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Genetic Variability and Association Among Chilli Genotypes for Quantitative and Qualitative Traits

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Abstract: A set of twenty-one breeding lines of chilli were screened for genetic variability, heritability and genetic advance for yield and related traits. A total of eight quantitative and two qualitative characters were studied including capsaicin content in the green chillies and the incidence of phytophthora fruit rot. Sufficient genetic variability was found for all characters. Screening for incidence of phytophthora fruit rot revealed that no genotype was completely resistant while 17 were moderately resistant and 4 were susceptible. Among all the genotypes, UHF-CHI-13 was superior in terms of yield with second-highest total capsaicin content and was least affected by phytophthora fruit rot. Correlation and path analysis at the green fruit stage for green fruit yield indicated that correlation between green fruit yield per plant and number of fruits per plant (0.842), green fruit breadth at middle (-0.634) and total capsaicin content in green chilli (-0.067) was due to the direct effect of these characters revealing true relationship between them. Thus, direct selection for these characters will be effective for yield improvement.

Keywords: Chilli, Correlation, Genetic variability, Path analysis

Chilli is a vital vegetable and spice crop in India because of its widespread use and richness of important nutrients and bioactive compounds with antibacterial, antioxidant, antiviral, anti-inflammatory, and anticancer properties (Mi et al 2022, Malik et al 2022). It is a solanaceous crop native to the American tropics, cultivated for its green, red, or dried berries. The two most significant commercial attributes of Indian chillies are their colour and pungency levels. The colour of chilli fruits is primarily conferred by capsanthin and capsorubin, which have considerable oxygen scavenging qualities and hence are the basis for its antioxidant nature, whilst the pungency is imparted by an active key compound 'capsaicinoids,' an alkaloid found in the placenta that may directly scavenge several free radicals (Antonious et al 2009, Nishino et al 2016, Stewart et al 2007). India is the world's largest producer, consumer and exporter of chilli with open-pollinated varieties dominating the total crop-grown area followed by hybrid varieties. Crop yield in India is low despite the vast amount of land under cultivation (Singh et al 2022). There is a vast spectrum of genetic diversity present in India. Thus, it is crucial to evaluate the genetic stock's potential and to have a thorough understanding of the genetic makeup of the genotypes and the heritable proportion of significant traits. To scale up such low yielding genotypes, it is essential to understand the underlying genetic make-up, variability, and interrelationships between key traits as well as yield components. Therefore, the present study was initiated to evaluate the twenty-one genotypes as part of a chilli improvement programme under hills of Himachal Pradesh.

MATERIAL AND METHODS

The experiment was conducted at Dr Yashwant Singh Parmar University of Horticulture and Forestry Nauni, Solan. A total of 21 genotypes namely Gundu-I and II, DKC-8, UHF-CHI-1 ,2, 3, 5, 7, 8, 9,10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and UHF Selection 4 were used for the screening. The nursery was sown in March 2018 followed by transplanting in the first week of May 2018 at a distance of 45cm×45cm with three replications in randomize complete block design. Observations were recorded for eight quantitative and two qualitative traits namely days to green fruit maturity, number of green fruits per plant, average green fruit weight (g), green fruit length (cm), green fruit breadth at the middle (cm), green fruit yield per plant (g), total capsaicin content (%) in green chilli (Sadasivam and Manickam 1996), fruit colour at mature green stage (as per the Royal Horticulture Society colour charts), fruiting habit and incidence of phytophthora fruit rot. The disease reaction for individual plants was derived using following scale (Sharma and Kumari 2014).

Grade	Fruit rot incidence (%)	Disease reaction
1	0.0 - 5.0	Resistant (R)
2	5.1 - 25.0	Moderately resistant (MR)
3	25.1- 50.0	Susceptible (S)
4	>50.0	Highly susceptible (HS)

Statistical analysis: The data on different traits was subjected to statistical analysis using SPSS 16.0 software to estimate GCV, PCV, Heritability and Genetic gain (%). GCV and PCV obtained were classified as low (0–10%), moderate (10–20%) and high (>20%) (Shivasubramanian and Menon 1973), heritability as low (0–30%), moderate (31–60%) and high (>60%) (Burton and Devane 1953) and genetic gain as low (0–25%), moderate (25–40%) and high (>40%) (Johnson et al 1955). To find out the nature of the association between the traits, correlation analysis (Al-Jibouri et al 1958) and path analysis (Dewey and Lu 1959) were computed.

RESULTS AND DISCUSSION

The presence of sufficient and significant genetic variability for all the traits is was observed (Table 1). Variation in fruit colour at the green stage and fruiting habit was also observed among the genotypes (Table 2).

Mean performance of genotypes: The genotype UHF-CHI-9 was earliest to mature (63.33 days) and had highest average green fruit weight (7.94 g) while UHF-CHI-13 produced the highest number of green fruits (198.89) and green fruit yield per plant (342.53g/plant). The maximum fruit length (14.92 cm) was in genotype UHF-CHI-8 and maximum fruit breadth at the middle (2.31 cm) was in Gundu-2. DKC-8 had the highest total capsaicin content in green chillies followed by UHF-CHI-13. The incidence of phytophthora fruit rot was highest in UHF-CHI-8 followed by UHF-Selection-4 whereas UHF-CHI-13 had the least. No genotype was completely resistant to the disease whereas, most of the genotypes i.e., 17 were moderately resistant and 4 were susceptible. Wide variation for these characters were also observed by various researchers (Shrishat et al 2007, Sarkar et al 2009, Amit et al 2014 and Pandiyaraj et al 2017).

Genetic variability parameters: The PCV was bigger than GCV (Table 3) suggesting the apparent variation in the characteristics was caused not just by genotype but also by environmental influences. However, the difference in PCV and GCV values was small which revealed that the environment has little influence on phenotypes and that phenotypic variability can be leveraged for improvement. Furthermore, the variances ranged from low to high, with high GCV and PCV for the number of fruits per plant, average green fruit weight, green fruit breadth at middle, green fruit length, green fruit yield per plant and total capsaicin content in green chilli indicating towards availability of significant variation for genetic improvement of chilli, despite the fact that PCV was greater than GCV. This level of variation in these characteristics allows for successful genotype selection and development. (Amit et al 2014, Mishra et al 2015, Pandiyaraj et al 2017). PCV and GCV was low in days to green fruit maturity therefore, cannot be utilized for selection. Further, to estimate the inheritance of characters, heritability was estimated which ranged from 90.7–94.85% offering a high probability of fixing of a character by selection (Table 3). Heritability alone is not sufficient to determine the effectiveness of selection as it includes both fixable and non-fixable variance thus, is combined with the estimates of genetic gain to increase the significance from the point of expected gain and type of selection method to be followed. High heritability with high genetic gain was observed for the number of green fruits per plant, average green fruit weight, green fruit yield per plant, green fruit breadth at middle, green fruit length, and total capsaicin content in green chilli (Table 3). High heritability with high genetic gain contributes to the additive gene effect of these traits suggesting the suitability of selection for improvement in contrast to low genetic gain observed for days to green fruit maturity similar to previously observed by Amit et al (2014) for days to green fruits maturity.

Correlation analysis: The genotypic correlation coefficient was larger than the phenotypic correlation coefficient, showing a significant underlying relationship between these traits under examination (Table 4). Earlier researchers reported similar findings (Chattopadhyay et al 2011, Kumar et al 2012, Krishnamurthy et al 2013). Total capsaicin content in green chilli showed a positive significant correlation with the number of green fruits per plant and green fruit breadth at the middle while a negative significant correlation with the fruit length and average green fruit weight suggesting that

Table 1. Analysis of variance (ANOVA)

Source of variation	df	X1	X2	X3	X4	X5	X6	X7
Replication	2	60.143	1.53	0.02	5.164	0.168	0.004	0.00003
Treatment	20	380.45*	3521.06*	4.88*	13464.87*	26.032*	0.582*	0.0239*
Error	40	5.61	4.95	0.015	9.67	0.149	0.002	0.00005

X1 Days to green maturity
X2 No. of green fruits per plant
X3 Average green fruit weight (g)
X4 Green fruit yield per plant
X5 Green fruit length (cm)
X6 Green fruit breadth at the middle (cm)
X7 Total capsaicin content (%)

selection for genotypes with a greater number of small-sized fruits would be a most suitable selection criterion for high pungent fruits. The green fruit length showed a positive significant correlation with the average green fruit weight whereas, days to green fruit maturity showed a negative significant correlation with average red fruit weight and green fruit length. These results were in harmony with earlier studies (Kumar et al 2003, Krishnamurthy et al 2013, Amit et al 2014 and Verma et al 2022). Average green fruit weight also showed a positive significant correlation with green fruit length. Bijalwan and Mishra (2016) also found a positive significant relationship between average fruit weight and fruit length.

Path analysis: Path analysis revealed high positive direct effect (0.817) of number of green fruits per plant on green fruit yield per plant followed by average green fruit weight (0.363) while green fruit breadth at the middle (-0.372), days to green fruit maturity (-0.314), green fruit length (-0.241) and total capsaicin content in green chilli (-0.129) showed a high negative direct effect on green fruit yield per

Table 2. Mean performance of genotypes for different traits under study

Genotypes	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
UHF-CHI-1	78.67	86.06	2.39	138.54	5.73	0.9	0.09	Green group 143 A	Drooping	15.67 (4.08)
UHF-CHI-2	83.33	84.2	2.86	176.64	5	0.89	0.06	Yellow green group 144 A	Drooping	19.39 (4.52)
UHF-CHI-3	79.67	105	3.36	243.96	7.8	1.13	0.07	Green group 141 A	Drooping	23.74 (4.97)
UHF-CHI-5	79.33	70.71	3.78	182.56	9.67	1.02	0.07	Green group 143 A	Drooping	15.18 (4.02)
UHF-CHI-7	72.33	95.54	4.3	290.92	10.8	1.14	0.06	Green group 144 A	Drooping	13.94 (3.86)
UHF-CHI-8	78.33	135.13	2.32	237.1	14.92	0.69	0.08	Green group 141 B	Drooping	12.98 (3.74)
UHF-CHI-9	63.33	30.93	7.94	107.39	13.09	1.54	0.04	Yellow green group 145 B	Drooping	29.84 (5.55)
UHF-CHI-10	67.67	79.93	3.56	188.31	8.2	0.89	0.05	Green group 139 A	Drooping	27.98 (5.38)
UHF-CHI-11	82	121.29	2.67	250.51	7.11	0.74	0.08	Green group 135 A	Drooping	20.22 (4.61)
UHF-CHI-12	77.67	87.85	3.04	216.08	5.9	0.9	0.07	Green group 143 B	Upright	14.61 (3.95)
Gundu-1	71.67	62.93	2.1	97.86	2.12	2.19	0.11	Green group 143 B	Drooping	24.07 (5.01)
Gundu-2	73.33	68.37	2.25	102.58	3.25	2.31	0.11	Green group 143 B	Drooping	25.04 (5.10)
UHF-CHI-13	101.67	198.89	1.95	342.53	5.66	0.68	0.1	Green group 143 B	Upright	8.53 (3.09)
UHF-CHI-14	99	111.93	3.14	278.81	8.41	0.77	0.06	Yellow green group 144 A	Drooping	17.46 (4.30)
UHF-CHI-15	89.33	109.97	2.64	229.39	8.33	1.03	0.07	Yellow green group 144 C	Drooping	15.95 (4.12)
UHF-CHI-16	88.67	77.28	2.83	154.84	7.93	1.01	0.08	Green group 141 B	Drooping	24.55 (5.06)
UHF-CHI-17	97.67	87.13	2.83	177.68	7.47	1.02	0.08	Green group 143 A	Drooping	23.06 (4.91)
UHF-CHI-18	93	75.67	2.81	139.85	7.71	1.01	0.06	Green group 143 A	Drooping	24.90 (5.09)
UHF-CHI-19	101.33	79.81	2.45	123.25	7.62	0.98	0.08	Green group 143 B	Drooping	22.44 (4.84)
UHF Selection 4	72	47.8	4.44	133.36	9.94	1.51	0.05	Green group 141 A	Drooping	28.06 (5.39)
DKC-8	89	90.06	2.92	192.91	6.03	0.85	0.11	Yellow green group 144 A	Upright	12.46 (3.67)
Mean	82.81	90.78	3.17	190.72	7.75	1.1	0.08			20(4.54)
CD (p=0.05)	3.91	3.67	0.2	5.13	0.64	0.07	0.005			

* Figures in the parenthesis are square root transformed values.X1-7:See Table 1 for details, X8: Fruit colour at green fruit stage, X9:Fruiting habit, X10: Incidence of phytophthora fruit rot

Table 3. Estimates of genetic variability parameters for different traits of chilli genotypes

Characters	PCV (%)	GCV (%)	Heritability	Genetic gain (%)
Days to green fruit maturity	9.8L	9.5L	90.7H	23.58L
No. of green fruits per plant	33.79H	33.71H	94.58H	74.21H
Average green fruit weight (g)	36.37H	36.19H	94.12H	76.12H
Green fruit length (cm)	34.24H	33.92H	93.31H	64.52H
Green fruit breadth at the middle (cm)	36.01H	35.8H	93.97H	72.49H
Green fruit yield per plant (g)	31.15H	31.12H	94.79H	68.59H
Total capsaicin content in green chilli (%)	22.83H	22.52H	92.67H	52H

Table 4. Correlation analysis among yield and yield contributing traits

Characters		X_1	X_2	X_3	X_4	X_5	X_6
X_2	G	0.537*					
	P	0.525*					
X_3	G	-0.530*	-0.537*				
	P	-0.516*	-0.534*				
X_4	G	0.344*	0.842*	-0.191			
	P	0.339*	0.841*	-0.189			
X_5	G	-0.189	-0.026	0.573*	0.204		
	P	-0.185	-0.025	0.565*	0.200		
X_6	G	-0.508*	-0.575*	0.165	-0.634*	-0.340*	
	P	-0.488*	-0.570*	0.163	-0.630*	-0.335*	
X_7	G	0.255*	0.299*	-0.680*	-0.067	-0.620*	0.256*
	P	0.242	0.293*	-0.669*	-0.065	-0.609*	0.254*

*Significant at 5% level of significance; See Table 1 for details

Table 5. Path analysis depicting direct and indirect effect of different traits on yield

Characters	X_1	X_2	X_3	X_4	X_5	X_6	GCC
X_1	-0.322	-0.173	0.171	0.061	0.164	-0.082	0.344*
X_2	0.458	0.854	-0.458	-0.022	-0.491	0.255	0.842*
X_3	-0.207	-0.209	0.39	0.224	0.064	-0.265	-0.191
X_4	0.052	0.007	-0.157	-0.273	0.093	0.169	0.204
X_5	0.15	0.17	-0.049	0.1	-0.296	-0.076	-0.634**
X_6	-0.036	-0.043	0.097	0.088	-0.036	-0.142	-0.067

* Significant at 5% level of significance, Residual effect = 0.115, GCC Genetic coefficient of correlation
X_1 = Days to green fruit maturity; X_2 =No. of green fruits per plant; X_3 =Average green fruit weight (g); X_4 =Fruit length at green fruit stage (cm); X_5 =Fruit breadth at the middle (cm); X_6 =Total capsaicin content in green chilli (%)

plant. High positive indirect effect was observed for days to green fruit maturity (0.439), followed by total capsaicin content in green chilli (0.244) via number of green fruits per plant. The residual effect at the genotypic level was observed to be 0.11, which signifies the relevance of selected characters in representing total genetic variability. Such results were also observed by earlier researchers (Patel et al 2015, Pujar et al 2017, Murmu et al 2017 and Vidya et al 2018). Correlation and path analysis at green fruit stage for green fruit yield indicated that correlation between yield and number of fruits per plant, green fruit breadth at middle and total capsaicin content in green chilli was due to the direct effect of these characters revealing true relationship between them. Thus, direct selection for these characters will be effective for yield improvement. Correlation between yield and days to green fruit maturity was due to indirect effect via number of green fruits per plant. Thus, indirect selection for this trait can be followed. However, average green fruit weight had the positive direct effect with yield but the correlation was negative. Direct selection for this character can be practiced to reduce the undesirable indirect effects.

CONCLUSION

There was significant variation for all the characters under study. Among all the genotypes, UHF-CHI-13 was found superior in terms of yield. It also gave the second-highest total capsaicin content and was least affected by phytophthora fruit rot. Correlation and path analysis for green fruit yield indicated that the correlation between green fruit yield and number of fruits per plant, green fruit breadth at middle and total capsaicin content in green chilli was due to the direct effect therefore, direct selection for these characters will influence the yield.

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