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Estimation of genetic variability in bell pepper (*Capsicum annuum* L. var. *grossum*)

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Abstract
The present investigation was carried out at the Experimental Research Farm, Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during *Kharif* 2013 to estimate variability, heritability and genetic gain in diverse germplasm of bell pepper. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Thirty five genotypes including three check cultivars were evaluated for different horticultural traits. High heritability (92.97%) coupled with high genetic gain (50.86%) was obtained for fruit yield. Hence, selection can prove effective for improvement in fruit yield in bell pepper. High heritability coupled with moderate genetic gain was obtained for number of fruits per plant, average fruit weight and pericarp thickness indicating some scope for their improvement through selection.

Keywords: bell pepper, GCV, genetic gain, heritability, PCV, range

Introduction
Bell Pepper (*Capsicum annuum* L. var. *grossum*) commonly known as Shimla Mirch or Sweet Pepper is a solanaceous vegetable and is popular for its delicious taste, pleasant flavour and nutritional qualities. Nutritionally, it is a rich source of vitamin C containing 150-180 mg per 100 g and vitamin A, constituting up to 12 per cent of total pigment content. Ascorbic acid present in it has antioxidant property and aid in prevention of certain types of cancer, cardiovascular diseases, stroke, atherosclerosis and cataracts. It is one of the highly remunerative vegetable crop grown in India. In Himachal Pradesh, Bell pepper is grown for off season produce during summer and rainy seasons thus, it serves as a crop of great economic importance to the farmers of the state. Considering its economic importance and demand as a high value crop, there is a need to develop and identify improved and superior quality cultivars. Estimation of variability is a pre-requisite for success in any breeding programme. Assessment of genetic variability in the germplasm by estimating various parameters of variability helps to identify the potential genotypes for their use either directly as varieties or as parents in future crop improvement programmes. The programme in breeding solely depends on magnitude of variability for the characters which are under improvement. Therefore, the knowledge on the estimates of variability in respect of yield and its heritable components in the genetic material with which the breeder is working is essential for straightening selection strategies. It is also necessary to partition the total variability into heritable and non-heritable components *viz.*, phenotypic coefficient of variability (PCV), genotypic coefficient of variability (GCV) and further to compute heritability and genetic gain for various traits of interest to the breeder. The estimates of genotypic and phenotypic coefficient of variation indicates the extent of genetic variability present in a given germplasm but, significance lies in the amount of heritable portion of the variation that plays significant role in improvement of a trait through selection. Keeping all this in view, the present investigation was conducted to estimate the various parameters of variability in bell pepper.

Materials and Methods
The present experiment was conducted at the Experimental Research Farm of the Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during *Kharif* season of 2013. Thirty five genotypes of bell pepper including three checks *viz.*, Nishat-1, California Wonder and Solan Bharpur were evaluated for

yield and different horticultural traits. Bell pepper genotypes along with their sources of collection have been presented in table 1. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Seedlings of each entry were transplanted on 1st May, 2013 at a spacing of 60 cm x 45 cm in a plot size of 3.0m x 1.80m in each replication. Standard cultural practices recommended for growing bell pepper crop in the mid hills were followed (Anonymous, 2013) [4]. Data were recorded on ten randomly taken plants from each plot/treatment and the average was worked out to record the mean value in each replication for all the characters under study. The mean values of data were subjected to analysis of variance and ANOVA was set for randomized block design (Gomez and Gomez, 1983) [7]. The observations were recorded on days to first flowering, days to first marketable picking, number of fruits per plant, fruit length (cm), fruit breadth (cm), average fruit weight (g), pericarp thickness (mm), plant height (cm), harvest duration (days), number of seeds per fruit, number of lobes per fruit, ascorbic acid content (mg/100g), capsaicin content (mg/g) and fruit yield (kg/plant, kg/plot and q/ha). The genotypic and phenotypic coefficients of variation were calculated as per the standard method suggested by (Burton and De Vane, 1953) [5]. Heritability in broad sense and expected genetic advance (GA) resulting from selection of five percent individuals was calculated as per commonly followed method Allard (1960) [3]. Genetic advance expressed as per cent of population mean was also calculated by the formula given by (Johanson *et al.*, 1955) [9].

Table 1: Bell pepper genotypes along with sources of collection used in the present study

Source	Genotype
IIVR, Varanasi	HACAV-271, VLCP-13, PRC-1, DARL-72, PT-12-3, CP-40, VLCP-3, Kt- 1
Department of Vegetable Science UHF, Nauni, Solan (HP)	UHF-1, UHF-2, UHF-3, UHF-4, UHF-5, UHFBP-6, UHFBP-7, UHFBP-8, UHFBP-18, UHFBP-19, UHFBP-20, UHF-14, UHFBP-21, Yolo Wonder, ACC-16, PC-2
World Vegetable Centre, Taiwan	EC-579997
HRS, Kandaghat, Distt. Solan (HP)	Kandaghat Sel – 9
Collections from district Solan and Sirmour (HP)	UHFBP-22, UHFBP-23, UHFBP-24, UHFBP-25, UHFBP-26, UHFBP-27
IIVR, Varanasi	Nishat-1*
IARI, Regional Station Katrain, Kullu (HP)	California Wonder*
Department of Seed Science and Technology, UHF, Nauni, Solan (HP)	Solan Bharpur*

*Check varieties

Results and Discussion

The observed variation in the characters among all the genotypes is due to effect of genotype and environment, environmental variations are not fixable. Hence, for determining the magnitude of genotypic and phenotypic variability, the genotypic and phenotypic coefficients of variation were worked out in the present study. A perusal of data for all the characters studied (table 2) indicated that the phenotypic coefficient of variation (PCV) were higher in magnitude than their corresponding genotypic coefficient of variation (GCV), though difference was very less in most of the characters which indicated little effect of environment on the characters estimated. The parameters of variability viz., coefficients of variation (phenotypic and genotypic), heritability in broad sense, genetic advance as percent of mean (genetic gain) were statistically worked out to generate an idea and scope for response of selection to various characters. The results are presented in table 2.

Coefficients of variation

The estimates of phenotypic coefficients of variation were high for capsaicin content (41.03%) whereas, moderate phenotypic coefficients of variation were recorded for fruit yield (kg plant^{-1}, kg plot^{-1} and q ha^{-1}) (26.55%), number of fruits per plant (21.48%), average fruit weight (18.95%), number of seeds per fruit (18.17%) and plant height (15.08%). The low PCV were observed for days to first marketable picking (5.60%) and days to first flowering (5.71%). Besides, this low PCV were recorded for pericarp thickness (14.75%), fruit length (14.70%), ascorbic acid content (13.36%), fruit breadth (13.16%), number of lobes per fruit (10.58%) and harvest duration (9.67%).

Similarily, genotypic coefficients of variation (GCV) were high for capsaicin content (40.10%). Whereas, moderate genotypic coefficient of variation (GCV) were recorded for fruit yield (kg/plant, kg/plot and q/ha) (25.60%), number of fruits per plant (20.19%), number of seeds per fruit (17.32%) and average fruit weight (16.86%). However GCV were low for days to first flowering (5.01%), days to first marketable picking (5.02%), fruit breadth (12.06%), fruit length (11.96%), pericarp thickness (13.50%), number of lobes per fruit (9.82%), plant height (12.70%), ascorbic acid content (11.45%) and harvest duration (8.51%). High phenotypic and genotypic coefficients of variation were observed for capsaicin content (mg/g) which was in accordance with Sood *et al.* (2009) [17]. Moderate phenotypic and genotypic coefficients of variation were recorded for number of fruits per plant, average fruit weight (g), number of seeds per fruit and fruit yield (kg plant^{-1}, kg plot^{-1} and q ha^{-1}). These results are in confirmation with earlier workers like Chatterjee and Kohli (2004) [6], Islam and Singh (2006) [8], Johri and Kumar (2007) [10], Sharma *et al.* (2010) [15]. Moderate phenotypic coefficient of variation and low genotypic coefficient of variation were recorded for plant height. The characters like days to first flowering, days to first marketable picking, fruit length, fruit breadth, pericarp thickness, harvest duration, number of lobes per fruit and ascorbic acid content showed low phenotypic and genotypic coefficient of variation. Some of these results were in confirmation with Sood *et al.* (2011) [16], Ahmed *et al.* (2012) [2], Afroza *et al.* (2013) [1] and Pandey *et al.* (2013) [13].

Heritability (broad sense)

Heritability in its broad sense amounts to the portion of variability which is attributable to genetic differences. High heritability coupled with high genetic advance is a reliable measure of the genetic gain through selection of best individual from the variable population. The concept of heritability has a productive value. Estimates of heritability (broad sense) were also worked out in the present studies and have been presented in table 2. The range of heritability was observed from 77.06 to 95.56 percent. In the present study,

high heritability was exhibited for all characters except days to first flowering (77.06%) which showed moderate heritability. Highest heritability was recorded for capsaicin content (95.56%) followed by fruit yield (92.97%), number of seeds per fruit (90.94%), average fruit weight (90.11%), number of fruits per plant (88.35%), harvest duration (87.31%), number of lobes per fruit (86.19%), ascorbic acid content (85.70%), fruit length (84.57%), fruit breadth (83.92%), pericarp thickness (83.70%), days to first marketable picking (80.40%) and plant height (80.26%). In the present study estimates of heritability (broad sense) were high for all the traits under study except for days to first flowering. High heritability for different traits indicated that large proportion of phenotypic variance has been attributed to genotypic variance and therefore, reliable selection could be made for these traits on the basis of phenotypic expression. Similar studies have been reported by Chatterjee and Kohli (2004) [6], Mishra *et al.* (2005) [11], Nazir *et al.* (2005) [12], Islam and Singh (2006) [8], Sharma and Sharma (2006) [14], Sharma *et al.* (2010) [15], Sood *et al.* (2011) [16], Ahmed *et al.* (2012) [2], Afroza *et al.* (2013) [1] and Pandey *et al.* (2013) [13].

Genetic gain

Although, estimates of high heritability are useful as they provide basis of transmissible genes from parent to progeny but more reliable conclusion is drawn when heritability is considered along with the genetic gain. Johanson *et al.* (1955) [9] reported that high heritability estimates coupled with high genetic gain were useful than the heritability alone for effective selection. Genetic advance expressed as per cent of population mean (genetic gain) was low to high for various characters studied. It ranged from 9.06% to 82.35% (table 2). It was found high for the characters viz. capsaicin content (82.35%) and fruit yield (50.86%). Lowest genetic gain of 9.06 per cent was observed in days to first flowering closely followed by days to first marketable picking (9.28%), harvest duration (16.38%), number of lobes per fruit (18.91%), ascorbic acid content (21.84%), fruit length (22.68%), fruit breadth (22.80%) and plant height (23.44%). Whereas, moderate genetic gain was recorded in number of fruits per plant (39.08%) followed by number of seeds per fruit (34.03%), average fruit weight at marketable stage (32.96%) and pericarp thickness (25.44%). Similar results were reported by Mishra *et al.* (2005) [11], Islam and Singh (2006) [8] and Ahmed *et al.* (2012) [2] for some of the traits. High heritability coupled with high genetic gain was found for characters like fruit yield per plant and capsaicin content which indicates that these characters were under the strong influence of additive gene action and hence simple selection based on phenotypic performance of these traits would be more effective. These findings are in agreement with Sood *et al.* (2009) [17] and Pandey *et al.* (2013) [13]. High heritability coupled with moderate genetic gain was found for the traits like number of fruits per plant, average fruit weight, number of seeds per fruit and pericarp thickness which indicates the predominance of non-additive variance in expression of these traits. So, selection for these traits may be referred for later generations. The characters like days to first marketable picking, fruit length, fruit breadth, plant height, harvest duration, number of lobes per fruit and ascorbic acid content recorded low genetic gain along with high heritability which indicated that these traits are strongly governed by non-additive gene effects. The improvement in these traits can be achieved by partitioning the genetic variance further and making selection for suitable types in segregating generations. Islam and Singh (2006) [8], Sood *et al.* (2009) [17] and Sharma *et al.* (2010) [15] reported similar results for some of the traits.

Table 2: Estimates of parameters of variability in bell pepper (*Capsicum annuum* L. var. *grossum*) for various traits.

Sr. No	Character	Range	Mean ± SE(d)	Coefficients of variability (%)		Heritability (%)	Genetic Gain (%)
				Phenotypic	Genotypic		
1.	Days to first flowering	35.00 - 46.00	39.83 ± 0.89	5.71	5.01	77.06	9.06
2.	Days to first marketable picking	52.67 - 69.00	62.42 ± 1.26	5.60	5.02	80.40	9.28
3.	No. of fruits per plant	9.00 - 24.00	15.15 ± 0.91	21.48	20.19	88.35	39.08
4.	Fruit length (cm)	4.87 - 7.97	6.79 ± 0.28	14.70	11.96	84.57	22.68
5.	Fruit breadth (cm)	3.54 - 6.06	5.13 ± 0.22	13.16	12.06	83.92	22.80
6.	Average fruit weight (g)	30.00 - 63.33	46.66 ± 2.13	18.95	16.86	90.11	32.96
7.	Pericarp thickness(mm)	3.09 - 5.98	4.52 ± 0.22	14.75	13.50	83.70	25.44
8.	Plant height (cm)	40.00 - 68.26	56.10 ± 2.89	15.08	12.70	80.26	23.44
9.	Harvest duration	41.00 - 62.00	54.94 ± 1.46	9.67	8.51	87.31	16.38
10.	No. of seeds per fruit	115 - 304.13	212.97 ± 9.51	18.17	17.32	90.94	34.03
11.	No. of lobes per fruit	2.00 + 3.87	3.33 ± 0.11	10.58	9.82	86.19	18.91
12.	Ascorbic acid content (mg/100g)	102.93 - 176.07	142.12 ± 5.43	13.36	11.45	85.70	21.84
13.	Capsaicin content (mg/g)	0.07 - 0.30	0.17 ± 0.01	41.03	40.10	95.56	82.35
14.	Fruit yield (kg/plant)	0.33 - 1.02	0.69 ± 0.04	26.55	25.60	92.97	50.86
15.	Fruit yield (kg/plot)	6.60 - 20.33	13.70 ± 0.79	26.55	25.60	92.97	50.86
16.	Fruit yield (q/ha)	97.78 - 301.23	202.98 ±11.67	26.55	25.60	92.97	50.86

Conclusion

The estimates of phenotypic and genotypic coefficients of variation were high for capsaicin content (mg/g) whereas, moderate phenotypic and genotypic coefficient of variation was recorded for fruit yield (kg/plant, kg/plot and q/ha), number of fruits per plant, average fruit weight (g), number of seeds per fruit indicating the existence of substantial variability, pointing ample scope for their improvement through selection. High heritability coupled with high genetic gain was found for characters like fruit yield per plant and capsaicin content which indicates that these characters were under the strong influence of additive gene action and hence simple selection based on phenotypic performance of these traits would be more effective.

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