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Genetic variability studies in bell pepper (*Capsicum annuum* L.)

■ SANTOSH KUMARI

Author for correspondence :
Department of Vegetable Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, SOLAN (H.P.) INDIA
Email : santoshstpc@gmail.com

ABSTRACT : Bell pepper is one of the most important vegetable crops grown all over the world. It is of commercial significance particularly for the hills of Himachal Pradesh. Present study was conducted at the Research Farm of Vegetable Science, Department of Vegetable Science, Nauni, Solan, H. P. Nineteen genotypes of bell pepper were assessed for genetic variability, heritability and genetic gain for the characters number of fruits per plant, average fruit weight, fruit yield per plant, fruit length, fruit breadth, plant height, number of seeds per fruit and pericarp thickness. Significant differences were observed for all the traits among nineteen diverse genotypes. Higher genotypic and phenotypic coefficients of variation were recorded for number of fruits per plant (30.49 % and 30.63 %), average fruit weight (30.85 % and 30.03 %) and fruit yield per plant (32.12 % and 32.26 %) indicating that these traits had wide genetic variability and would respond better to selection. High heritability coupled with high genetic gain was observed for number of fruits per plant (57.85 % and 57.85 %), average fruit weight (60.62 % and 60.62 %) and fruit yield per plant (65.80 % and 65.80 %) indicating the role of additive gene action for the inheritance of these traits. Fruit yield per plant had positive and significant correlation with number of fruits per plant (0.752) and average fruit weight (0.625). Maximum positive direct effect towards yield per plant was contributed by number of fruits per plant (0.737) and average fruit weight (0.675).

KEY WORDS : Bell pepper, Co-efficients of variation, Heritability, Genetic gain, Correlation, Path analysis

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Bell pepper is a high value vegetable and an important crop of temperate regions. It is used as salad, cooked as vegetable, pickled or processed and is appreciated worldwide for its flavour, aroma and colour, It is an important source of vitamin A and vitamin C. The crop originated in new world tropics and subtropics and was introduced in India by Britishers in nineteenth century in Shimla and Nilgiri hills. Capsicum is now widely cultivated in Karnataka, Tamilnadu, Himachal Pradesh, Uttarakhand and Darjeeling district of West Bengal. Mid hills of Himachal Pradesh are leading suppliers of fresh market bell pepper of excellent quality due to congenial climate which produces big sized blocky fruits with high flavour and shiny skin, to the plains during summer and rainy season and sells at premium prices, thus bringing lucrative returns to the hill farmers. Presence of sufficient variability in basic genetic material of any crop is a pre requisite for effective selection and improvement of superior genotypes. It is also equally important to assess the relative proportion of genetic and environmental components of variability, nature and extent of association between different yield attributes and relative importance of each component on yield. The genetic parameters like genetic coefficients of variability, heritability, genetic gain, nature and extent of association between different yield attributes and relative importance of direct and indirect influence of each of the component traits on yield provide insight into the genetic makeup of material and the basis of selection for yield contributing traits. There is a need for genetic restructuring of the bell pepper germplasm for increasing the productivity considering the preference of the consumers for typical bell shaped fruits with moderate size. For this, the first step is evaluation of available variability in the germplasm so as to identify the potential genotypes for

their use either directly as varieties or as parents in future breeding programme. Therefore, the present experiment was conducted to estimate the extent of genetic variability for important characters in different genotypes of bell pepper.

RESEARCH METHODS

The present investigation was carried out at the experimental farm of department of Vegetable Science, Dr Y S Parmar University of Horticulture & Forestry, Nauni, Solan, HP during summer, 2012. The experimental site is located at Nauni, about 13 km from Solan, at an elevation of 1270 m above mean sea level lying between latitude 30052' North and latitude 77011'East. It falls under the mid hill zone of Himachal Pradesh. The climate ranges from sub tropical to sub temperate. It experiences 1100-1300 mm rainfall annually, most of which occurs during monsoon season. The experimental material for the present investigation comprised of nineteen genotypes (LC-1, PC-1, California Wonder, HC-201, Feroz, Gazio Collection, ACC-16, EC-579997, Yolo Wonder, Kandaghat Selection-9, Kannual Collection, UHF-14, Solan Bharpur, SP-633, Sel-10-2, Sel-9, Sel-104-1-1-4, SP-701 and Sel-64-1-1-4) of bell pepper. The experiment was laid out in a randomized block design with three replications. Plants were transplanted in first week on May, 2012 at a spacing of 60 x 45 cm. The standard cultural practices were followed as per cultural practices given in the package of practices for growing vegetable crops in Himachal Pradesh. The observations were recorded for the characters number of fruits per plant, average fruit weight (g), fruit yield per plant (g), fruit length (cm), fruit breadth (cm), pericarp thickness (mm)), number of seeds per fruit and plant height (cm). The genotypic coefficient of variation and phenotypic coefficient of variation were estimated as per method suggested by Burton and Devane (1953). Heritability in broad sense and genetic gain were computed according to Johnson *et al.* (1955). Correlation coefficient analysis was done as per Al-Jibouri *et al*. (1958). Path coefficient analysis was estimated according to formulae suggested by Dewey and Lu (1959).

RESEARCH FINDINGS AND DISCUSSION

Significant differences were observed for all the traits among nineteen diverse genotypes (Table 1). This indicates sufficient possibility for selecting the horticulturally superior genotypes. The results are in agreement with the findings of Elangovan *et al.* (1981) and Joshi and Singh (1983) who also supported the existence of variability for various traits in bell pepper genotypes. The extent of variability present in the bell pepper germplasm was measured in terms of range, genotypic and phenotypic coefficients of variation, heritability (broad sense), genetic advance and genetic gain. Mean performance of genotypes has been presented in Table 2.

Co-efficient of variability:

In general, phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the traits under study indicating the influence of environment on the manifestation of characters (Table 3). Higher genotypic and phenotypic coefficients of variation were recorded for number of fruits per plant (30.49 % and 30.63 %), average fruit weight (30.85 % and 30.03 %) and fruit yield per plant (32.12 % and 32.26 %). Moderate genotypic and phenotypic coefficients of correlation were found for fruit length (16.54 % and 16.75 %) and number of seeds per fruit (21.74 % and 21.90 %). Low genotypic and phenotypic correlation coefficients were observed for fruit breadth (11.34 % and 11.66 %), plant height (7.68 % and 8.11 %) and pericarp thickness (6.07 % and 6.62 %). High values of PCV and GCV indicated the existence of substantial variability, ensuring ample scope for their improvement through selection. These results further confirmed the findings of earlier researchers for fruit yield per plant (Vani *et al*., 2007; Ukkund *et al*., 2007; Kumari, 2008 and Sharma *el al*., 2010), for number of fruits per plant (Sreelathakumary and Rajamony, 2002; Mishra *et al*., 2005 and Sharma *el al*., 2010), for average fruit weight (Sreelathakumary and Rajamony, 2002 and Sharma *et al*., 2010), for pericarp thickness, plant height, fruit length and number of seeds per fruit (Kumari, 2008). Less difference between phenotypic and genotypic coefficient of variation in all traits indicated less influence of environment on these traits.

Heritability:

Estimates of heritability (broad sense) have been presented in Table 3. Heritability estimates were recorded high for all the traits under study. Higher heritability was found for the characters fruit yield per plant (99 %), number of fruits per plant (98 %), average fruit weight (98 %), number of seeds per

Table 1 : Analysis of variance for different traits under study in bell pepper

Source	d.f.	Mean sum of squares							
		Number of fruits per plant	Average fruit weight (g)	Fruit yield per plant (g)	Fruit length (cm)	Fruit breadth (cm)	Pericarp thickness (mm)	Number of seeds per fruit	Plant height (cm)
Replications	2	0.05	1.51	192.29	0.02	0.009	0.009	24.39	1.21
Treatments	18	39.75*	514.30*	215255.93*	4.33*	0.79*	0.24*	6091.02*	48.65*
Error	36	0.15	2.75	624.45	0.03	0.01	0.01	28.85	1.80

* indicates significance of value at P=0.05

Table 2 : Mean performance of different genotypes for different traits under study in bell pepper

Genotype	Number of fruits per plant	Average fruit weight (g)	Fruit yield per plant (g)	Fruit length (cm)	Fruit breadth (cm)	Pericarp thickness (mm)	Number of seeds per fruit	Plant height (cm)
LC-1	14.25	45.24	640.00	6.40	4.56	4.15	152.00	50.00
PC-1	15.50	50.00	760.25	8.32	4.40	4.38	156.65	46.72
California Wonder	13.00	75.20	950.14	8.48	6.00	4.45	175.32	60.15
HC-201	20.00	52.50	1000.20	7.42	4.50	4.35	162.15	56.22
Feroz	18.50	45.00	820.50	8.70	3.75	4.70	200.25	54.00
Gazio Collection	23.00	52.15	1150.40	6.50	4.25	4.32	250.30	48.18
ACC-16	15.12	70.00	1020.56	5.73	4.14	4.30	160.72	47.00
EC-579997	16.25	68.25	1080.80	5.90	4.16	4.34	176.28	49.15
Yolo Wonder	13.16	68.00	850.28	8.00	4.60	4.40	226.00	46.30
Kandaghat Selection-9	12.00	38.25	440.39	6.08	4.12	4.20	253.20	49.50
Kannual Collection	13.18	43.00	750.58	6.76	4.26	4.50	170.86	47.75
UHF-14	13.85	75.18	1025.63	6.33	4.50	4.24	182.52	50.50
Solan Bharpur	14.00	58.12	800.65	6.40	4.45	4.70	180.40	52.60
SP-633	17.25	70.00	1200.42	8.70	5.50	4.80	235.00	52.00
Sel-10-2	10.00	40.44	380.20	9.00	4.00	5.00	280.62	51.25
Sel-9	9.50	66.30	600.10	6.80	4.70	4.48	300.15	49.80
Sel-104-1-1-4	16.00	55.12	850.18	5.25	4.20	5.10	260.22	52.15
SP-701	18.75	73.18	1340.30	8.20	4.65	4.82	210.35	59.32
Sel-64-1-1-4	12.55	40.00	460.42	8.60	4.62	4.9	195.46	55.32
$CD_{0.05}$	0.66	2.77	41.66	0.32	0.20	0.20	8.96	2.24

Table 3 : Estimates of parameters of variability for different traits under study in bell pepper

Traits	Mean	Range	Coefficient of variation (%)		Heritability (%)	Genetic advance	Genetic gain (%)
			GCV	PCV			
Number of fruits per plant	14.83	9.00-25.00	30.49	30.63	98	8.58	57.85
Average fruit weight (g)	57.15	38.25-75.20	30.85	30.03	98	34.64	60.62
Fruit yield per plant (g)	832.74	380.20-1340.30	32.12	32.26	99	547.86	65.80
Fruit length (cm)	7.24	5.25-9.00	16.54	16.75	97	2.42	33.46
Fruit breadth (cm)	4.49	3.75-6.00	11.34	11.66	94	1.01	22.57
Pericarp thickness (mm)	4.53	4.15-5.10	6.07	6.62	84	0.36	8.00
Number of seeds per fruit	206.76	152.00-300.15	21.74	21.90	98	91.41	44.21
Plant height (cm)	51.47	46.30-60.15	7.68	8.11	89	7.65	14.83

fruit (98 %), fruit length (97 %), fruit breadth (94 %), plant height (89 %) and pericarp thickness (84 %). High heritability estimates for fruit yield per plant (Das and Choudhary, 1999; Sreelathakumary and Rajamony, 2002 and Sharma *et al*., 2010), average fruit weight (Das and Choudhary, 1999 and Sharma *et al*., 2010), number of fruits per plant (Sreelathakumary and Rajmony, 2002; Sharma *et al*., 2010), fruit length (Bhardwaj *et al*., 2007; Sharma *et al*., 2010), fruit breadth, pericarp thickness and number of seeds per fruit (Kumari, 2008), plant height (Ibrahim *et al*., 2001; Bhardwaj *et al*., 2007 and Sharma *et. al*., 2010) observed by earlier workers were in consonance with the present study.

Genetic gain:

The genetic gain (genetic advance as per cent of population mean) was high for number of fruits per plant (57.85 %), average fruit weight (60.62 %) and fruit yield per plant (65.80 %).

Genetic gain was moderate for fruit length (33.46 %) and number of seeds per fruit (44.21 %). Low genetic gain was observed for fruit breadth (22.57 %), pericarp thickness (8.00 %) and plant height (14.83 %).

High heritability along with high genetic gain was observed for number of fruits per plant, average fruit weight and fruit yield per plant indicating role of additive gene action for their inheritance and could be improved through

selection.The results are in consonance with Sree Lathakumary and Rajamony (2002), Subas Shreshtha (2003), Chatterjee and Kohli (2004), Mishra *et al.* (2005), Nazir *et al.* (2005a), Bhardwaj *et al.* (2007) and Sharma *el al*. (2010). High heritability along with low genetic gain was observed for fruit breadth, pericarp thickness and plant height indicating non additive gene activity and these traits could be improved through hybridization. Low genetic gain for pericarp thickness has been reported by Subas Shreshtha (2003).

Correlation co-efficients of variation:

The correlation co-efficients among different characters were worked out at phenotypic and genotypic levels and are presented in Table 4. Number of fruit per plant had positive significant correlation with fruit yield per plant (0.752). These results are supported by the findings of Kohli and Chatterjee (2001), Mishra *et al*. (2002), Sweta Rani (2003), Bindal (2005), Kumari (2008) and Sharma *et al*. (2010). Average fruit weight had positive and significant correlation with fruit yield per plant (0.625) and fruit breadth (0.639). The results are in agreement with the findings of Subas Shreshtha (2003), Sweta Rani (2003), Chatterjee and Kohli (2004), Bindal (2005), Bharadwaj *et al.* (2007), Kumari (2008) and Sharma *et al.* (2010). Hence, on the basis of correlation studies and their coefficient of determination, the selection for number of fruits per plant, average fruit weight and fruit breadth will be effective for isolating plants with higher fruit yield in bell pepper. Fruit length had positive significant correlation with plant height (0.632). This association has also been reported by Sharma *et al*. (2010). Fruit breadth also had positive significant correlation with plant height (0.695). Pericarp thickness had positive and significant correlation with number of seeds per fruit (0.623) and plant height (0.659). Positive and significant correlation of pericarp thickness with seeds per fruit has also been reported by He *et al.*(1989), Ibrahim *et al.* (2001) and Bindal (2005) and Kumari (2008) .

Path co-efficient analysis:

Path analysis helps in partitioning correlation co-efficients into direct and indirect effects of component characters in yield. Direct and indirect effects of all the traits on yield were computed at the genotypic level. The results

Table 4 : Estimates of phenotypic (P) and genotypic (G) correlation coefficients among different traits under study in bell pepper

Traits		Average fruit weight (g)	Fruit yield per plant (g)	Fruit length (cm)	Fruit breadth (cm)	Pericarp thickness (mm)	Number of seeds per fruit	Plant height (cm)
Number of fruits per plant	P	0.020	0.752*	-0.089	-0.248	-0.013	-0.165	0.037
	G	0.007	0.750*	-0.108	-0.283	-0.061	-0.180	0.002
Average fruit weight (g)	P	1.000	0.625**	-0.068	0.639**	-0.088	-0.076	0.188
	G	1.000	0.622**	-0.089	0.629**	-0.151	-0.092	0.158
Fruit yield per plant (g)	P		1.000	-0.133	0.111	-0.048	-0.205	0.086
	G		1.000	-0.149	0.093	-0.092	-0.218	0.061
Fruit length (cm)	P			1.000	0.362	0.398	0.060	0.632**
	G			1.000	0.339	0.372	0.043	0.608
Fruit breadth (cm)	P				1.000	0.061	-0.068	0.695**
	G				1.000	-0.035	-0.099	0.656**
Pericarp thickness (mm)	P					1.000	0.623**	0.659**
	G					1.000	0.613	0.581
Number of seeds per fruit	P						1.000	-0.048
	G						1.000	-0.091

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 5 : Estimates of direct and indirect effects of different traits under study on yield per plant in bell pepper

Traits	Number of fruits per plant	Average fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Pericarp thickness (mm)	Number of seeds per fruit	Plant height (cm)
Number of fruits per plant	0.737	0.005	-0.079	-0.208	-0.045	-0.132	0.002
Average fruit weight (g)	0.004	0.675	-0.060	0.357	-0.101	-0.061	0.106
Fruit length (cm)	0.0001	0.000	-0.0008	-0.000	-0.0003	-0.000	-0.000
Fruit breadth (cm)	0.004	-0.008	-0.005	-0.015	0.0005	0.001	-0.006
Pericarp thickness (mm)	-0.004	-0.010	0.026	-0.002	0.070	0.029	0.026
Number of seeds per fruit	0.008	0.004	-0.002	0.004	-0.025	-0.049	0.004
Plant height (cm)	-0.000	-0.004	-0.012	-0.013	-0.014	0.002	-0.029

Residual effect: 0.1821

have been presented in Table 5. Perusal of data from table indicated that maximum positive direct effect towards yield per plant was contributed by number of fruits per plant (0.737) and average fruit weight (0.675). The results are in conformity with Nair *et al*. (1984), Chatterjee and Kohli (2004), Nazir *et al*. (2005), Kumari (2008) and Sharma *et al.*(2010). So number of fruits per plant and average fruit weight could be considered as important selection criterias in the improvement of fruit yield. Average fruit weight had maximum positive indirect effect via fruit breadth (0.357) followed by plant height (0.106) and number of fruits per plant had maximum positive indirect effect via average fruit weight on fruit yield per plant. These findings are in consonance with the findings of Sharma *et al*. (2010). Other characters which showed positive direct effect, but in small magnitude, was of pericarp thickness (0.070). Negative direct effects were observed for fruit length (-0.0008), fruit breadth (-0.015), number of seeds per fruit (-0.049) and plant height (-0.029). At genotypic level, the residual effect was recorded to be 0.1821.

Direct and indirect contributions of component traits towards fruit yield, selection on the basis of horticultural traits *viz.*, average fruit weight and number of fruits per plant would be a paying preposition in the genotypes included in the study.

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