Assessment of genetic variability in chilli (*Capsicum annuum* L.) genotypes for growth and yield traits

Abstract

Genetic variability, heritability, and genetic advance as a percent of mean were evaluated for 17 characters in chillithrough field assessment. The study encompassed all observed traits and analysis of variance revealed significant variability among genotypes for each character. Notably, Number of fruits per plant, Average fresh fruit weight (g), Green chilli yield per plant (g), Dry chilli yield per plant (g), Dry chilli yield per plot (kg), and Dry chilli yield per/ha (q) exhibited higher values for both Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV), indicating substantial genetic variability with minimal environmental influence.Plant height (cm), Average fresh fruit weight (g), Number of fruits per plant, Fruit diameter (mm), Number of seeds/fruit, Green chilli yield per plant (g), Dry chilli yield per plant (g), Dry chilli yield per plot (kg), and Dry chilli yield per/ha (q) demonstrated high heritability and genetic advance as a percent of mean. This suggests the prevalence of additive gene action in the inheritance of these yield attributes. Consequently, simple selection is anticipated to be effective for enhancing these traits.

Introduction

Chilli (*Capsicum annum* L.) holds a crucial role as both a vegetable and spice crop, playing an indispensable part in the Indian diet owing to its pungency, spicy taste, and vibrant color and flavor. It occupies a predominant position among spices cultivated throughout India, contributing approximately 37% to the overall spice production in the country (Ralte and Ekhe 2022). Chilli is one of the most important vegetable crops grown all around the world as an essential ingredient in cuisine as vegetables, condiments, spices, pickles and sauces (Chethan *et al*., 2022). The distinctive qualities of chilli are attributed to its pungency, derived from the crystalline acrid volatile alkaloid Capsaicin, and its captivating red color, a result of the pigment Capsanthin.In India, the primary chilli-producing states include Andhra Pradesh, Orissa, Maharashtra, West

Bengal, Karnataka, Rajasthan, Uttar Pradesh, and Tamil Nadu (Rajamanickam, 2020). The cultivation of chilli predominantly relies on open-pollinated varieties, cultivated over an extended period, resulting in low average productivity. Green chilli occupies 4.26 lakh hectares in India, with an average annual production of 46.99 lakh tones and a productivity of 11 t/ha. In contrast, the area dedicated to dry chilli is 8.82 lakh hectares, yielding an annual production of 18.36 lakh tons, with a productivity of 2.1 t/ha (Anon, 2021-22). Addressing this, there is an need for the development of high-yielding varieties to enhance productivity. Additionally, the evaluation and development of location-specific varieties with higher yield potential are crucial. Despite these imperatives, there have been limited efforts to release suitable, location-specific varieties, making the selection from existing variations the most effective breeding procedure.Globally, there are over 400 chilli cultivars, and India stands out as a significant reservoir of genetic diversity in chilli, encompassing various quality factors. Recognizing the importance of genetic variability for enhancing yield and other traits, acquiring such information is crucial for effectively screening superior accessions (Constantino *et al*., 2020). A critical evaluation of the nature and extent of variability in germplasm is a prerequisite for formulating effective breeding methods, as the genetic improvement of any crop hinges on the magnitude of genetic variability and the heritability of economically important traits (Jogi *et al.,* 2017). Selection based on multiple traits simultaneously might diminish the effectiveness of improving a single trait. Therefore, it is imperative to dissect overall variability into its heritable and non-heritable components, utilizing genetic parameters such as genotypic coefficient of variation, heritability, and genetic advance over mean (Vidyashree *et al*., 2018). Hence, this study was conducted to ascertain the extent of genetic variability for essential growth and yield characters.

Material and Methods

The investigation was carried out on "Morphological characterization of chilli(*Capsicum annuum* L.) genotypes for yield and yield related traits" during the *kharif* season of 2020-21at the research field, Department of Biotechnology and Crop Improvement, Kittur Rani Channamma College of Horticulture Arabhavi, (UHS, Bagalkot). which is located in the Northern Dry Zone (Zone-III, Region-2) among the agro -climatic zones of Karnataka at 16˚15' North latitude and 74˚45' East longitude at an altitude of about 612 meters above sea level. The meteorological data recorded at the meteorological observatory of K.R.C College of Horticulture, Arabhavi. The

experiment comprised fifty genotypes of chilli collected from different sources. Thirty five days old seedlings were transplanted to the experimental plot the experimental plot was ploughed and brought to fine tilth and were applied farm yard manures (FYM) and recommended dose of fertilizers (NPK)as per the UHS, Bagalkot package of practice. Seedlings were transplanted at spacing of 60 cm × 45 cm in two replications. Observations were recorded from five randomly selected plants in each experimental plot for seventeen growth and yield related traits namely Plant height (cm), Plant spread East-West (cm), Plant spread North-South (cm), Number of primary branches, Number of secondary branches, Days to first flowering, Days to 50 per cent flowering, Days to picking, Fruit length (cm), Fruit diameter (mm), Number of seeds per fruit, Average fresh fruit weight (g), Number of fruits per plant, Green chilli yield per plant (g), Dry chilli yield per plant (g), Dry chilli yield per plot (kg) and Dry chilli yield per hectare (q). The estimates of genotypic and phenotypic coefficient of variation were calculated according to Burton and Devane (1953), heritability in broad sense (Falconer, 1981) and expected genetic advance as per the procedure of Johnson et al. (1955).

Result and Discussion

The effectiveness of any crop improvement programme involving selection and hybridization depends on the existence of genetic variability among the tested materials (genotypes) and extent to which the characters are heritable (heritability). Therefore, it is a pre-requisite to assess the nature and magnitude of variability as one of the basic principles for achieving success in a breeding programme. Variability refers to the presence of differences among the individuals of plant population. Variability results due to differences either in the genetic constitution of the individual of a population or in the environment in which they are grown. The existence of variability is essential for a crop improvement. Selection is effective when there is genetic variability among the individual in population. Hence, insight into the magnitude of variability particularly genetic variability present in a population is of paramount important to a plant breeder for starting a judicious breeding programme.The extent of variability with respect to various characters in different genotypes measured in terms of general mean, genotypic

coefficient of variation, phenotypic coefficient of variation along with heritability and expected genetic advance as per cent of mean.

A wide variation in the mean performance of genotypes was observed for all the characters under study. The analysis of variance showed that all the genotypesslightly differed for all the seventeen characters. On examining the ANOVA, the nature and magnitude of variability for different yield and yield related characters were significant for all characters studied among the chilli genotypes(Table 1).*Viz.*, plant height, plant spread (east-west) (cm), plant spread (north-south) (cm), number of primary branches, number of secondary branches, days to 50 per cent flowering,days to picking (cm), number of fruits per plant, average fresh fruit weight, fruit length (cm), fruit diameter (cm), number of seeds /fruit, dry chilli yield per plant (g), dry chilli yield per plot (kg), dry chilli yield per ha (q), green chilli yield per plant (g). The values indicate highly significant differences for all the characters under study, there by suggesting existence of large amount of variations among the genotypes. So, there is scope for considerable improvement in this crop through the characters studied. Similar to the present findings, investigations carried out earlier also revealed wide variations for various characters (Patel *et al*., 2015; Janaki *et al*., 2015 and Mishra *et al*., 2015).

The high degree of experimental precision was maintained during the study that was evident from the coefficients of variation (CV) values which were below 18 % for all the characters. The CVs were highest in green chilli yield per plant (14.02 %), followed by average fresh fruit weight (13.99 %), dry chilli yield per plot (13.16 %), dry chilli yield per hectare (12.53 %) and number of fruits per plant (11.33 %). Among the CV values estimated, the least was observed for days to picking (2.41 %), indicates that good precision was maintained in conducting the experiment.A wide variation in the mean performance of genotypes was observed for all the characters under study. It may be contemplated from the statistics of general mean values of the characters that, there is a great deal of variability for characters under study. These statistics quite hopefully provide a strong impetus for selecting promising genotypes for specific objectives, because of the magnitude and wide to moderately wide spectrum of variations observed in each character among the genotypes under evaluation. Among the growth parameters studied, average plant height reported was 69.14 cm and the genotypes DP1 KCA-20-2 (92.70 cm), KRCCH Local 2 (88.75 cm), KCA-02-2 (88.20 cm) recorded higher plant

height. Number of primary branches with a mean of 3.61 cm was found to be highest in the genotype Arka Meghana (4.90), HUB-03 (4.60) and in genotype KCA- 21-1 (4.40). Number of secondary branches recorded abundant variability, with a mean value of 9.70 and maximum were revealed in Arka Khyati (11.65) followed by Arka Shweta and T-12 Seln 1 (11.25).Plant spread of the plant was recorded in both the directions east-west and north- south. Mean plant spread in east-west direction was 59 72 cm. Larger canopy spread was found in the T-12 Selection 2 (74.95 cm), KCA-24-2 (72.75 cm), DD-M-DP1 W (71.55 cm). However, mean plant spread in north south direction was 61.14 cm and maximum was observed in the genotype KCA 21-1 (71.55 cm), ChilliSuryamuki (71.20 cm) and HUB-02 (70.25 cm). Plant height, number of primary branches, number of secondary branches, plant spread and stem diameter play vital role for the overall growth and development of the plant as increased height and more number of primary and secondary branches would allow greater biomass production in turn leading to more leaves per branch and high photosynthesis rate. Ultimately resulting in higher yield potential of the crops (Zhang *et al*., 2012).

Three earliness parameters *viz*., days to first flowering, days to 50 per cent flowering and days picking were recorded in the present study. Days to first flowering varied from 37.50 days to 56.50 days the genotypes KCA-24-1 (37.50) and KCA-32-5 (39.00), KCA-26-2, KCA-30 and KCA-17-2 (41.00) exhibited early blooming. Days to 50 per cent flowering varied from 43 to 64 days with the average of 53.07 days. GPM 33-1 (43.00), KCA-24-1 (43.50) and KCA -32-5 (45.00) took maximum number of days to attain 50 per cent flowering. The genotypes KCA 24-1, KCA 17-2, KCA 26-2 and DD-M-DP1W exhibited early for days to picking with 71 days. Duration of a crop is one of the significant traits considered as a component of selection after the yield potentiality which in turn depends on the days taken for flowering and days to harvest. Early maturing types with considerably higher yield levels are always preferred, as they result in higher returns within a short period of time. Flowering pattern and habit is studied in chilli as early yield is determined by the first flower setting fruits. A delay in fruit set can reduce yields and make them more prone to wind damage and lodging. Hence, early flowering and fruit set has been reported as beneficial in *Capsicum* spp. In addition, fruits from the early flowers when compared to later fruits are usually larger (Bosland and Votava, 2000)

Among the fruit parameters, fruit diameter exhibited considerable variability with an average diameter of 11.89 mm. High fruit diameter was observed in Byadagi Dabbi (15.30 mm), Arka Shweta (15.05 mm) and Arka Meghana (14.25 mm). The top genotypes which showed longest fruit length were Arka Shweta (11.17 cm), Arka Meghana (10.96) and Arka khyati (10.50 cm). number of seeds per fruit recorded significant variation, the genotypes PSB cluster (74.60), ByadagiKaddi (74) and KCA- 21-1 (73.70) recorded highest number of seeds per fruit. The diameter and length of the fruit vary largely which depends on plant density, environment chosen for cultivation and the cultivar used. Number of fruits per plant differed abundantly which varied from 53.80 to 166.20 with an average of 104.39 the top yielders recorded maximum number of fruits per plant like KCA-5-3 (166.20) and Arka Shweta (166.20), Arka Meghana and Arka Khyati (161.10). Weight of the fresh fruit was recorded in all genotypes showed considerable variation, maximum fruit weight was recorded in genotype like DD-M-DP1, Arka Khyati (5.34 g) and Byadagi Dabbi (5.30 g).

Yield enhancement is the ultimate breeding objective and fruit yield in chilli is a complex quantitative character influenced by many componential traits as well as environment. The *per se* performance of genotypes for growth and yield parameters gives us the idea about the promising genotypes for a combination of traits and the average performance of the evaluated germplasm. The dry chilli yield per plant varied widely. The average dry chilli yield per plant was of 86.27g where in the genotypes Byadagi Dabbi (147.74 g), Anugraha (140.67 g), KCA-5-3 (124.97 g), KCA-17-2 (113.08 g) and KCA-26-2 (100.14 g) were the top five performing lines. Among commercial hybrids Arka Shweta (161.48 g), Arka Meghana (154.56 g) and Arka Khyati (149.17 g) were performed top. The genotypes Arka Meghana, Arka Shweta, Arka Khyati, Anugraha Byadagi Dabbi, KCA 5-3, KCA-17-2, KCA -19-4, KCA-26-2, KCA -32-5, Anugraha and GPM-40 were performed well and considered as high yielders with respect to green and dry chilli yield.

The range of the character indicates the phenotypic variability, which is reliable and includes genotypic, environmental and genotypic-environmental interaction components and does not reveal the reason for higher degree of variability because, the phenotypic expression includes heritable (genotype) and non-heritable (environment) components. Heritablecomponents is further classified as reproducible (additive geneaction and A × A epistatic interaction) and non-

reproducible (dominant gene action, A ×D and D × D epistaticgene action) gene actions. Hence, it is necessary to divide the observed variability into PV, GV, PCV and GCV, which exhibit the extent of variability present in the various characters. The clear form of selection is done considering variability component along with the heritability, which enables the plant breeder to decide the extent of selection pressure to be applied under particular environment.

The estimate of genetic parameters *viz*., phenotypic and genotypic coefficient of variation along with heritability in broad sense and genetic advance as percentage of mean for different characters are given in (Table 2). In present experiment high to moderate genotypic co-efficient of variation and phenotypic co-efficient of variation (>10 %) were recorded for plant height(14.73 & 16.18), days to first flowering(10.02 & 10.92), number of fruits per plant(29.66 & 31.75), average fresh fruit weight (g) (23.24 & 27.13), fruit length (cm) (11.06 & 13.04), fruit diameter (mm) (14.09 & 16.90), number of seeds per fruit (14.23 & 14.87), dry chilli yield per plant (g)(35.32 & 37.25), dry chilli yield per plot (kg)(32.82 & 35.36), dry chilli yield per ha (q)(32.94 & 35.25), green chilli yield per plant (g)(35.21 & 37.89). Which, indicate the wide variability among the genotypes and the results obtained by present study are in agreement with the results obtained by Jyothi *et al. (*2011), Datta and Das (2013), Cherian (2000), Shivkumar and Hosamani (2006), Bharadwaj *et al. (*2007), Shirshat*et al. (*2007) and Sarkar *et al. (*2009). It shows the presence of high variability in the genotypes for selection and the difference between PCV and GCV were minimum for the traits studied in this experiment, indicating that trait under the study was less influenced by the environment.Low genotypic coefficient of variation and phenotypic coefficient of variation was observed for plant spread east-west, plant spread north-south number of secondary branches days to picking, This suggests the need for generation of variability either by introduction, exploration or by hybridization to get substantial gain in their improvement. Similar results were also reported in chilli by Manju and Sreelathakumary (2002), Bijalwan (2015), Kadwey *et al. (*2016) and Meena *et al.* (2016).

Heritability separates the environmental influence from the phenotypic variance and will be used as prone to changes like errors from environment, planting material *etc*. The estimation of heritability will determine the effectiveness of selection of a particular trait provided, it is considered in the conjunction with the predicted genetic advance as suggested by Johnson *et al. (*1995). Heritability is influenced by biometrical method, generation of inbreeding and hybrids,

sample size of experiment and environment. Heritability is an index of transmissibility and is of primary interest to plant breeder. The ratio of genotypic variance to the phenotypic variance or total variance is known as heritability. It is generally expressed in per cent. Thus, heritability is the heritable portion of phenotypic variance. It is a good index of the transmission of characters from parents to their off-springs. The estimates of heritability help the plant breeder in selection of elite genotypes from diverse genetic population. Poehlman and Borthakur (1972) opined that the characters not influenced by environment will have high heritability. According to Randhawa *et al*. (1975) higher the heritability value of a character, less will be the environmental influence on expression of that character, there by indicating better opportunity for selecting a genetically good individual.In the present experiment, majority of the traits like plant height (76.74), plant spread from east-west (cm) (95.50), plant spread from north-south (cm) (85.71), number of secondary branches (65.42), days to 50 per cent flowering(83.17), days to first flowering(84.29), days to picking (cm) (88.98), number of fruits per plant (87.26), average fresh fruit weight (73.38), fruit length (cm) (72.00), fruit diameter (cm) (69.46), number of seeds /fruit (91.65), dry chilli yield per plant (g) (89.93), dry chilli yield per plot (kg) (86.15), dry chilli yield per ha (q) (87.35), green chilli yield per plant (g) (86.31) showed high heritability except, number of primary branches (51.61) which showed moderate heritability suggesting that these characters might be highly heritable and less influenced by environment and selecting genotypes on the basis of such characters would be worthwhile in chilli improvement. The results obtained are in agreement with the findings of Ukkund*et al*. (2007), Sharma *et al. (*2010) and Chattopadhyay *et al. (*2011).

Though the studies of heritability estimates are important, their scope is limited since they are estimated in broad sense and are prone to change with changes in environment and the testing material. Further, the heritability estimate by itself may not be alone a useful index of genetic potentiality of a character. According to Eswro*et al*. (1963), genetic advance as per cent of mean (GAM) indicates the potentiality of selection at particular level of selection intensity. Thus, heritability estimates along with genetic advance are more valuable than heritability alone in predicting the response of selection (Johnson *et al*., 1955; Robinson, 1963).

In the present investigation, high estimates of heritability coupled with highgenetic advance over mean observed for characters like plant height, number of fruits per plant, average fresh fruit

weight, fruit length (cm), fruit diameter (cm), number of seeds /fruit, dry chilli yield per plant (g), dry chilli yield per plot (kg), dry chilli yield per ha (q), green chilli yield per plant (g) may be ascribed to effect of additive genes (Panse and Sukhatme, 1954; Kadwey*et al.*,2016) and maybe amenable for selection. Heterosis breeding offers quick and quantum jump in yield (Duradundi *et al*., 2018). Further improvement of these characters would be easier through mass selection, progeny selection or any modified selection procedure aiming to exploit the additive gene effect rather than simple selection.

Conclusion

The study was conducted to assess the genetic variability and heritability of yield and yield-related traits in 50chilli genotypes. The results revealed significant variations among the genotypes for all the characters studied. High heritability coupled with high genetic advance was observed for plant height, number of fruits per plant, average fresh fruit weight, fruit length, fruit diameter, number of seeds per fruit, and dry and green chilli yield per plant and plot, indicating the predominance of additive gene action and the effectiveness of selection for improvement of these traits. Heritability estimates were moderate for plant spread, number of primary and secondary branches, days to flowering and picking, suggesting the influence of both additive and non-additive gene action. Low heritability was observed for days to picking, indicating the need for generation of variability for improvement of this trait. Overall, the findings suggest that the selected chilli genotypes possess substantial genetic variability for yield and yield-related traits, and selection would be effective for their improvement.

Table 1. Analysis of variance for growth and yield parameters among the germplasm accessions in chilli

Sl. No.	Source of variation/Characters	Replications	Treatments	Error	S.Em±	CD @ 5%	CD @ 1%
	Degrees of freedom	**1**	**49**	**49**			
I. Growth parameters							
1.	Plant height (cm)	147.13	395.60**	52.06	3.40	10.39	13.86
2.	Plant spread (East-West) (cm)	27.98	122.78**	2.82	1.11	3.37	4.50
3.	Plant spread (North- South) (cm)	24.35	117.75**	10.36	2.13	6.46	8.62
4.	Number of primary branches	0.00040	0.46**	0.07	0.17	0.55	0.74
5.	Number of secondary branches	2.92	1.51**	0.31	0.35	1.12	1.50
II. Earliness parameters							
6.	Days to first flowering	51.84	48.88**	4.16	1.35	4.10	5.47
7.	Days to 50 per cent flowering	16.81	54.57**	5.01	1.45	4.49	6.00
8.	Days to picking	0.09	64.20**	3.74	1.28	3.88	5.18
III. Yield parameters							
9.	Number of fruits per plant	1476.09	2057.51**	140.00	7.90	23.77	31.71
10.	Average fresh fruit weight (g)	3.51	1.66**	0.25	0.32	1.01	1.35
11.	Fruit length (cm)	0.57	2.45**	0.39	0.41	1.27	1.69
12.	Fruit diameter (mm)	27.17	8.58**	1.54	0.81	2.49	3.33
13.	Number of seeds/fruit	242.14	139.99**	6.09	1.63	4.96	6.61
14.	Green chilli yield per plant (g)	80314.26	67389.29**	4950.93	45.11	141.39	188.56
15.	Dry chilli yield per plant (g)	3806.15	1961.84**	104.06	6.53	20.50	27.33
16.	Dry chilli yield per plot (kg)	0.031	0.23**	0.017	0.081	0.26	0.35
17.	Dry chilli yield per/ha (q)	6.55	80.38**	5.42	1.53	4.68	6.24

Table 2. Mean performance and estimates of genetic variability parameters for growth and yield among germplasm accessions in chilli

SI. No.	Characters	Mean	Range		Coefficient of Variations (%)		h^2_{bs} (%)	GAM (%)
			Minimum	Maximum	PCV (%)	GCV (%)		
1.	Plant height (cm)	69.14	49.20	92.70	16.81	14.73	76.74	26.58
2.	Plant spread (East-West) (cm)	59.72	36.80	74.95	9.94	9.71	95.50	19.55
3.	Plant spread (North- South) (cm)	61.14	36.40	71.55	9.63	8.91	85.71	17.00
4.	Number of primary branches	3.61	2.60	4.90	12.22	8.78	51.61	12.99
5.	Number of secondary branches	9.70	7.85	11.65	9.85	7.96	65.42	13.27
6.	Days to first flowering	47.16	37.50	56.50	10.92	10.02	84.29	18.96
7.	Days to 50 % flowering	53.07	43.00	64.00	10.28	9.38	83.17	17.62
8.	Days to picking	80.23	71.00	94.00	7.26	6.85	88.98	13.31
9.	Number of fruits per plant	104.39	53.80	166.20	31.75	29.66	87.26	57.07
10.	Average fresh fruit weight (g)	3.61	1.83	5.34	27.13	23.24	73.38	41.01
11.	Fruit length (cm)	9.16	5.65	11.17	13.04	11.06	72.00	19.34
12.	Fruit diameter (mm)	13.31	8.80	15.30	16.90	14.09	69.46	24.19
13.	Number of seeds/fruit	57.46	41.80	74.60	14.87	14.23	91.65	28.08
14.	Green chilli yield per plant (g)	501.81	179.51	897.31	37.89	35.21	86.31	67.38
15.	Dry chilli yield per plant (g)	86.27	29.13	161.48	37.25	35.32	89.93	69.00
16.	Dry chilli yield per plot (kg)	1.00	0.32	1.91	35.36	32.82	86.15	62.75
17.	Dry chilli yield per/ha (q)	18.58	6.08	35.45	35.25	32.94	87.35	63.43

GCV – Genotypic coefficient of variation, PCV – Phenotypic co-efficient of variation, GAM- Genetic advance as per cent of mean

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