Annals of Plant and Soil Research 24(3):447-451 (2022)
https://doi.org/10.47815/apsr.2022.10190

Variability and association studies for yield and quality characters among bacterial wilt tolerant advanced breeding lines of bell pepper (*Capsicum annuum* L.)

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Received: February, 2022; Revised accepted: April, 2022

ABSTRACT

Forty-three bell pepper genotypes collected from indigenous and exotic sources were evaluated during summer-rainy season, 2018 at Palampur to estimate genetic parameters of variability, heritability, genetic advance and correlation coefficient for yield and quality characters. Results revealed that significant variations were found among genotypes, indicating that yield and quality traits have enough variations. For all the traits studied, recorded values of phenotypic coefficients of variation (PCV) were greater than genotypic coefficients of variation (GCV). GCV was shown to be highest for marketable fruit yield per plant followed by capsanthin content and heritability was observed to be highest for capsanthin content followed by vitamin C. The three characters viz., marketable fruit yield per plant, capsanthin content, and vitamin C have shown high heritability coupled with high genetic advance as a percentage of mean suggesting the predominance of additive genetic control. High heritability coupled with moderate genetic advance was observed in pericarp thickness and TSS indicated the role of slightly additive gene action. Although TSS had a significant negative correlation with Vitamin C, the capsanthin content showed a positive correlation. Vitamin C and capsanthin content had a strong positive correlation with pericarp thickness; however, TSS had a significant negative correlation. There was no significant association between any of the quality parameters and marketable fruit yield per plant indicating that these traits can be improved independently.

Keywords: Bell pepper, capsanthin content, correlation, variability, yield

INTRODUCTION

Bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.) is very popular among vegetables as it adds delicacy and salubrious flavor to every dish. It is cherished by consumers because of its refreshing taste, fascinating color, and exceptional biochemical composition. It is also widely recognized as Shimla mirch or sweet pepper or capsicum and is extensively grown in both open and protected environments throughout the world. In the few past years, its demand is increasing among consumers because of the speedy growth of the fast-food industry in India (Singh *et al.,* 2018). It has achieved a pride place among high-value and low-volume vegetable crops. Capsicum fruits can be eaten raw or cooked. It is also commonly used in stuffings, pizza dough, soups, and stews. In addition to this, it has high therapeutic and nutritional properties. It reduces cholesterol levels in the blood, enhances blood circulation, uplifts the immune system, and mitigates arthritic pain (Thakur *et al.,* 2019a). It is exceptionally rich in vitamins (A, C and E), carotenoids (capsanthin and capsorubin), phenols (Anaya-Esparza *et al.,* 2021), flavonoids, and xanthophylls, which are important in the prevention of chronic and age-related diseases.

These days, quality bell pepper is in high demand not just for domestic use but also for export. High capsanthin content, TSS, vitamin C, and a thick pericarp of the fruits are all desirable qualities in bell peppers (Sharma and Sood, 2018). To benefit all capsicum producers and consumers, an improvement in fruit quality that does not reduce fruit yield is urgently needed. Keeping these points in mind, an initiative to increase bell pepper productivity while maintaining quality must be prioritized. The most significant prerequisite for planning and implementing a successful breeding program is the availability of genetically variable material with great yield potential and better quality characters. Furthermore, to increase quality production, it is critical to investigate the interrelationships between yield and quality characters. Studies on variability, particularly for quality attributes, are currently lacking in bell pepper (Hedau *et al.*, 2013) because of the lower variability and limited growing areas. Therefore, an attempt was made to study the

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extent of variability and nature of the association between yield and quality characters in bell pepper germplasm to increase quality production.

MATERIALS AND METHODS

The present study was carried out at the Research farm of the Department of Vegetable Science and Floriculture which is located at 32° 6' N latitude, 76° 3' E longitude, and an elevation of 1290.80 m above mean sea level and represents Himachal Pradesh's humid sub-temperate mid-hill zone (Zone-II) with 2500 mm annual rainfall. Maximum and minimum mean temperature, rainfall, relative humidity and sunshine hours were varied from 17.70°C to 33.60°C, 4.90°C to 20.64°C, 0.00mm to 297.20mm, 28.10% to 93.43% and 3.43hours to 9.70hours, respectively. The soils of experimental farm were silty clay loam in texture lies in *Typic hapludalf* suborder with a pH of 5.0 to 5.6. A total of 43 genotypes were examined under open field conditions. Among these, 39 were bacterial wilt tolerant advanced breeding lines developed through intervarietal crosses and four were checks (California Wonder, Kandaghat Selection, EC-464107 and EC-464115) collected from various indigenous and exotic sources. The nursery was sown during the 1st week of February and the crop was transplanted in triplets in the main field at a spacing of 60 × 45 cm during the 2nd fortnight of March adopting randomized complete block design (RCBD). Suitable drainage channels were built throughout the field in June and July to drain out excess water to protect the crop from water logging conditions. The observations were recorded on marketable fruit yield per plant and pericarp thickness. Marketable fruit yield per plant (g) was calculated by dividing the total marketable yield of all the pickings of selected plants by the number of plants used for recording data. The pericarp thickness (mm) was measured from an equatorial section of the green fruits with the help of Vernier Caliper and accordingly means values were calculated. Total soluble solids (°Brix) were determined by "Erma Hand Refractometer". Vitamin C (mg/100 g) was estimated by using '2, 6-dichlorophenol indophenol' dye (Ranganna, 1977). Capsanthin content (ASTA units) was determined by using 'acetone' (AOAC, 1980).

The data for various parameters were subjected to analysis of variance according to Panse and Sukhatme (1984), the phenotypic and genotypic coefficients of variation (PCV and GCV) were estimated by using the formula of Burton and De Vane (1953), and heritability in a broad sense (h^2_{bs}) and the expected genetic advance (GA) resulting from selection of 5% superior individuals were calculated as per the method proposed by Burton and De Vane (1953) and Johnson *et al.* (1955). The phenotypic and genotypic coefficients of correlation were worked out as suggested by Al-Jibouri *et al.* (1958). The estimates of PCV and GCV were classified in three categories *viz.,* low (< 10%), moderate (10-20%) and high (> 20%). The magnitude of heritability was categorized as low (< 30%), moderate (30-60%) and high (> 60%). The genetic advance as percentage of mean was also differentiated into low (< 10%), moderate (10-30%) and high (> 30%) estimates. The statistical analysis was done using OPSTAT software.

RESULTS AND DISCUSSION

Analysis of variance and mean performance

The differences attributable to genotypes (Table 1) were significant for all the characters studied interpreting that there was enough genetic variability to use in a breeding program, and also substantial scope for improvement and selection of genotypes for yield and quality traits. Singh *et al.* (2018) also reported similar results with different breeding materials. The presence of genetic variability in the germplasm is the basic requirement for any plant breeder to initiate a breeding programme. Greater the variability in the available germplasm, better would be the chances of selecting superior genotypes**.** A wide range was observed for marketable fruit yield per plant (90.32-541.44 g) which determines the yield potential of a genotype. Capsanthin content, TSS, Vitamin C and pericarp thickness are the major quality attributes in bell pepper and tremendous variations with respect to these traits (67.56-149.53 ASTA units, 3.00-5.00 °Brix, 59.13-138.04 mg/100g, 2.97-5.13 mm, respectively) were obtained in the germplasm. Wide variations in these traits were also reported by Devi *et al.* (2015); Rana *et al.* (2015) for marketable fruit yield per plant, Vijaya *et al.* (2014) for capsanthin content, Thakur *et al*. (2019a) for TSS, Sharma *et al*. (2017); Esho (2019) for vitamin C, and Thakur *et al.* (2017) for pericarp thickness.

Table 1: Values of range, mean, standard error and variability parameters of 43 genotypes of bell pepper for different traits

Component\Trait	Marketable fruit yield per plant (g)	Capsanthin content (ASTA units)	TSS (ºBrix)	Vitamin C content (mg/100g)	Pericarp thickness (mm)
MSS	19727.82*	1382.05*	0.78*	1080.92*	0.52*
Range	90.32-541.44	67.56-149.53	3.00-5.00	59.13-138.04	2.97-5.13
$CD_{0.05}$	60.94	3.46	0.32	3.21	0.27
Mean	333.11	97.30	3.76	97.27	3.84
SE(m)±	21.63	1.23	0.11	1.14	0.10
SE(d)±	30.59	1.74	0.16	1.61	0.14
PCV (%)	26.02	22.13	14.26	19.59	11.38
GCV (%)	23.46	22.02	13.27	19.48	10.54
Heritability (h^2 %)	81.31	99.03	86.64	98.93	85.70
Genetic advance (% of mean)	43.58	45.15	25.45	39.91	20.10

MSS: Mean sum of squares due to genotypes at 5%, CD: Critical Difference at 5%

Coefficient of Variation

Results obtained from the study showed that the PCV values were slightly higher than GCV values, although the differences were very less (Table 1), suggesting very small influence of environment in the manifestation of characters. The phenotypic and genotypic coefficients of variation were estimated high for marketable fruit yield per plant (26.02 and 23.46) followed by capsanthin content (22.13 and 22.02) and moderate for vitamin C (19.59 and 19.48), TSS (14.26 and 13.27), and pericarp thickness (11.38 and 10.54) advocating ample diversity and greater potential for improvement through phenotypic selection. Singh *et al.* (2018); Thakur *et al*. (2019a) also found high PCV and GCV values for capsanthin content and marketable fruit yield per plant. Sood *et al*. (2007); Sharma *et al*. (2017) reported moderate estimates of PCV and GCV for TSS, vitamin C, and pericarp thickness.

Heritability and genetic advance

In the present study, heritability estimates (Table 1) were recorded high for all characters. The highest value was observed in capsanthin content (99.03 %) followed by vitamin C (98.93 %), TSS (86.64 %), pericarp thickness (85.70 %), and marketable fruit yield per plant (81.31 %) demonstrating that genotypic variance accounted for a considerable percentage of phenotypic variance and hence these characters might be selected on a phenotypic basis. Strong heritability however, does not imply high genetic gain, and it is not enough to improve by phenotypic selection alone. When used to assess genetic advance, heritability estimates are more useful, hence genetic advance has an advantage over heritability as a guiding element for plant breeders in selection programs. Capsanthin content had the highest value of genetic advance (45.15 %) (Table 1) followed by marketable fruit yield per plant (43.58 %) and vitamin C (39.91 %). On the other hand, TSS (25.45 %) and pericarp thickness (20.10 %) were determined to had moderate genetic advance. Marketable fruit yield per plant, capsanthin content, and vitamin C content all showed high heritability coupled with high genetic advance, indicating the predominance of additive gene action and, as a result, a high genetic gain is expected from selection in such conditions. Pericarp thickness and TSS, on the other hand, had high heritability coupled with modest genetic advance, suggesting the presence of slightly additive gene action. Sood *et al.* (2011); Thakur *et al.* (2017); Singh *et al.* (2018) also reported similar findings for these traits. On the contrary, Pandey *et al.* (2013) reported moderate estimates of heritability for vitamin C.

Table 2: Correlation coefficient between yield and quality traits

Trait		Capsanthin content (ASTA units)	TSS (°Brix)	Vitamin C (mg/100g)	Marketable fruit yield per plant (g)
Pericarp thickness (mm)	P	0.172	-0.388*	0.168	-0.080
	G	0.195*	-0.446*	0.192*	-0.106
Capsanthin content (ASTA units)	P		-0.208*	0.240*	0.007
	G		-0.227*	0.240*	0.013
TSS (°Brix)	P			-0.065	-0.069
	G			-0.075	-0.039
Vitamin C (mg/100g)	P				0.037
	G				0.039

**represents significance at 5%*

Correlation coefficient among quality attributes

In general, the values of genotypic correlation coefficients were higher than phenotypic correlation coefficients (Table 2). This could be explained by the fact that the traits tested had a strong underlying genotypic association, but their phenotypic expression was hindered by environmental influences. At both phenotypic and genotypic levels, capsanthin content was found to have a significant positive association with vitamin C (0.240 and 0.240) and significant negative with TSS (-0.208 and -0.227), indicating that selection for capsanthin content would simultaneously lead to an increase in vitamin C content. Similar results were obtained by Sood *et al.* (2007). At both the phenotypic and genotypic levels, pericarp thickness had a significant and negative correlation with TSS (-0.388 and -0.446). At the genotypic level, it demonstrated a substantial positive correlation with vitamin C (0.192) and capsanthin content (0.195) indicating simultaneously improvement of pericarp thickness, vitamin C, and capsanthin content. Singh *et al.* (2018) also observed similar findings with different materials.

Correlation coefficient between yield and quality attributes

Capsanthin and vitamin C content showed a positive but non-significant correlation, and pericarp thickness and TSS had a negative but non-significant correlation with marketable fruit yield per plant. It implies that there is no inter-relationship between yield and quality parameters (Table 2) and both can be improved independently. Similar results were obtained by Singh *et al*. (2018); Thakur *et al.* (2019b). In the end, it may be concluded that the mean squares due to genotypes were significant for all the characters studied which demonstrated the directional selection could be beneficial for desired genetic improvement. Characters having high heritability and high to moderate genetic advance as a percentage of the mean suggest the involvement of additive genes and selection will be rewarding for the improvement of such characters. Significant positive correlations among quality traits specify that these can be improved simultaneously to produce enriched quality bell peppers. More emphasis should be given to traits like capsanthin content, vitamin C, and pericarp thickness. Non-significant correlations among yield and quality traits signify that these can be improved independently.

ACKNOWLEDGEMENT

The authors are heartily thankful to Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur (HP) for providing necessary facilities and financial support in the form of merit scholarship to conduct this experiment.

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