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EVALUATION OF GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE IN CHILLI (*CAPSICUM ANNUUM* L.)

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ABSTRACT

The present study was conducted at the College of Horticulture and Forestry, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya, during the rainy season of 2022-23. The objective of this study is to determine the variability among genotypes, as well as the heritability and genetic advance of various traits. Evaluation was carried out with 40 chilli genotypes, including one check, namely KA-2, in a randomised block design with three replications for different yield and quality traits. The study revealed a high degree of variability across all traits, indicating their suitability for selection in future breeding efforts. High PCV, GCV, heritability, and genetic advance were observed for ascorbic acid, fruit yield per plant, average fruit weight, fruit length, and the number of fruits per plant. These traits, which showed high GCV, PCV, heritability, and genetic advance as a percentage of the mean, should be considered reliable criteria for selection aimed at improving yield and yield-related traits in chilli.

Key words: Chill, GCV, PCV, Variability, Heritability, Genetic Advance

Introduction

Chilli/ hot pepper (*Capsicum annuum* L.) is one of the important vegetable crops in India. It has a chromosome number 2n=2x=24 and is a member of the Solanaceae family. It is grown for both the domestic market and exports (Patel *et al*., 2024). The origin of chillies is in Mexico or South America (Andrews 1984). Portuguese traders brought it from Brazil to India in 1584 (Thamburaj and Singh, 2013) and to China in the 17th century. Chilli is a widely grown vegetable cum spice crop in Asia as well as the world. India, China, Ethiopia, Myanmar, Mexico, Peru, Vietnam, Pakistan, Ghana, and Bangladesh are the top countries in the world for chilli production. India is one of the leading countries in terms of area and production, and also tops among all of these in exporting chillies. It contributes over 33% of India's total spice exports and accounts for 16% of global spice trade (Anonymous 2024-25). In India, chilli ranked first among spice crops in terms of production; i.e., green chilli is cultivated on 852.413 thousand hectares, and production is 19576.35 thousand metric tons. production (Anonymous 2024-25). The major chilli growing states are Andhra Pradesh, Telangana, Karnataka, Madhya Pradesh, Bihar, Maharashtra, Jharkhand, Chhattisgarh and Haryana. These states account for nearly 80% of the area under this crop in India (Anonymous, 2024).

Table 1: Distinguishing morphological traits of the genotypes of chilli.

Sr.	Name of genotype	Colour (Mature green stage)	Colour (Red ripe stage)	Flowering Habit	Fruiting habit
1.	NDC-20-1	Dark Green	Red	Solitary	Drooping
2.	NDC-20-2	Green	Red	Solitary	Drooping
3.	NDC-20-3	Light Green	Red	Solitary	Drooping
4.	NDC-20-4	Light Green	Light Red	Solitary	Drooping
5.	NDC-20-5	Light Green	Red	Solitary	Drooping
6.	NDC-20-6	Green	Dark Red	Solitary	Drooping
7.	NDC-20-7	Dark Green	Dark Red	Solitary	Drooping
8.	NDC-20-8	Green	Light Red	Solitary	Drooping
9.	NDC-20-9	Green	Light Red	Solitary	Drooping
10.	NDC-20-10	Green	Red	Cluster	Upright
11.	NDC-20-11	Dark Green	Dark Red	Solitary	Drooping
12.	NDC-20-12	Green	Red	Solitary	Drooping
13.	NDC-20-13	Dark Green	Dark Red	Solitary	Drooping
14.	NDC-21-1	Green	Red	Solitary	Drooping
15.	NDC-21-2	Yellow	Orange	Solitary	Upright
16.	NDC-21-3	Green	Light Red	Solitary	Drooping
17.	NDC-21-4	Light Green	Light Red	Solitary	Drooping
18.	NDC-21-5	Dark Green	Dark Red	Solitary	Drooping
19.	NDC-21-6	Light Green	Red	Solitary	Drooping
20.	NDC-21-7	Dark Green	Dark Red	Solitary	Drooping
21.	NDC-21-8	Light Green	Red	Solitary	Drooping
22.	NDC-21-9	Light Green	Light Red	Solitary	Drooping
23.	NDC-21-10	Green	Red	Solitary	Drooping
24.	NDC-21-11	Green	Red	Solitary	Drooping
25.	NDC-21-12	Dark Green	Dark Red	Solitary	Drooping
26.	NDC-21-13	Light Green	Light Red	Solitary	Drooping
27.	NDC-21-14	Light Green	Red	Solitary	Drooping
28.	NDC-22-1	Green	Red	Solitary	Drooping
29.	NDC-22-2	Dark Green	Red	Solitary	Drooping
30.	NDC-22-3	Green	Dark Red	Solitary	Drooping
31.	NDC-22-4	Light Green	Red	Solitary	Drooping
32.	NDC-22-5	Light Green	Red	Solitary	Drooping
33.	NDC-22-7	Green	Red	Solitary	Drooping
34.	NDC-22-8	Green	Light Red	Solitary	Drooping
35.	NDC-22-9	Green	Red	Solitary	Drooping
36.	NDC-22-10	Dark Green	Dark Red	Solitary	Drooping
37.	NDC-22-11	Dark Green	Dark Red	Solitary	Drooping
38.	NDC-25	Light Green	Red	Solitary	Drooping
39.	NDC-26	Green	Light Red	Solitary	Drooping
40.	KA-2	Dark Green	Dark Red	Solitary	Drooping

To start any crop improvement programme, a thorough assessment of the genetic variability among indigenous genotypes for yield and its related traits is crucial (Hari Har Ram, 2021). Estimates of GCV and PCV offer important insights into the level of variability within the germplasm. Parameters such as heritability and genetic advance help in understanding the environmental impact on trait expression and in estimating the potential genetic gain from selection. Hence, systematic characterisation of new genotypes is necessary to determine variability and identify superior, promising genotypes for use in future breeding programmes (Dayal *et al.*, 2023).

Material and methods

The experimental plant material consists of 40 chilli genotypes. These genotypes were evaluated in a Randomised block design with 3×1.8 m^2 plots and three replications during the spring-winter season of 2022-23. Twelve plants of each entry per replication were

Table 2: Analysis of variance (mean squares) for thirteen quantitative characters in chilli.

S. No.	Traits	Source of variation		
		D.F.		
		R	T	E
		2	39	78
1.	Days to 50% flowering	2.33	36.70**	9.69
2.	Days to first harvest at the mature green stage	34.76	37.04**	19.8
3.	Days to first harvest at red-ripe stage	28.16	61.02**	32.44
4.	No. of primary branches per plant	0.3	0.46**	0.09
5.	No. of secondary branches per plant	0.07	0.83**	0.2
6.	Plant height (cm)	117.81	284.96**	28.7
7.	Fruit length (cm)	0.48	10.07**	0.7
8.	Fruit circumference (cm)	0.11	0.69**	0.16
9.	Pedicel length (cm)	0.04	0.90**	0.11
10.	Average fruit weight (g)	0.22	12.43**	0.32
11.	No. of fruits per plant	6.16	200.73**	17.29
12.	Ascorbic acid (mg/100g)	106.56	5623.63**	13.1
13.	Fruit yield per plant (g)	563.01	41265.80**	1396.03

R: Replication; T: Treatments; E: Error
** Significant at 1% level

transplanted in 1st week of September on raised beds with a spacing of 60×50 cm. The crop will be raised according to the recommended Package of Practices for Vegetables by the Department of Vegetable Science, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya.

Geographically, the experimental site falls within a humid sub-tropical climate and is located between 24.470 and 26.560 N latitude and 82.120 and 83.980 E longitude, at an altitude of 113 m above mean sea level in the Genetic Alluvial Plains of Eastern Uttar Pradesh.

Soil

The experimental field had sandy loam soil, low in organic matter, nitrogen, medium in phosphorus, potash, and slightly alkaline in nature with pH 8.5. The mechanical composition of soil was 60.9 per cent, 27.8 per cent silt and 11.3 per cent clay.

Climate

The experimental site is located in the humid subtropical area and receives approximately 1200 mm of rainfall annually. Winters are typically cool and dry, with a little light shower. The temperature during the crop season varied between 5.7 (min) to 38.9 (max).

The data were collected on the days to 50% flowering, days to first fruit harvest at mature green stage, days to first fruit harvest at red ripe stage, plant height (cm), primary branches per plant, secondary branches per plant, no. of fruit per plant, fruit length (cm), pedicel length (cm), fruit circumference (mm), average fruit weight (g), ascorbic acid (mg/100g), fruit yield per plant (g) and some morphological traits viz. colour at mature green stage, colour at red ripe stage, flowering habit and fruiting habit. The collected quantitative data were analysed by Windostat 9.2 data analysis software. The data were subjected to analysis as per the procedure described by Panse and Sukhatme (1954). The coefficient of phenotypic and genotypic variation was calculated according to Burton and De Vane (1953). Heritability, genetic advance, and genetic gain were calculated according to the formulae of Johnson *et al.*, (1955).

Result and Discussion

The data collected in the field for morphological traits show a significant difference between genotypes (Table 1 and Fig. 1). In terms of colour at the mature green stage, green colour is exhibited by 15 genotypes, followed by light green by 13, dark green by 11, and only one genotype (NDC-21-2) shows yellow colour. At the red ripe stage, red colour appears in 19 genotypes, followed by dark red in 11, light red in 9, and only one genotype (NDC-21-2) shows orange colour. Regarding flowering habit, all genotypes display solitary flowering habit except for one (NDC-20-10), which shows a cluster flowering habit. For the fruiting habit, all genotypes exhibit a drooping nature except for two genotypes (NDC-20-10 and NDC-21-2).

There is significant variation among genotypes for each character under investigation. All treatments were found highly significant for all characters (Table 2). In other words, the genotypes' performances for these traits differed statistically, suggesting that there is considerable opportunity for selection within the available chilli germplasm.

The outcome further supported the findings of Swetha *et al.*, (2023) and Patel *et al.*, (2015). The analysis of variance (ANOVA) indicated substantial variation among

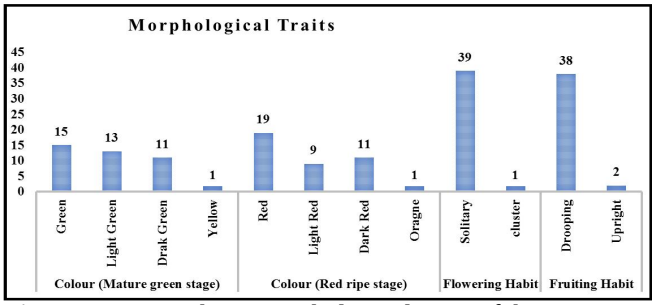

Fig. 1: Distinguishing morphological traits of the genotypes of chilli.

Table 3: 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 %	BS	GA5	GAM
	Min.	Max.							
Days to 50% flowering	42.67	56.00	50.53	6.16	8.56	5.94	48.20	4.29	8.49
Days to first harvest at the mature green stage	63.33	76.67	71.67	6.21	7.05	3.35	22.50	2.34	3.27
Days to first harvest at red-ripe stage	84.33	102.67	94.19	6.05	6.88	3.28	22.70	3.03	3.22
No. of primary branches per plant	2.53	4.07	3.27	9.06	14.11	10.82	58.80	0.56	17.08
No. of secondary branches per plant	4.93	7.40	5.93	7.53	10.80	7.74	51.40	0.68	11.43
Plant height (cm)	33.13	75.40	57.27	9.36	18.65	16.14	74.90	16.47	28.76
Fruit length (cm)	5.49	13.08	9.47	8.84	20.65	18.66	81.70	3.29	34.74
Fruit circumference (cm)	2.79	5.39	4.08	9.87	14.27	10.31	52.20	0.63	15.34
Pedicel length (cm)	2.63	4.91	3.44	9.42	17.70	14.99	71.70	0.90	26.14
Average fruit weight (g)	2.20	10.67	6.22	9.17	33.61	32.33	92.60	3.98	64.08
No. of fruits per plant	41.67	76.33	57.77	7.20	15.33	13.54	78.00	14.22	24.62
Ascorbic acid (mg/100g)	53.67	208.17	116.88	3.10	37.13	37.00	99.30	88.78	75.95
Fruit yield per plant (g)	134.67	692.33	355.29	10.52	34.11	32.45	90.50	225.91	63.59

BS: h^2 (Broad Sense) %; GA5: Genetic Advance 5%; GAM: Genetic Advance as % of Mean 5%

the 43 genotypes for all quantitative characters under study.

The estimates of genotypic and phenotypic coefficients of variation for thirteen characters of chilli germplasm have been presented in Table 3. The estimates of phenotypic coefficients of variation (PCV) were higher than genotypic coefficients of variation (GCV) for all the characters. The highest phenotypic (>20%) as well as genotypic coefficients of variation were observed in the case of ascorbic acid (37.13% and 37.00%), followed by fruit yield per plant (34.11% and 32.45%), average fruit weight (33.60% and 32.33%), and fruit length (20.65% and 18.67%). Moderate (10-20%) estimates of PCV and GCV were estimated for pedicle length (17.70% and 14.99%), no. of fruit per plant (15.33% and 13.53%), fruit circumference (14.27% and 10.30%), primary branches per plant (14.10% and 10.81%), secondary branches per plant (10.80% and 7.74%). The phenotypic and genotypic coefficients of variations were lower (<10%) for days to 50% flowering (8.55% and 5.93%), days to first harvest at mature green stage (7.05% and 3.34%) and days to first harvest at red ripe stage (6.87% and 3.27%), low GCV and PCV for these traits indicated that there was less variation for this trait. Similar, results have been reported by Semba and Deo (2022), they observed plant height (PCV 25.62% and GCV 24.95%), leaf width (PCV 22.82% and GCV 21.64%), fruit length (PCV 36.49% and GCV 35.49%), fruit width (PCV 28.46% and GCV 27.36%), pedicel length (PCV 26.31% and GCV 25.04%), fruit weight (PCV 25.12% and GCV 23.70%), no. of fruit per plant (PCV 38.5% and GCV 37.29%), and fruit yield per plant (PCV 44.14% and GCV 42.27%) demonstrating a wide range of genetic variability for these traits.

Estimates of heritability (broad sense) and genetic advance for different characters have been presented in Table 3. The heritability in the broad sense ranged from 22.5 per cent in the case of days to first harvest at the mature green stage to 99.3 per cent for ascorbic acid.

Very high estimates of heritability (>80%) were recorded for four characters i.e. ascorbic acid (99.3%) followed by average fruit weight (92.6%), fruit yield per plant (90.5 %), and fruit length (81.7%). However, high heritability (60-80%) was recorded for three characters i.e. no. of fruit per plant (78.0%), plant height (74.9%), pedicel length (71.7%) and moderate heritability (40-60%) was recorded for four characters i.e. no of primary branches per plant (58.8%), fruit circumference (52.2%), no of secondary branches per plant (51.4 %), days to 50% flowering (48.2%) and lower heritability (<40%) recorded for remaining characters i.e. days to first harvest at red ripe stage (22.7%) followed by days to first harvest at mature green stage (22.5%) estimated in all 13 characters. It's supported by the finding of Hulagannavar *et al.*, (2024). In the present experiment, showed high heritability for all characters except the number of primary branches, which showed moderate heritability.

The highest value of genetic advance in per cent of the mean was shown by ascorbic acid (75.95%). The days to the first harvest at the red ripe stage exhibited the lowest value (3.22) for this parameter. The characters that observed very high estimates of genetic advance were fruit yield per plant (225.91), and the lowest was estimated for no primary branches per plant (0.56). Similar

results were also reported by Patel *et al.*, (2022). They recorded high genetic advance as per cent of mean in no of fruit per plant (50.56%) followed by ascorbic acid (51.40%) and fruit length (41.70%) while low genetic advance in per cent of mean found in days to red ripe maturity (6.05%) followed by days to 50% flowering and primary branches per plant (18.04%).

High heritability coupled with high genetic advance in per cent of mean were recorded for ascorbic acid (99.3% and 75.95%), average fruit weight (92.6% and 64.08%), fruit yield per plant (90.5% and 63.59%), fruit length (81.7% and 34.74%), no of fruit per plant (78.00% and 24.62%) plant height (74.9% and 28.76%), no. of fruit per plant (80.00% and 23.62%) and pedicel length (71.7% and 26.14%) indicating that these traits were little influenced by environment. Thus, it requires low selection intensity for improvement. Similar results, including high heritability and genetic advance, were also reported by Swetha et al. (2023b). They recorded high heritability (>75%) with high GA (>20%) in plant height (91.28, 55.33), fruit length (98.94, 95.80), and fruit girth (96.34, 75.07). Moderate h^2 and GA were recorded for the number of fruits per plant (43.58, 19.48) and the number of primary branches (46.22, 16.35). While the traits like days to first flowering (26.69, 5.69) and days to 50% flowering (27.41, 8.38) exhibited low h^2 coupled with low GA. And also, a similar result was reported by Singh *et al.* (2023) and Assefa *et al.*, (2023). The broad sense heritability (H^2) values ranged from 53.3% for unmarketable yield to 99.4% for fruit number per plant. Whereas genetic advance as a percentage of the mean (GAM) was estimated to range from 31.7–93.0% for fruit diameter and fruit number per plant, respectively. Accordingly, both broad-sense heritability and genetic advance as per cent of mean values were high for all characters except for some, i.e. fruit yield per plant, fruit diameter, fruit length, and number of fruits per plant, which show moderate to high heritability and genetic advance as a percentage of mean.

Conclusion

Based on the findings of the present experiment, it may be concluded that considerable variability exists among chilli genotypes. NDC-21-8 followed by NDC-21-1, NDC-21-13, NDC-20-5, NDC-22-4 and NDC-26 were found as significant and most promising genotypes for fruit yield per plant, along with some other traits. The high PCV and GCV shown for Ascorbic acid, fruit yield per plant, and average fruit weight, along with high heritability and high genetic advance for these significant traits, indicated a greater chance of selection response.

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