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GENETIC ARCHITECTURE OF QUALITY TRAITS IN BELL PEPPER [*CAPSICUM ANNUUM* L. VAR. *GROSSUM* SENDT.]

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ABSTRACT

Fourty six bell pepper genotypes were evaluated for quality traits during the summer-rainy season 2015. The estimates of PCV and GCV were high for capsanthin (45.84%, 45.70%) and ascorbic acid (40.06% and 40.02%); moderate for marketable fruit yield per plant (29.57%, 28.65%) and TSS (22.81%, 21.37%). High to moderate heritability along with high to moderate genetic advance were observed for marketable fruit yield per plant (93.84%, 57.16%), capsanthin (99.39%, 93.86%), ascorbic acid (99.83%, 82.37%) and TSS (87.76%, 41.23%), indicated additive genetic control for the inheritance of these traits and could be improved through selection. Low heritability with low genetic advance for pericarp thickness (22.22%, 6.28%) indicating non-additive gene action. Genotypic correlations were higher than their corresponding phenotypic ones indicating strong inherent association among such traits, the phenotypic expression of correlation gets reduced under the influence of environment. The genotypic correlations were partitioned into direct and indirect effects to know the relative importance of the components. Ascorbic acid content (-0.105, -0.108) and TSS (-0.153, -0.175) had negative correlation with marketable fruit yield per plant. Direct negative effect on fruit yield per plant was found with ascorbic acid, capsanthin and TSS. Therefore, indirect selection practiced on these traits will result in the improvement of respective characters and fruit yield.

INTRODUCTION

Bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.; 2n = 2x = 24) a member of family Solanaceae, commonly known as sweet pepper or Shimla mirch is native of Mexico with secondary centre of origin in Guatemala (Bukasov, 1930). In India, bell pepper was first introduced by the Britishers in the 19th century in Shimla hills and is commercially grown in Himachal Pradesh, Jammu and Kashmir, Uttrakhand, Arunachal Pradesh and Darjeeling district of West Bengal during summer rainy months and as an autumn-winter crop in Maharashtra, Karnataka, Tamil Nadu and Bihar. In India, it is cultivated over an area of 46 thousand hectares with the production of 288 thousand metric tonnes (Anonymous, 2016) and is grouped under non-traditional category of vegetables (Kalloo and Pandey, 2002). It is grown world wide for its delicate taste, pleasant flavour, colour and is one of the highly remunerative vegetables cultivated in most parts of the world especially in temperate regions of Central and South America and European countries. Bell pepper fruits are generally blocky, square, thick fleshed, three to four lobed, low to mild pungency and have a glossy exterior of different, vivid colours including green, red, yellow, orange, purple and brown to black. It has attained a status of high value crop in recent years and occupies a pride place among vegetables because it adds delicacy to every dish and is one of the most popular salad ingredients of the world coupled with appreciable quantities of vitamin C (Chassy *et al.*, 2006), provitamin A (β-carotene) and oxygenated carotenoids (capsanthin, capsorubin and cryptocapsin) and neutral phenolic compounds or flavonoids called quercertin, luteolin and capsaicinoids which are beneficial for prevention of common degenerative diseases such as cancer, cardiovascular diseases, cataracts, diabetes, Alzheimer's and Parkinson's (Hasler, 1998 and Rios *et al.*, 2013). Fruit quality, along with fruit yield and resistance to insect-pest and diseases is an important criteria in capsicum breeding programs (Kumar *et al.*, 2015). Quality bell pepper is not only in big demand for home consumption, but also have great export potential. The desired quality characteristics in bell pepper include high TSS, ascorbic acid, capsanthin content and thick pericarp of the fruits (Bhat *et al.*, 2016). Improvement in fruit quality that does not lower the fruit yield is need of the hour to benefit all the capsicum growers and consumers. Like fruit yield, quality is not easily amenable to selection due to its complex nature. Therefore, efforts to enhance bell pepper productivity with quality must receive top priority. For planning and execution of a successful breeding program, the most essential pre-requite is the availability of substantial desirable genetic variability for important characters in the germplasm and the extent to which the desirable characters are heritable. Knowledge of correlation between different quality characters are basic and foremost endeavor to find out guidelines for selection of quality genotypes and selective importance of direct and indirect influence of each of the quality traits on yield so as to improve the plant as a whole rather than individual trait. In this regard a good number of works has been reported by many workers viz., Afroza *et al.* (2013), Kumar *et al.* (2015), Sharma and Sridevi (2016), Thapa *et al.* (2016), Kadwey *et al.* (2016), Padilha *et al.* (2016), Rohini *et al.* (2017), Shumbulo *et al.*

(2017) and Thakur *et al*. (2017). In the present investigation, an attempt was made to unravel the variability and correlation between quality parameters of advance breeding lines and lines from AVRDC for four important quality characters.

MATERIALS AND METHODS

The present investigation was undertaken at the Experimental Farm of Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, (HP), India from February-August 2015. The investigation was carried out for 46 genotypes (43 F_5 progenies, one susceptible check and two resistant checks) of bell pepper derived from different inter-varietal crosses and had been selected earlier in the Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Fourty six genotypes (Table 1) were evaluated along with susceptible check (California Wonder) and resistant checks (EC-464107) and (EC-464115) in randomized block design in 2015 with three replications. The seedlings were transplanted with an inter and intra row spacing of 60 cm and 45 cm, respectively during the second week of April. Fruits of five plants were harvested at marketable stage for recording fruit yield per plant. Pericarp thickness was estimated with the help of Vernier Caliper. Capsanthin content in red ripe fruits was determined as per procedure given by AOAC (1980). Ascorbic acid content was estimated at marketable green fruit stage by '2, 6-Dichlorophenol-Indophenol Visual Titration Method' as described by Ranganna (1979). Total Soluble Solids (TSS) was determined with the help of "Erma Hand Refractometer" under room temperature conditions and readings were taken as per method given by (AOAC 1970). The analysis of variance was analyzed for ANOVA as per the method suggested by Panse and Sukhatme (1984). The phenotypic, genotypic coefficients of variation were estimated following Burton and De Vane (1953), heritability and genetic advance as per Johnson *et al*. 1955. Phenotypic and genotypic correlations were calculated as per Al-Jibouri, 1958 and path coefficient at phenotypic and genotypic level was carried out following Dewey and Lu, 1959.

RESULTS AND DISCUSSION

The analysis of variance showed that the genotypes differ significantly among themselves for the characters studied, indicating presence of adequate variability. These findings are in close conformity with earlier workers for pericarp thickness (Kumari 2013 and Muhammad *et al*., 2015), marketable fruit yield per plant (Maga *et al*., 2013), capsanthin (Kumar 2013 and Shaha *et al*., 2014), ascorbic acid (Pandey *et al*., 2013, Kumar *et al*.,2015 and Muhammad *et al*., 2015) and TSS (Tsegay *et al*., 2013 and Naik *et al*., 2014). The range, mean values, phenotypic and genotypic coefficients of variations, heritability and genetic advance as percentage of mean for capsanthin content, ascorbic acid content, TSS, pericarp thickness and marketable fruit yield per plant are presented in Table 2.

The genotypic coefficients of variation (gcv) were slightly higher than their corresponding phenotypic coefficient of variation (pcv) which indicated that though there is a strong inherent association between various characters studied, the phenotypic expression of the correlation gets reduced under the influence of environment. Similar results have also been reported by Maga *et al*. (2013), Pandey *et al*. (2013), Thakur *et al*. (2013), Kumari *et al*. (2013) and Rana *et al*. (2015) in bell pepper. High to moderate values of PCV and GCV (*i.e*. high for capsanthin content (45.84%, 45.70%), ascorbic acid content (40.06%, 40.02%) and moderate for total soluble solids (22.81%, 21.37%) and marketable fruit yield per plant and low for pericarp thickness (13.71%, 6.47%). High to moderate values of PCV and GCV are indicative of sufficient variability ensuring ample scope for improvement through selection. The estimates of heritability act as a predictive

Table1 : Description of parental bell pepper lines used in the study

Sr. No.	Progeny	Pedigree	Sr. No.	Progeny	Pedigree
1	P-1	(P13 X KS)-9-8-2	24	P-24	(P14 X KS)-43-5-1
2	P-2	(P13 X KS)-12-1-1	25	P-25	(P14 X KS)-70-5-2
3	P-3	(P13 X KS)- 15-2-1	26	P-26	(P14 X KS)-52-1-1
4	P-4	(P13 X KS)-15-3-2	27	P-27	(P14 X KS)-52-2-7
5	P-5	(P13 X KS)-16-6-1	28	P-28	(P14 X KS)-70-8-1
6	P-6	(P13 X KS)-24-1-2	29	P-29	(P14 X KS)-53-3-2
7	P-7	(P13 X KS)-24-2-1	30	P-30	(P14 X KS) -76-3-1
8	P-8	(P13 X KS)-24-3-1	31	P-31	(P14 X KS)- 54-2-1
9	P-9	(P13 X KS)-24-3-8	32	P-32	(P14 X KS)-55-3-1
10	P-10	(P13 X KS)-28-4-1	33	P-33	(P14 X KS)-57-4-1
11	P-11	(P13 X KS)-28-4-9	34	P-34	(P14 X KS)-57-6-1
12	P-12	(P13 X KS)-34-1-2	35	P-35	(P14 X KS)-58-2-1
13	P-13	(P13 X KS)-38-1-4	36	P-36	(P14 X KS)-68-2-1
14	P-14	(P13 X KS)-38-2-1	37	P-37	(P14 X KS)- 70-4-1
15	P-15	(P13 X KS)-38-2-6	38	P-38	(P14 X KS)- 72-1-1
16	P-16	(P13 X KS)-38-10-2	39	P-39	(P14 X KS)- 73-1-1
17	P-17	(P13 X KS)-38-12-4	40	P-40	(P14 X KS)- 76-2-1
18	P-18	(P13 X KS)-42-1-2	41	P-41	(P14 X KS)- 45-10-1
19	P-19	(P13 X KS)-42-4-1	42	P-42	(P14 X KS)- 45-10-1
20	P-20	(P13 X KS)-83-8-2	43	P-43	(P14 X KS)- 57-2-1
21	P-21	(P13 X KS)-84-4-1	44	EC-464107	Resistant check
22	P-22	(P13 X KS)-84-2-2	45	EC-464115	Resistant check
23	P-23	(P14 X KS)-43-6-1	46	California Wonder	Susceptible check

Table 2: Range, mean, phenotypic coefficient of variation (pcv), genotypic coefficient of variation (gcv), heritability and genetic advance in bell pepper

Trait	Range	Mean	pcv (%)	gcv (%)	Herit ability(h^2_{bs})	Genetic advance (% of mean)
Capsanthin content (ASTA units)	54.03-505.94	222.11 + 4.60	45.84	45.7	99.39	93.86
Ascorbic acid content (mg/100g)	40.22-218.26	94.43 + 0.91	40.06	40.02	99.83	82.37
Total soluble solids (^{0}Brix)	1.85-4.80	2.88 + 0.13	22.81	21.37	87.76	41.23
Pericarp thickness (mm)	3.33-4.70	4.04 + 0.28	13.71	6.47	22.22	6.28
Marketable fruit yield per plant (g)	80.00-2265.00	1417.70 + 60.10	29.57	28.65	93.84	57.16

Table 3 : Phenotypic (P) and genotypic (G) correlation coefficients among marketable fruit yield and quality traits in bell pepper

Character		Pericarp thickness	Capsanthin content	Acorbic acid content	TSS
Marketable fruit yield	P	0.146	0.114	-0.105	-0.153
per plant	G	0.244*	0.117	-0.108	-0.175*
Pericarp thickness	P		0.159	-0.085	0.085
	G		0.347*	-0.178*	-0.324*
Capsanthin content	P			0.159	-0.054
	G			0.159	-0.062
Ascorbic acid content	P				-0.086
	G				-0.092

*Significant at 5% level

Table 4 : Path coefficients showing at phenotypic (P) and genotypic (G) levels and direct and indirect effects of quality traits on marketable fruit yield in bell pepper

Character		Pericarp thickness	Capsanthin content	Ascorbic acid content	Total soluble solids	Correlation coefficient with Marketable fruit yield per plant
Pericarp thickness	P	0.0028	-0.0008	-0.0003	0.0003	0.146
	G	-0.0675	0.0078	-0.0006	0.0259	0.244*
Capsanthin content	P	0.0004	-0.0057	-0.0022	0.0000	0.114
	G	-0.0205	0.0257	-0.0024	0.0012	0.117
Ascorbic acid content	P	0.0001	-0.0013	-0.0091	0.0001	-0.105
	G	-0.0038	0.0061	-0.0103	0.0022	-0.108
Total soluble solids	P	-0.0003	0.0001	0.0003	-0.0028	-0.153
	G	0.0239	-0.0004	0.0003	-0.0733	-0.175*

Residual effect: P = 0.0195; G = - 0.0013; The Bold values indicate direct effects.

instrument in expressing the reliability of phenotypic value. Therefore, it helps the breeder to make selections for a particular character when heritability is high. Heritability in broad sense is a parameter of tremendous significance as its magnitude indicates the reliability with which a genotype can be recognized by its phenotypic expression.

The genetic advance is a useful indicator of the progress that can be expected as a result of exercising selection on the pertinent population.

The heritability was recorded high for ascorbic acid (99.83%), capsanthin content (99.39%), marketable fruit yield per plant (93.84%) and TSS (87.76%) indicating that these traits were less influenced by environment. It was low for pericarp thickness (22.22%). The highest genetic advance was predicted for capsanthin content (93.86%) followed by ascorbic acid content (82.37%) and marketable fruit yield per plant (57.16). However, it was moderate (41.23%) for TSS and low (6.28%) for pericarp thickness. The higher estimates of heritability coupled with high to moderate genetic advance for capsanthin content, ascorbic acid content, TSS and marketable fruit yield per plant indicated that heritability of the trait is mainly owing to additive effects and consequently a high genetic gain is expected from selection under such a situation. However, low heritability associated with low genetic advance for pericarp thickness is indicative of non-additive gene action and consequently improvement of these traits through recombination breeding is possible. Similar results were obtained by earlier workers for ascorbic acid content (Pandey *et al.*, 2013), TSS (Naik *et al.*, 2014), pericarp thickness (Sood *et al.*,2011 and Naik *et al.*, 2014) and marketable fruit yield per plant (Ahmed *et al.*, 2012 and Kumari, 2013). The genotypic correlations were higher than their corresponding phenotypic for all the traits under study suggesting strong inherent association between these traits at genotypic level (Table3).

At phenotypic and genotypic level, pericarp thickness showed positive association with capsanthin content and ascorbic acid content, thus indicating that selection for capsanthin content would simultaneously lead to an improvement in pericarp thickness and ascorbic acid. The genotypic correlations were partitioned into direct and indirect effects to know the relative importance of the components (Table 4). Ascorbic acid con tent and total soluble solids had non-significant negative correlation with marketable fruit yield per plant. The negative genotypic correlation of these traits with marketable fruit yield and negative direct effects was counter balanced by positive indirect path. The low magnitude of residual effect at phenotypic level (0.0195) and negative at genotypic level (-0.0013) indicated that the traits included in the present investigation accounted for most of variation present in the dependent variable *i.e.* marketable

fruit yield per plant. This indicated that for quality traits like capsanthin content (P-11), ascorbic acid (P-3) and TSS (P-1) progenies can be further put to direct use as cultivars or involved in future breeding programmes for enhancing the fruit quality in bell pepper varieties. Further, to keep balance between marketable fruit yield per plant and quality traits in bell pepper, it is necessary that genotypes with high fruit yield per plant be given weightage after that other quality traits.

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