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Research Article

Genetic variability and character association studies for green fruit yield and quality component traits in chilli (*capsicum annuum* var. *longum* (dc.) sendt.)

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Abstract
Genetic variability, correlation and path coefficient analysis were studied for green fruit yield and its components in 40 diverse genotypes of chilli. The analysis of variance revealed the significant differences among the genotypes for all the characters studied which indicating that presence of great deal of genetic variability for different traits. The high estimates of GCV and PCV were obtained for number of primary branches per plant, number of secondary branches per plant, number of fruits per plant, average fruit length (cm), average fruit girth (cm), fruit shape index, average fruit weight (g), green fruit yield per plant (g), chlorophyll content (mg/100g), ascorbic acid content (mg/100g) and capsaicin content (mg/g), while it was low for moisture content (%). The characters like days to flowering (days), plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of fruits per plant, average fruit length (cm), average fruit girth (cm), fruit-shape index, average fruit weight (g), green fruit yield per plant (g), chlorophyll content (mg/100g), ascorbic acid content (mg/100g) and capsaicin content (mg/g) exhibited high genetic advance coupled with high heritability, indicating better scope for improvement of these traits by an effective selection programme. The results of correlation studies indicated that genotypic correlation coefficients were higher in magnitude than their corresponding phenotypic correlation coefficients for all the traits. Green fruit yield per plant had high, significant and positive association with number of fruits per plant, average fruit weight, moisture content and chlorophyll content at both genotypic and phenotypic levels which indicating that these traits were main yield attributing traits. Path analysis revealed that characters like number of secondary branches per plant, number of fruits per plant and average fruit weight had high and positive direct effects on green fruit yield. For maximizing the green fruit yield per plant weightage should be given to early flowering, more number of fruits per plant, high average fruit weight, more number of secondary branches per plant and high moisture content.

Key words
Green Chilli, Genetic Variability, Correlation, Path Analysis.

Introduction:

Chilli (*Capsicum annuum* L.) is an important vegetable and condiment crop having immense commercial and therapeutic value. Chillies are one of the rich sources of vitamin A and C per 100 g fresh weight available. Chilli also known as bird pepper, cayenne, paprika, hot and sweet pepper belongs to the genus *Capsicum* of Solanaceae family, subfamily Solanoideae and tribe Capsiceae (Hunziker, 2001; Knapp *et al*., 2004). In world, the production of chilli in green form is about 7 to 8 million tonnes (MT) and 2 to 3 million tonnes in dry form. India is the largest producer of chilli in the world accounting for 1.1 million tonnes of production annually followed by China with a production of around 0.4 million tonnes. In India, the crop is extensively cultivated in about 7.94 lakh hectares with a production of 12-13 lakh tonnes. (Anon., 2013). The genus *Capsicum* consists of approximately 22 wild and 5 cultivated species, which includes *C. annuum*, *C. baccatum*, *C. chinense*, *C. frutescens* and *C. pubenscens*. Chilli has been classified under often cross pollinated crops and the extent of natural out crossing has also reported up to 66.4 per cent (Singh *et al.,* 1994). Due to long history of cultivation, out crossing nature and popularity of crop, large genetic diversity is available throught India and abroad in most of its cultivated areas. Before breeding through selection, it is essential to know the importance of inter-association of various component characters and their association with green fruit yield. The information on genetic variability and character association between yield and its components are most important to initiate the breeding programme to evolve high yielding varieties. Very little work has been done on chilli and therefore, the present study was undertaken to estimate the extent of genetic variability and character association in a set of 40 diverse genotypes of chilli.

Material and method

The experiment was conducted with 40 diverse genotypes during *kharif-rabi* 2012-13 at Main Vegetable Research Station, Anand Agricultural University, Anand (Gujarat). The experiment materials were grown in a randomized complete block design with three replications. Each experimental unit was represented by single row

accommodating 10 plants with 60x60 cm inter and intra row spacing. Normal crop raised following all recommended cultural practices and plant protection measures. Five competitive plants were selected at random from each single row plot in each replication and observations were recorded on 14 characters *viz*., days to flowering (days), plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of fruits per plant, average fruit length (cm), average fruit girth (cm), fruit-shape index (cm), average fruit weight (g), green fruit yield per plant (g), moisture content (%), chlorophyll content (mg/100g), ascorbic acid content (mg/100g) and capsaicin content (mg/g). The observations on days to flowering and days to maturity were recorded on population basis. The mean over replication of each character was subjected to statistical analysis. The estimates of genotypic and phenotypic coefficient of variation were calculated according to Burton (1952), heritability in broad sense and expected genetic advance as per the procedure of Allard (1960). The genotypic and phenotypic correlation were calculated following the method of Hazel *et al.* (1943) whereas the path coefficient analysis as per method given by Dewey and Lu (1959).

Result and discussion

Variability, Heritability and Genetic Advance: The results obtained under the present investigation are presented in Table 1 to 4. Analysis of variance revealed significant differences among the genotypes for all the characters. A wide range of variability was exhibited by most of the traits under study (Table 1). The wide range of variation noticed in all the characters would offer scope of selection for improvement of desirable types. The highest Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) were observed for green fruit yield per plant followed by primary branches per plant, secondary branches per plant, number of fruits per plant, fruit length, fruit girth, fruit shape-index, fruit weight, chlorophyll content, ascorbic acid content and capsaicin content while it was moderate for days to flowering and plant height. Remaining characters showed low GCV (Table 2). The presence of high GCV for green fruit yield per plant, number of fruit per plant, primary branches per plant, secondary branches per plant, fruit length, fruit girth, fruit shape-index, fruit weight suggested the possibility of improving and fixing these characters through affecting selection. High GCV for green fruit yield per plant and number of fruit per plant was also reported by Munshi and Behera (2000), Varkey (2001), Gogoi and Gautam (2002), Sreelathkumary and Manju (2002), Gogate (2003), Sreelathakumary and Rajamony (2004), Patel (2006), Samadia (2007), Ukkund *et al.* (2007), Tembhurne *et al*. (2008), Gupta *et al.* (2009), Sharma *et al.* (2010) and Kumar *et al.* (2012). High heritability observed for secondary branches per plant, number of fruits per plant, fruit length, fruit weight, green fruit yield per plant, chlorophyll content, ascorbic acid content and capsaicin content. These traits were less influenced by environmental factors. High heritability coupled with high genetic advance as percentage of mean indicating better scope for improvement in the characters by effective selection. Characters *viz*., days to flowering, plant height, primary branches per plant, secondary branches per plant, number of fruits per plant, average fruit length, average fruit girth, fruit shape-index, average fruit weight, green fruit yield per plant, chlorophyll content, ascorbic acid content and capsaicin content exhibited high heritability with high genetic advance which could be effectively improved by selection. Johnson *et al.* (1955) and Arya and Saini (1977) have suggested that characters with high heritability coupled with high genetic advance would respond better to selection than those with high heritability and low genetic advance. The character like moisture content showed low genetic advance coupled with high heritability which indicating presence of both additive and non additive gene action.

Correlation:The results on correlation coefficients revealed that both genotypic and phenotypic correlations followed the same trend but the genotypic correlations were generally higher than the phenotypic correlations indicating that the phenotypic expression of correlations is reduced under the influence of environment (Table 3). It was observed that green fruit yield per plant had positive and significant correlation with number of secondary branches per plant (rg = 0.763 and rp = 0.728), number of fruits per plant (rg = 0.742 and rp = 0.735), average fruit length (rg = 0.318 and rp = 0.291), average fruit weight (rg = 0.488 and rp = 0.468), moisture content (rg = 0.552 and rp = 0.457), chlorophyll content (rg = 0.754 and rp = 0.732) and ascorbic acid content (rg = 0.317 and rp = 0.308) at both levels, while average fruit girth (rp = 0.256) had significant association at phenotypic level only. Days to flowering (rg = -0.446 and rp = -0.400) had negative and significant correlation with green fruit yield per plant. (Table 3). Plant height showed significant positive correlation with primary branches per plant and secondary branches per plant at phenotypic level only. Primary branches per plant showed positive and significant correlation with secondary branches per plant at both levels and ascorbic acid content at phenotypic level. Other characters *viz.*, number of fruits per plant, fruit length, fruit girth, fruit weight, moisture content, chlorophyll content and ascorbic acid content contributed positive association towards yield in respective order of magnitude.

The observed positive correlation of green fruit yield with various traits was supported by earlier workers *viz*., Dutta *et al.* (1979), Munshi *et al.* (2000), Varkey (2001), Gogate (2003), Kumar *et al.* (2008), Singh and Singh (2011) and Kumar *et al.* (2012) for number of fruits per plant; Gogate (2003), Patel (2006), Kumar *et al.* (2008), Tembhurne *et al*. (2007) for number of secondary branches per plant, Kour and Singh (2009), Sharma *et al.* (2010), Hasanuzzaman and Golam (2011) and Kumar *et al.* (2012) for average fruit length. Venkata Rao and Chhonkar (1981), Varkey (2001) and Gogate (2003) reported significant negative correlation of days to flowering with green fruit yield per plant.

Path coefficient analysis: In the present study path coefficient analysis has been conducted taking green fruit yield per plant as dependent variable. The persual of the results revealed that fruit shape index and capsaicin content had negative, non-significant and negligible association with green fruit yield per plant. Therefore, it was not added in path coefficient table. Number of fruits per plant had the highest direct effect on green fruit yield per plant followed by number of secondary branches per plant. (Table 4). Similarly the average fruit weight, secondary branches per plant and moisture content had direct effect on green fruit yield per plant. This may indicate that direct selection of these characters would likely be effective in increasing green fruit yield. Average fruit length, chlorophyll content and ascorbic acid content had high indirect effect *via* average fruit weight and secondary branches per plant. These indirect effects had not only supported the low magnitude direct effect but also resulted in high significant positive correlation with green fruit yield. The observed positive direct effect of various traits on green fruit yield was also supported by earlier workers *viz*., Venkata Rao and Chhonkar (1981), Dahiya *et al.* (1991) and Gogate (2003) for number of secondary branches per plant; Dahiya *et al.* (1991), Munshi *et al.* (2000), Gogate (2003), Sujata *et al*. (2003), Sharma *et al*. (2010) and Kumar *et al.* (2012) for number of fruits per plant; Munshi *et al.* (2000), Gogate (2003), Kour and Singh (2009), Sharma *et al.* (2010), Hasanuzzaman and Golam (2011) and Kumar *et al.* (2012) for average fruit weight; However, in contrarary to the present findings, Kour and Singh (2009) and Sharma *et al.* (2010) found indirect effect of secondary branches per plant with green fruit yield.

From the present study, it is evident that genotypes studied may provide good source of materials for further breeding program. Therefore, information on the genetic parameters such as coefficient of variation, heritability, genetic advance, genetic correlation coefficient and path coefficient analysis can help the breeder to evolve suitable cultivars within a short time. On the basis of results as summarized above, it is concluded that the great deal of variability for the important characters studied even in highly selected lines under the present investigation. While imposing selection for genetic improvement of green fruit yield, due weightage should also be given to early flowering, more number of secondary branches per plant, more number of fruits per plant, high average fruit weight and high moisture content.

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Table 1. Analysis of variance for various characters under study Genotypes

Sr. No.	Characters	Mean squares		
		Replication	Treatment	Error
	d.f.	2	39	78
1	Days to flowering	21.820	166.70**	9.89
2	Plant height	0.9687	359.17**	38.36
3	Number of Primary branches per plant	0.0935	0.5185**	0.0218
4	Number of Secondary branches per plant	0.0315	0.5487**	0.093
5	Number of fruits per plant	365.25	4951.08**	80.32
6	Average fruit length	0.6484	19.636**	0.5889
7	Average fruit girth	0.076	1.8312**	0.0712
8	Average Fruit shape- index	0.0332	2.675**	0.1616
9	Average fruit weight	0.0288	4.5135**	0.0785
10	Green fruit yield per plant	4452.50	91614.61**	1396.33
11	Moisture content	1.1875	72.95**	0.6739
12	Chlorophyll content	0.6387	96.72**	0.4323
13	Ascorbic acid content	1.8125	1355.66**	3.124
14	Capsaicin content	0.0031	0.429**	0.0052

Note: ** Indicate significance at 1% level

Table 2 . The estimates of variability parameters for different characters in chilli

Sr. No.	Characters	$\hat{\sigma}^2_g$	$\hat{\sigma}^2_p$	GCV	PCV	H^2 (%)	GA (%)
1.	Days to flowering	52.27	62.16	17.62	19.22	84.09	33.29
2.	Plant height	106.94	145.29	15.21	17.73	73.60	26.97
3.	Number of primary branches per plant	0.17	0.19	24.88	26.47	88.31	48.17
4.	Number of secondary branches per plant	1.80	1.89	33.00	33.84	95.10	66.26
5.	Number of fruits per plant	1623.58	1703.90	45.19	46.29	95.29	90.88
6.	Average fruit length	6.35	6.94	28.69	29.99	91.50	56.60
7.	Average fruit girth	0.58	0.65	22.09	23.39	89.21	42.93
8.	Average fruit shape-index	0.84	1.00	34.20	37.35	83.88	64.55
9.	Average fruit weight	1.48	1.56	33.35	34.23	94.87	66.85
10.	Green fruit yield per plant	30072.75	31469.08	56.89	58.20	95.56	114.57
11	Moisture content	2.21	2.88	1.76	2.02	76.74	3.18
12	Chlorophyll content	32.09	32.52	35.43	35.87	98.67	72.89
13	Ascorbic acid content	450.82	453.95	22.40	22.47	99.31	45.98
14	Capsaicin content	0.14	0.15	21.56	21.96	96.45	43.68

Table 3. Genotypic and phenotypic correlation between green fruit yield and other traits in chilli

Characters		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Rg**		-0.446**	0.213	0.139	0.763**	0.742**	0.318*	0.287	0.092	0.488**	0.552**	0.754**	0.317*	-0.026
	Rp		-0.400**	0.192	0.128	0.728**	0.735**	0.291**	0.256*	0.088	0.468**	0.457**	0.732**	0.308**	-0.019
2	**Rg**			0.031	-0.118	-0.210	-0.231	0.019	-0.425**	0.208	-0.380*	-0.515**	-0.559**	-0.224	0.255
	Rp			0.021	-0.099	-0.203	-0.194	0.015	-0.348**	0.154	-0.339**	-0.397**	-0.508**	-0.203	0.226*
3	**Rg**				0.301	0.298	0.216	0.025	0.212	-0.013	-0.016	0.105	0.145	0.169	-0.031
	Rp				0.226*	0.247*	0.211	-0.004	0.200	-0.054	-0.010	0.042	0.119	0.142	-0.003
4	**Rg**					0.398*	0.090	-0.137	-0.038	-0.106	-0.022	0.083	0.166	0.296	-0.225
	Rp					0.374**	0.086	-0.129	-0.015	-0.116	-0.034	0.074	0.162	0.276*	-0.209
5	**Rg**						0.487**	0.277	0.176	0.077	0.407**	0.448**	0.686**	0.457**	0.015
	Rp						0.463**	0.250*	0.156	0.064	0.383**	0.389**	0.664**	0.445**	0.019
6	**Rg**							0.046	0.103	-0.005	-0.147	0.160	0.454**	0.216	0.213
	Rp							0.034	0.103	-0.018	-0.141	0.121	0.439**	0.208	0.206
7	**Rg**								-0.215	0.862**	0.399*	0.374*	0.157	0.136	0.102
	Rp								-0.203	0.846**	0.380**	0.306**	0.152	0.130	0.103
8	**Rg**									-0.628**	0.372*	0.396*	0.261	-0.046	-0.481**
	Rp									-0.627**	0.338**	0.300**	0.253*	-0.042	-0.443**
9	**Rg**										0.112	0.066	-0.047	0.089	0.328*
	Rp										0.111	0.060	-0.047	0.080	0.301**
10	**Rg**											0.544**	0.528**	0.147	-0.305
	Rp											0.453**	0.512**	0.144	-0.287**
11	**Rg**												0.516**	0.060	-0.217
	Rp												0.459**	0.054	-0.119
12	**Rg**													0.453**	-0.201
	Rp													0.449**	-0.207
13	**Rg**														-0.042
	Rp														-0.040

***,** Significance at 5% and 1% levels, respectively. Rg-** Genotypic correlation coefficients, **Rp-** Phenotypic correlation coefficients **1)** Green fruit yield per plant **2)** Days to flowering **3**) Plant height **4)** Number of primary branches per plant **5)** Number of secondary branches per plant **6)** Number of fruits per plant **7)** Average fruit length **8)** Average fruit girth **9)** Fruit shape-index **10)** Average fruit weight **11)** Moisture content **12)** Chlorophyll content **13)** Ascorbic acid content and **14)** Capsaicin content.

Table 4. Path coefficient analysis showing direct and indirect effects of various traits on green fruit yield per plant in chilli.

Sr. No.	Genotypes	1	2	3	4	5	6	7	8	9	10	11	'r_g' with GFYP
1.	Days to flowering	**-0.042**	0.001	0.001	-0.041	-0.159	0.0001	0.023	-0.173	-0.053	-0.004	0.002	-0.446**
2.	Plant height	-0.001	**0.018**	-0.003	0.058	0.149	0.0001	-0.011	-0.007	0.011	0.001	-0.002	0.213
3.	Number of primary branches per plant	0.005	0.006	**-0.011**	0.078	0.062	0.0001	0.002	-0.010	0.009	0.001	-0.003	0.139
4.	Number of secondary branches per plant	0.009	0.005	-0.004	**0.195**	0.335	0.0001	-0.009	0.185	0.046	0.005	-0.004	0.763**
5.	No. of fruits per plant	0.010	0.004	-0.001	0.095	**0.689**	0.0001	-0.006	-0.067	0.016	0.003	-0.002	0.742**
6.	Average fruit length	-0.001	0.000	0.002	0.054	0.032	**-0.001**	0.011	0.182	0.039	0.001	-0.001	0.318*
7.	Average fruit girth	0.018	0.004	0.000	0.034	0.071	0.0001	**-0.053**	0.169	0.041	0.002	0.000	0.287
8.	Average fruit weight	0.016	0.000	0.000	0.079	-0.101	0.0001	-0.020	**0.455**	0.056	0.004	-0.001	0.488**
9.	Moisture content	0.021	0.002	-0.001	0.087	0.110	0.0001	-0.021	0.247	**0.103**	0.004	-0.001	0.551**
10.	Chlorophyll content	0.023	0.003	-0.002	0.134	0.313	0.0001	-0.014	0.240	0.053	**0.008**	-0.004	0.754**
11.	Ascorbic acid content	0.009	0.003	-0.003	0.089	0.149	0.0001	0.002	0.067	0.006	0.003	**-0.009**	0.317*

Note: Diagonal values are direct effects
Residual effect = 0.053**, *,** Significance at 5% and 1% levels, respectively.**
'r_g' Genotypic correlation coefficients with Green fruit yield per plant (GFYP)