



Estimation of Genetic Variability and Trait Association for Yield and Yield Related Traits of Chilli (*Capsicum annum* L.)

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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

The selection of superior traits in plants is a key component of natural selection. Genetic diversity in plant populations is one of the fundamental drivers of natural selection and serves as a valuable resource for crop improvement through trait selection. The present experiment was conducted on chilli (*Capsicum annum* L.) during the autumn–winter season of 2024–2025, with the primary objective of assessing the genetic variability, heritability (in the broad sense), and genetic advance as a percentage of mean among chilli genotypes. The experimental material consisted of 35

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genotypes, including a check variety (Kashi Anmol), laid out in a Randomized Complete Block Design (RCBD) with three replications. Observations were recorded for thirteen quantitative traits. Among all the traits, the highest phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were observed for ascorbic acid content (39.13% and 37.48%, respectively), followed by average fruit weight (35.45% and 31.86%), fruit yield per plant (34.54% and 31.84%), fruit length (28.11% and 22.83%), and plant height (22.65% and 19.45%). Heritability (in the broad sense) estimates ranged from 24.56% (in days to mature red ripe stage) to 98.18% (in ascorbic acid content). High heritability was recorded for ascorbic acid (98.18%), followed by fruit yield per plant (94.37%), pedicel length (90.00%), average fruit weight (88.68%), fruit length (88.00%), number of fruits per plant (79.89%), and plant height (74.90%). Based on these findings, it can be concluded that there exists substantial genetic variability within the studied chilli genotypes. The high heritability coupled with high genetic advance for key traits such as ascorbic acid content, fruit yield, and fruit size indicates that selection would be effective and genetic improvement through breeding is feasible. Therefore, there is ample scope for successful crop enhancement aimed at improving yield and yield-attributing traits in the current chilli germplasm.

Keywords: Chilli; variability; GCV; PCV; heritability; genetic advances.

1. INTRODUCTION

“Chilli (*Capsicum annum* L.) is one of the most important vegetable and spice crops, cultivated widely across India. It belongs to the family Solanaceae and has a chromosome number of $2n = 24$. Globally, there are approximately 400 distinct types of chilli (or chile) varieties. India ranks among the leading countries in area and production, and it is the top exporter of chilli worldwide. Chilli accounts for over 33% of India’s total spice exports and contributes approximately 16% to the global spice trade” (Anonymous, 2020–21). “In India, chilli holds the top position among spice crops in terms of production. As per data from 2020–21, green chilli is cultivated on 1,264.62 thousand hectares, with a total production of 7,278.32 thousand metric tonnes. Chilli thrives in warm, humid tropical and subtropical climates, and can withstand temperatures exceeding 40°C. It is cultivated between 45° north and south latitudes, and up to 2000 meters above sea level. Chilli is a frost-sensitive crop, favoring a temperature range of 15–35°C for optimal growth (Singh et al., 2023). Fruit setting is significantly reduced at temperatures below 10°C, while the ideal temperature for fruit setting is around 24°C. The pungency of chilli is due to the presence of capsaicin, whose chemical name is N-Vanillyl-8-Methyl-6-E-Nonamide. Capsaicin, in both natural and synthetic forms, is also utilized in law enforcement and personal defense as a safer alternative to chemical, electrical, or physical restraint methods. The red color in chilli is primarily due to capsanthin ($C_{40}H_{56}O_3$) (36%) and capsorubin, while yellow and orange hues are attributed to lutein and beta-carotene,

respectively (Maurya et al., 2017). Chilli also contains oleoresin, which enhances color and flavor in food products” (Chattopadhyay et al., 2011). “For effective crop improvement, it is essential to employ a strategic breeding approach that exploits the natural variability in the base population. Traits such as the genotypic and phenotypic coefficients of variation, heritability, and genetic advance play a crucial role in breeding programs. Heritability is a key trait for plant breeders, as it indicates the extent to which a trait can be improved through selection. It reflects the degree of resemblance between parents and their offspring and is widely used to predict the response to selection. However, high heritability alone is insufficient for effective selection unless it is accompanied by high genetic advance” (Burton, 1953). Substantial heritability estimates, when paired with high genetic gain, provide promising prospects for genetic improvement in subsequent generations. While phenotypic variability can fluctuate due to environmental influences, genetic variability is more stable and valuable for selection and hybridization in crop improvement programs.

2. MATERIALS AND METHODS

The present investigation, entitled “Studies on Genetic Variability, Character Association, and Genetic Divergence in Chilli (*Capsicum annum* L.)”, was conducted at the Agricultural Research Farm of Rama University, Mandhana, Kanpur. The experiment was laid out in a Randomized Block Design (RBD) with three replications, during the autumn–winter season of 2024–2025, to evaluate the performance of 35 chilli

genotypes. Each treatment consisted of 12 plants arranged in two rows, with a spacing of 60 × 50 cm. The net plot size for each treatment was 3.0 × 1.8 m². All recommended agronomic practices and plant protection measures were followed to ensure healthy crop growth and development. Observations were recorded on the following thirteen quantitative traits: Days to 50% flowering, Days to maturity (mature green stage), Days to maturity (red ripe stage), Plant height (cm), Number of primary branches per plant, Number of secondary branches per plant, Number of fruits per plant, Fruit length (cm), Pedicel length (cm), Fruit diameter (mm), Average fruit weight (g), Fruit yield per plant (kg), Ascorbic acid content (mg/100 g).

To assess the extent of genetic variation, the phenotypic and genotypic coefficients of variation (PCV and GCV), heritability (in the broad sense), and genetic advance as percent of mean were estimated using the methods described by Burton and De Vane (1953).

$$GCV = \frac{\text{Genotypic standard deviation}}{\text{Mean } (\bar{X})} \times 100$$

$$GCV = \frac{\sqrt{\sigma^2_g}}{\bar{X}} \times 100$$

$$PCV = \frac{\text{Phenotypic standard deviation}}{\text{Mean } (\bar{X})} \times 100$$

$$PCV = \frac{\sqrt{\sigma^2_p}}{\bar{X}} \times 100$$

3. RESULT AND DISCUSSION

The analysis of variance revealed that the mean squares due to treatments were highly significant for all thirteen quantitative traits (Table 1), indicating the presence of substantial genetic variability among the genotypes for each character under study. In other words, the performance of genotypes differed significantly across traits, signifying that the existing Chilli germplasm offers ample scope for selection and genetic improvement.

3.1 Genotypic and Phenotypic Coefficients of Variation

The estimates of the genotypic coefficient of variation (GCV) and phenotypic coefficient of

variation (PCV) for thirteen characters are presented in Table 2. For all characters, PCV values were higher than the corresponding GCV values, suggesting the influence of environmental factors on the expression of these traits. The highest GCV and PCV were recorded for: Ascorbic acid (37.48% and 39.13%), Average fruit weight (31.86% and 35.45%), Fruit yield per plant (31.84% and 34.54%), Fruit length (22.83% and 28.11%), Plant height (19.45% and 22.65%).

Moderate levels of GCV and PCV were observed for: Pedicel length (15.54% and 19.74%), Number of fruits per plant (13.85% and 15.33%), Primary branches per plant (10.86% and 14.51%), Fruit diameter (10.56% and 14.27%), Secondary branches per plant (7.74% and 11.65%), Lower GCV and PCV were found for: Days to 50% flowering (6.45% and 8.23%), Days to maturity (mature green stage) (6.52% and 7.54%), Days to maturity (red ripe stage) (4.66% and 7.52%). Low values of GCV and PCV for days to maturity suggest less genetic variability, indicating that these traits are more stable and less influenced by environmental conditions. These results are in close agreement with earlier studies by Singh et al. (2017), Kumari et al. (2017), Jogi et al. (2017), Gulzar and Malik (2022), Janaki et al. (2015), and Saisupriya et al. (2022).

3.2 Heritability and Genetic Advance

Heritability in the broad sense is a crucial parameter for breeders, as it indicates the degree of transmission of traits from parents to progeny and helps in determining the effectiveness of selection. However, high heritability alone is not sufficient; it should be coupled with high genetic advance to make meaningful progress in selection (Burton, 1953). The heritability estimates for the traits ranged from: 24.56% for days to mature green stage, To 98.18% for ascorbic acid content, Traits showing high heritability (>75%): Ascorbic acid (98.18%), Fruit yield per plant (94.37%), Pedicel length (90.00%), Average fruit weight (88.68%), Fruit length (88.00%), Number of fruits per plant (79.89%), Plant height (74.90%), Traits with moderate heritability (50–75%): Secondary branches per plant (58.28%), Primary branches per plant (56.28%), Fruit diameter (54.00%), Days to 50% flowering (47.82%), Traits with low heritability (<50%): Days to maturity (red ripe stage) (28.15%), Days to maturity (green fruit stage) (24.56%), The highest genetic advance as

Table 1. Analysis of variance (mean squares) for thirteen quantitative characters in Chilli

S.No.	Traits D.F.	Source of variation		
		Replication 2	Treatments 31	Error 62
1.	Days to 50% flowering	25.12	36.70**	7.81
2.	Days to mature green stage	138.88	340.17**	16.42
3.	Days to mature red ripe stage	284.41	55.21**	24.72
4.	Plant height	117.81	252.94**	26.79
5.	Primary branches per plant	0.15	0.37**	0.17
6.	Secondary branches per plant	0.72	1.18**	0.41
7.	No. of fruit per plant	8.25	165.38**	13.47
8.	Fruit length	2.45	8.53**	0.59
9.	Pedicle length	0.04	0.79**	0.19
10.	Fruit diameter	0.69	8.35**	1.46
11.	Average fruit weight	0.16	1.37**	0.12
12.	Ascorbic acid	1.47	3732.11**	4.51
13.	Fruit yield per plant	467.22	39248.73**	1281.06

**Significant 1% level, *Significant at 5% level

Table 2. Estimates of range, grand mean, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in the broad sense, genetic advance (Ga) and Ga in per cent of mean for thirteen characters in chilli germplasm

Traits	Range		Grand Mean	ECV %	PCV %	GCV %	h ² (Broad Sense) %	Genetic Advance 5%	Genetic Advance as % of Mean 5%
	Minimum	Maximum							
Days to 50% flowering	44.00	52.57	48.35	7.18	8.23	6.45	47.82	4.41	6.48
Days to mature green stage	65.67	77.39	69.42	5.88	7.54	6.52	24.56	3.35	3.78
Days to mature red-ripe stage	84.67	102.67	92.45	6.36	7.52	4.66	28.15	3.03	4.22
No. of primary branches per plant	2.22	4.12	3.78	11.52	14.51	10.86	56.68	0.94	17.24
No. of secondary branches per plant	5.00	7.87	6.64	8.21	11.65	7.74	58.28	0.68	9.52
Plant height	38.12	72.00	58.54	19.24	22.65	19.45	74.90	18.15	24.41
Fruit length	5.74	11.13	8.57	12.41	28.11	22.83	88.00	4.74	34.41
Fruit diameter	5.15	13.55	7.52	11.54	14.27	10.56	54.00	0.74	15.35
Pedicle length	2.34	4.32	3.56	8.15	19.74	15.54	90.00	0.18	25.74

Traits	Range		Grand Mean	ECV %	PCV %	GCV %	h ² (Broad Sense) %	Genetic Advance 5%	Genetic Advance as % of Mean 5%
	Minimum	Maximum							
Average fruit weight	2.21	10.13	5.74	9.23	35.45	31.86	88.68	17.80	67.08
No. of fruits per plant	45.47	77.20	61.45	7.20	15.33	13.85	79.89	2.86	24.72
Ascorbic acid	53.67	184.86	126.65	4.14	39.13	37.48	98.18	4.03	75.95
Fruit yield per plant	0.113	.0289	0.210	11.45	34.54	31.84	94.37	163.52	69.15

percent of mean was recorded for: Ascorbic acid (75.95%), Average fruit weight (67.08%), Fruit yield per plant (63.89%), Fruit length (34.41%).

The lowest genetic advance as percent of mean was observed for: Days to mature green fruit (3.78%), Pedicel length (0.18%). These findings are supported by previous reports of Farwah et al. (2020), Haralayya et al. (2020), and Saisupriya et al. (2022). The combination of high heritability with high genetic advance for traits like ascorbic acid (98.18%, 75.95%), fruit yield per plant (94.37%, 63.89%), average fruit weight, fruit length, and pedicel length indicates that these traits are predominantly controlled by additive gene action and less affected by environmental factors. Hence, direct selection for these traits in breeding programs would be effective. These findings are consistent with the results reported by Nahak et al. (2018) and Lakshmidhevamma et al. (2021).

4. CONCLUSION

Based on the above result of the highest phenotypic as well as genotypic coefficient of variation were observed in case of ascorbic acid (39.13% and 37.48%) followed by average fruit weight (35.45% and 31.86%) fruit yield per plant (34.54% and 31.84%), fruit length (28.11% and 22.83%), plant height (22.65% and 19.45%). The heritability in broad sense ranged from 24.56 per cent in case of days to mature red ripe stage to 98.18 per cent for ascorbic acid. So, there is plenty of room for improvement in the current germplasm to generate new enhanced varieties of Chilli in the future.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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