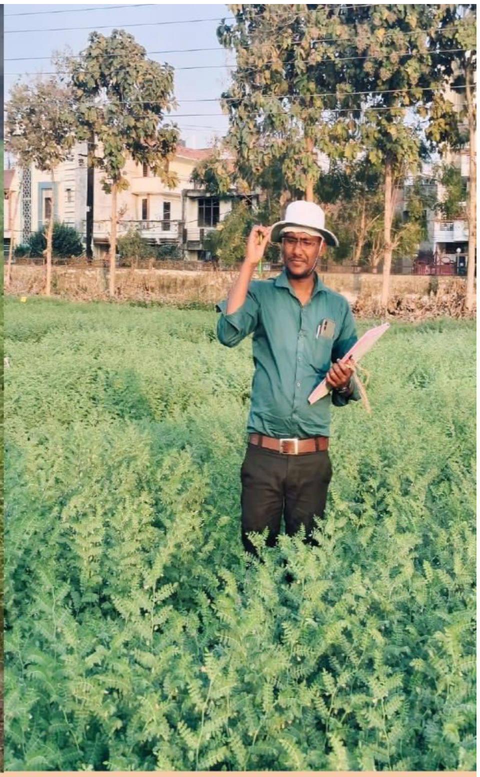

Fig. 02 Image, while recording Phenotypic Data

Character association

Correlation coefficient

Correlation coefficients are vital in plant breeding as they reveal relationships among traits and grain yield. By identifying positive associations, breeders can select traits like pods per plant, harvest index, or biomass that enhance yield. Negative correlations highlight trade-offs, guiding balanced selection strategies for improved productivity and genetic advancement.

Grain yield per plant exhibited significant positive correlations with number of pods per plant (r = 0.435), harvest index (r = 0.448), and biological yield (r = 0.542**), highlighting these traits as major yield determinants. Days to maturity also showed a positive correlation (r = 0.269*), while plant height had a weak positive association (r = 0.147). In contrast, 100-grain weight revealed a negative correlation (r = -0.182), suggesting a trade-off between seed size and yield. Overall, pod number, harvest index, and biomass emerged as the most reliable selection criteria for enhancing grain yield in chickpea. The estimates of Correlation Coefficient for all studied characters are shown in *Table 03* [Yadav et al., 2025].

Path Coefficient

Path coefficient analysis is crucial in plant breeding as it partitions correlations into direct and indirect effects, revealing the true contribution of each trait to yield. Unlike simple correlations, it identifies causal relationships, helping breeders prioritize traits such as pods per plant or harvest index for effective selection and genetic improvement.

Path coefficient analysis revealed that biological yield per plant had the highest direct effect on grain yield (0.959), followed by harvest index (0.892) and number of pods per plant (0.057). Indirect contributions were notable, with biological yield via harvest index (-0.41) and harvest index via biological yield (-0.44). Days to maturity showed a small negative direct effect (-0.059) but a positive indirect effect through biological yield (0.34). Plant height (-0.018) and days to 50% flowering (0.107) contributed weakly, while 100-grain weight (0.039) had negative indirect effects (-0.29).

Overall, biological yield, harvest index, and pod number were key yield determinants. The estimates of Path Coefficient for all studied characters are shown in *Table 04* [J. K. Dawane et al., 2020].

In conclusion, the study demonstrates that chickpea genotypes exhibit substantial genetic variability for key agronomic traits, particularly yield and pod-related attributes. ANOVA confirmed significant differences for days to flowering, maturity, pods per plant, seed weight, and grain yield, validating their importance in selection. Genetic variability analysis revealed high heritability and genetic advance for grain yield, pods per plant, and flowering time, indicating strong additive gene action and suitability for direct improvement.

Correlation analysis highlighted positive associations of yield with pod number, harvest index, and biological yield, while seed weight showed a negative relationship, reflecting trade-offs in selection. Path coefficient analysis further emphasized biological yield and harvest index as the most influential determinants of grain yield, with pods per plant contributing indirectly. Collectively, biomass, harvest efficiency, and pod traits emerge as primary targets for effective genetic enhancement in chickpea breeding programs. In continuation of conclusion of research work, it is stated that approx. similar results were exerted by Abhinav *et al.,* (2024), Vipul *et al.,* (2025) and Amit *et al.,* (2024).

Authors' contributions

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

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Competing Interests

All the authors have declared that no competing interests exist.

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