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Path analysis identify indirect selection criteria for fruit yield in bacterial wilt tolerant genotypes of bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.)

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Abstract
Understanding the direction and magnitude of the correlation between fruit yield and its attributing traits in bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.) is a prerequisite for the identification of such characters whose selection would prove beneficial in any breeding programme. The correlation coefficient analysis measures the mutual relationship between various characters and it determines the component traits on which selection can be relied upon the effect of improvement. The correlation coefficient analysis was studied in 43 genotypes in bell pepper for different characters *viz.*, days to 50 per cent flowering, days to first picking, plant height (cm), primary branches per plant, harvest duration (days), fruit length (cm), fruit width (cm), pericarp thickness (mm), lobes per fruit, average fruit weight (g), marketable fruits per plant, marketable fruit yield per plant (g), capsanthin content (ASTA units), TSS (ºBrix) and ascorbic acid content (mg/100g) under Randomized Complete Block Design with three replications during summer-rainy season, 2018. Significant and positive correlation of marketable fruit yield per plant, both at genotypic and phenotypic levels was recorded with marketable fruits per plant, harvest duration, average fruit weight and fruit width while significant and negative correlations were observed with days to 50 per cent flowering and days to first picking. The data pertaining to phenotypic and genotypic path revealed that marketable fruits per plant had maximum positive direct effect on marketable fruit yield per plant followed by average fruit weight. Similarly, marketable fruit yield was also increased by positive indirect effects of harvest duration and fruit width. Thus, direct selection for the above traits will be helpful in improving marketable fruit yield of bell pepper.

Keywords: Bell pepper genotypes, correlation coefficient, path analysis

Introduction

Bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.; 2n=2x=24) popularly known as Sweet pepper, Capsicum or Shimla Mirch is a high value vegetable and an important cash crop for temperate regions (Thakur *et al.*, 2019) [18]. It was introduced in India by the Britishers during the 19th century in Shimla hills, hence popularly known as "Shimla Mirch". It is an important vegetable crop of sub-tropical and sub-temperate climates which is grown throughout the country for its immature fruits, used in various preparations and salads. In the recent years, its consumption has shown quantum jump because of the rapid growth of fast food industry in India. It imparts special aroma to various dishes which is due to the presence of a flavouring compound (2-methoxy-3-isobutylpyrazine) (Singh *et al.*, 2018) [15]. In India, it is cultivated over an area of 24 thousand hectares with the production of 326 thousand tonnes (Anonymous, 2018) [4]. Bell pepper holds a very coveted position as a leading off season vegetable in Himachal Pradesh generating cash revenues to the farmers by selling of the produce in the neighbouring states and metropolitan cities. In Himachal Pradesh, it is extensively grown as a cash crop in Zone I, II and III in open environment and covers an area of 2,402 hectares with the production of 56,787 tonnes (Anonymous, 2017) [3].

Sufficient variability in the genetic stock is a pre-requisite for initiation of any breeding programme. The correlation between different quantitative and quality characters provides an idea of association that could be effectively exploited to formulate selection strategies for improving yield components. For any effective selection programme, it would be desirable to consider the relative magnitude of association of various characters with yield. The correlation coefficient being the result of cause and effect relationship between different characters may not always provide complete information. Thus, a better understanding of association between the characters is provided by path-coefficient analysis. Knowledge of relationship between the characters is important for indirect improvement of characters which are difficult to quantify and having low heritability.

Materials and Methods

The present investigation was undertaken at the Experimental Farm of Department of Vegetable Science and Floriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Palampur from February-July, 2018. The Experimental Farm is situated at 32°6' N latitude, 76°3' E longitude under mid hill zone of Himachal Pradesh at Palampur at an elevation of 1290.8 m above mean sea level. The place experiences severe winters and mild summers. Agro-climatically, the location represents mid-hill zone of Himachal Pradesh (Zone-II) and is characterized by humid sub-temperate climate with high annual rainfall (2500 mm) of which 80 per cent is received during June to September. The soil of the experimental block was acidic in nature with pH ranging from 5.0 to 5.6 and soil texture was silty clay loam. The experimental material comprised of 43 genotypes of bell pepper of which 39 were advanced breeding lines derived from different inter-varietal crosses. These genotypes were evaluated along with susceptible check (California Wonder), moderately resistant check (Kandaghat Selection) and two resistant checks (EC-464107 and EC-464115) as per the details given in table 1. The nursery was sown on 8th February, 2018 for summer- rainy season crop in plastic pro-trays at the Vegetable Research Farm of CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur. Before sowing, the seeds were treated with Bavistin and Dithane M-45 as a prophylactic measures against fungal pathogens. The seedlings were transplanted in Randomized Complete Block Design (RCBD) with three replications on 3rd April, 2018. Each entry/genotype accommodated 12 plants per replication with inter and intra row spacing of 60 cm and 45 cm, respectively. The experimental field was prepared by ploughing 3-4 times with power tiller upto a depth of 20 cm followed by leveling. The farm yard manure was applied at the rate of 20 t/ha, the chemical fertilizers were applied as per the recommended package of practices (90 Kg N, 75 Kg P_2O_5 and 50 Kg K_2O/ha). One-third dose of N and full doses of FYM, P_2O_5 and K_2O were applied at the time of field preparation. Remaining two third dose of N was top dressed in two equal amounts after 30 and 45 days of transplanting. The data were recorded on five randomly selected plants for days to 50 per cent flowering, days to first picking, plant height (cm), primary branches per plant, harvest duration (days), fruit length (cm), fruit width (cm), pericarp thickness (mm), lobes per fruit, average fruit weight (g), marketable fruits per plant and marketable fruit yield per plant (g). Capsanthin content (ASTA units) from the ripened fruit sample was estimated by the method as described by AOAC (1980) [5]. Total Soluble Solids (ºBrix) was estimated by Hand Refractometer. Ascorbic acid content (mg/100g fresh weight) from the crushed fruit sample was estimated by the method as described by Ranganna (1977) [11].

The genotypic and phenotypic correlations were calculated as per Al-Jibouri *et al.* (1958) [2] by using analysis of variance and covariance matrix in which total variability split into replications, genotypes and errors. The genotypic and phenotypic correlation coefficients were used to find out their direct and indirect contributions towards marketable yield per plant. The direct and indirect paths were obtained according to the method given by Dewey and Lu (1959) [6].

Results and Discussion

Correlation coefficient analysis

The correlation coefficient is a measure of degree of association between two characters. The correlations are of important consideration in the quantitative inheritance of characters and are of practical value in the selection of two or more traits simultaneously. Characters of economic importance like yield is regarded as a complex character or super character which is influenced by many component or contributing traits. If significant correlation values are found between yield and other economic traits, a considerable improvement can be made through selection. The correlation coefficients among the different characters were worked out at phenotypic and genotypic levels. In general, the genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients.

Correlation between marketable fruit yield and other traits

The correlation coefficients among characters (table 2) showed that marketable fruit yield per plant had positive and significant association with marketable fruits per plant (0.889 and 0.884) followed by harvest duration (0.524 and 0.663), average fruit weight (0.275 and 0.234) and fruit width (0.180 and 0.229) at both phenotypic and genotypic levels. Positive association of marketable fruit yield per plant at phenotypic and genotypic level with harvest duration (Sood and Kumar 2013; Minakshi 2017; Sharma *et al.* 2017 and Sharma *et al.* 2019) [17, 8, 13, 12], fruit width (Sharma *et al.* 2017; Sharma *et al.* 2019 and Thakur *et al.* 2019) [13, 12, 18], average fruit weight (Afroza *et al.* 2013; Rana *et al.* 2015; Minakshi 2017; Sharma *et al.* 2017; Sharma *et al.* 2019 and Thakur *et al.* 2019) [1, 10, 13, 12, 18, 8] and marketable fruits per plant (Sood and Kumar 2013; Minakshi 2017; Sharma *et al.* 2017; Singh *et al.* 2018; Sharma *et al.* 2019 and Thakur *et al.* 2019) [17, 8, 13, 15, 12, 18]. This reflects that selection on the basis of these traits might lead to higher marketable yield per plant. Therefore, these traits need to be given special focus for the improvement of fruit yield.

The negative association of marketable fruit yield per plant was observed both at phenotypic and genotypic level with days to 50 per cent flowering (Sood *et al.* 2011; Rana *et al.* 2015 and Sharma *et al.* 2017) [17, 10, 13] and days to first picking (Naik *et al.* 2014 and Sharma *et al.* 2017) [9, 13]. This kind of association indicates that early maturing genotypes had low yield potential. Also, it showed negative and significant correlation with fruit length and lobes per fruit (Minakshi, 2017) [8] at genotypic level. In contrary, Sharma *et al.* (2019) [12] and Thakur *et al.* (2019) [18] reported positive association of lobes per fruit with fruit yield per plant.

Correlation among other traits

Besides this, positive and significant correlation at both phenotypic and genotypic levels was observed for days to first picking with lobes per fruit and TSS; plant height with harvest duration and TSS; harvest duration with average fruit weight, marketable fruit yield per plant and marketable fruits per plant; fruit length with TSS; fruit width with lobes per fruit, average fruit weight and marketable fruit yield per plant; pericarp thickness with lobes per fruit; average fruit weight with marketable fruit yield per plant; marketable fruits per plant with marketable fruit yield per plant and capsanthin content with ascorbic acid. Similarly, positive and significant correlation at genotypic levels was recorded for days to 50 per cent flowering with plant height and fruit width; plant height with primary branches; pericarp thickness with capsanthin content and ascorbic acid and lobes per fruit with ascorbic acid (table 2). Afroza *et al.* (2013) [1]; Rana *et al.* (2015) [10] and Sharma *et al.* (2017) [13] reported positive association of plant height with primary branches per plant; Sood and Kumar (2013) [17]; Sharma *et al.* (2017) [13] and Sharma *et al.* (2019) [12] reported positive association of plant height with harvest duration. Significant and positive association of average fruit weight and marketable fruit yield per plant was reported by Afroza *et al.* (2013) [1]; Rana *et al.* (2015) [10]; Minakshi (2017) [8]; Sharma *et al.* (2017) [13]; Sharma *et al.* (2019) [12] and Thakur *et al.* (2019) [18]. Significant and positive association of marketable fruits per plant and marketable fruit yield per plant was reported by Minakshi (2017) [8]; Sharma *et al.* (2017) [13]; Singh *et al.* (2018) [15]; Sharma *et al.* (2019) [12] and Thakur *et al.* (2019) [18].

Negative association at both phenotypic and genotypic levels of days to 50 per cent flowering with marketable fruit yield per plant; days to first picking with average fruit weight and marketable fruit yield per plant; plant height with pericarp thickness; primary branches with average fruit weight; harvest duration with lobes per fruit; fruit length with fruit width, pericarp thickness, lobes per fruit and marketable fruits per plant; fruit width with capsanthin content; pericarp thickness with average fruit weight and TSS; average fruit weight with capsanthin content and marketable fruits per plant and capsanthin content with TSS. Similarly, negative and significant correlation at genotypic levels was recorded for days to 50 per cent flowering with primary branches per plant and marketable fruits per plant; plant height with lobes per fruit; primary branches with harvest duration; fruit length with marketable fruit yield per plant; fruit width with TSS and lobes per fruit with marketable fruit yield per plant and marketable fruits per plant (table 2). Johri *et al.* (2010) and Sood and Kumar (2013) [17] have reported similar results for fruit length with pericarp thickness; Rana *et al.* (2015) [10]; Sharma *et al.* (2017) [13] and Singh *et al.* (2018) [15] for days to 50 per cent flowering and Sharma *et al.* (2017) [13] for days to first picking with average fruit weight and marketable fruit yield per plant.

Path-coefficient analysis

The correlation coefficients provide information regarding the association of different characters among themselves, whereas better insight into the cause of the association is provided by the path-coefficient analysis (table 3). The path-coefficient analysis allows partitioning of correlation coefficients into direct and indirect effects of various traits towards dependent variable and thus, helps in assessing the cause-effect relationship as well as effective selection. The present study revealed that the direct effects obtained at genotypic level were markedly different from those at phenotypic level. These differences might be due to varying degree of influence of environment on various traits studied, which were also observed from the results of component variance analysis and correlation studies.

Estimates of direct effects at phenotypic and genotypic level

At phenotypic level, the direct positive effect of various traits on marketable fruit yield per plant could be arranged in the following descending order *viz.*, marketable fruits per plant (0.9617), average fruit weight (0.4399), harvest duration (0.0073) and lobes per fruit (0.0051). Whereas, direct negative effects were exhibited by days to first picking (-0.0281), days to 50 per cent flowering (-0.0123), primary branches per plant (-0.0123), TSS (-0.0109), plant height (-0.0080), capsanthin content (-0.0075), fruit length (-0.0054), fruit width (-0.0050), ascorbic acid (-0.0029) and pericarp thickness (-0.0002). Earlier researchers Rana *et al.* (2015) [10] reported negative direct effect of days to 50 per cent flowering on marketable fruit yield per plant, Minakshi (2017) [8] and Sharma *et al.* (2017) [13] reported positive direct effect of marketable fruits per plant and average fruit weight and negative effect of days to first picking, days to 50 per cent flowering, capsanthin content and TSS. Sharma *et al.* (2017) [13] reported positive direct effect of lobes per fruit and negative effect of plant height and ascorbic acid. Singh *et al.* (2018) and Sharma *et al.* (2019) [15, 22] revealed positive direct effect of marketable fruits per plant and average fruit weight and negative direct effect of fruit width, plant height and ascorbic acid on marketable fruit yield per plant.

Estimates of direct effects at genotypic level showed that marketable fruits per plant (0.9969) had the highest positive direct effect on marketable yield per plant followed by average fruit weight (0.4701), plant height (0.0187), pericarp thickness (0.0149), fruit width (0.0101), lobes per fruit (0.0086), capsanthin content (0.0038) and fruit length (0.0035), while primary branches per plant (-0.0417), days to first picking (-0.0369), days to 50 per cent flowering (-0.0304), harvest duration (-0.0158), ascorbic acid (-0.0106) and TSS (-0.0015) exhibited negative direct effects. Rana *et al.* (2015) [10] reported negative direct effect of days to 50 per cent flowering on marketable fruit yield per plant, Minakshi (2017) [8] reported positive direct effect of marketable fruits per plant, average fruit weight and fruit width and negative direct effect of primary branches per plant, days to 50 per cent flowering, harvest duration and ascorbic acid. Sharma *et al.* (2017) [13] reported positive direct effect of average fruit weight and fruit width and negative direct effect of primary branches per plant, days to 50 per cent flowering, harvest duration and ascorbic acid. Singh *et al.* (2018) [15] observed positive direct effect of marketable fruits per plant followed by fruit length and average fruit weight, while negative direct effect of days to 50 per cent flowering and primary branches per plant. Sharma *et al.* (2019) [12] reported positive direct effect of average fruit weight and negative direct effect of ascorbic acid. Thakur *et al.* (2019) [18] also found positive direct effect of fruit weight and fruit width on fruit yield per plant.

Estimates of indirect effects at phenotypic and genotypic level

Days to 50 per cent flowering exhibited negative significant association with marketable fruit yield per plant which was because of maximum negative indirect effect via marketable fruits per plant (-0.1609 and -0.2505) both at phenotypic and genotypic level, respectively followed by average fruit weight (-0.0100) at phenotypic level. Days to first picking had negative and significant association with marketable fruit yield per plant which was because of negative indirect effect via marketable fruits per plant (-0.1097 and -0.1276) followed by average fruit weight (-0.0784 and -0.0920). Harvest duration exhibited positive and significant correlation with marketable fruit yield per plant which was because of positive indirect effects via marketable fruits per plant (0.4296 and 0.5391) followed by average fruit weight (0.0857 and

0.1256). At genotypic level, fruit length had negative correlation with marketable fruit yield per plant which was because of negative indirect effect via marketable fruits per plant (-0.1934) followed by fruit width (-0.0069) and pericarp thickness (-0.0057). For fruit width, break up of association revealed that the indirect effects via average fruit weight (0.1320 and 0.1562) and marketable fruits per plant (0.0434 and 0.0654) were the main contributor in building up the positive correlation with marketable fruit yield per plant at phenotypic and genotypic level, respectively. Lobes per fruit had significant negative association with marketable fruit yield per plant at genotypic level. The indirect effects via marketable fruits per plant (-0.1738), average fruit weight (-0.0172), days to first picking (-0.0074) and primary branches per plant (-0.0069) were the main contributor to the total association. A positive indirect effect of average fruit weight was noticed via days to first picking (0.0050 and 0.0072) and primary branches per plant (0.0022 and (0.0103) both at phenotypic and genotypic levels, respectively and via capsanthin content (0.0015) and harvest duration (0.0014) at phenotypic level. These indirect effects add to the direct effect resulting in positive association of average fruit weight with the marketable fruit yield per plant at both the levels. Marketable fruits per plant exerted positive indirect effect via days to first picking (0.0032 and 0.0047) and days to 50 per cent flowering (0.0021 and 0.0076) at both phenotypic and genotypic levels, respectively and via harvest duration (0.0032) and plant height (0.0027) at genotypic level. These indirect effects add to the direct effect resulting in positive correlation of marketable fruits per plant with the marketable fruit yield per plant at both phenotypic and genotypic levels. Similar results were reported by Rana *et al.* (2015) [10], Minakshi (2017) [8], Sharma *et al.* (2017) [13], Sharma *et al.* (2019) [12] and Thakur *et al.* (2019) [18].

It is now realized that the association between the characters, whose degree is being measured, does not exist by itself that a complicated interaction pathway is involved in which various other attributes may also take part. Therefore, it would be interesting to study the direct and indirect contribution of each trait towards marketable fruit yield per plant.

In present investigation, marketable fruits per plant showed maximum positive direct effect on marketable fruit yield per plant followed by average fruit weight (table 3). Thus, higher number of marketable fruits per plant and average fruit weight should be considered in selection criteria for increasing the marketable fruit yield per plant. However, marketable fruit yield per plant was also significantly increased by maximum positive indirect effects of harvest duration via marketable fruits per plant followed by fruit width via average fruit weight. Therefore, from present study, it is concluded that characters such as marketable fruits per plant, average fruit weight, harvest duration and fruit width have highest selection index and thereby more emphasis need for inclusion of these characters in improvement programme. As observed in the present investigation, the contribution of average fruit weight had been reported by Sharma *et al.* (2010) [14], Sood *et al.* (2011) [16], Rana *et al.* (2015) [10], Minakshi (2017) [8], Sharma *et al.* (2017) [13], Singh *et al.* (2018) [15] and Sharma *et al.* (2019) [12] and marketable fruits per plant by Minakshi (2017) [8], Sharma *et al.* (2017) [13], Singh *et al.* (2018) [15] and Sharma *et al.* (2019) [12].

The residual effects were 0.0135 and 0.0004 at phenotypic and genotypic levels, respectively. The low magnitude of residual effect indicated that the traits included in the present investigation accounted for most of the variation present in the dependent variable i.e. marketable fruit yield per plant.

Conclusion

It is concluded that marketable fruit yield per plant had positive and significant association with marketable fruits per plant, harvest duration, average fruit weight and fruit breadth. Path coefficient analysis depicted that marketable fruits per plant and average weight had maximum direct effect on marketable fruit yield per plant. Similarly, marketable fruit yield per plant was also increased by positive indirect effects of harvest duration and fruit width. Hence direct selection on the basis of these traits is reliable for yield improvement in bell pepper.

Table 1: List of bell pepper genotypes and their sources

Genotypes	Sources
DPCBWR-14-1, DPCBWR-14-2, DPCBWR-14-3, DPCBWR-14-4, DPCBWR-14-5, DPCBWR-14-5-1, DPCBWR-14-6, DPCBWR-14-6-1, DPCBWR-14-7, DPCBWR-14-7-1, DPCBWR-14-8-1, DPCBWR-14-9, DPCBWR-14-10, DPCBWR-14-11, DPCBWR-14-11 (BS), DPCBWR-14-12, DPCBWR-14-13, DPCBWR-14-14, DPCBWR-14-15, DPCBWR-14-16, DPCBWR-14-17, DPCBWR-14-20, DPCBWR-14-22, DPCBWR-14-23, DPCBWR-14-24, DPCBWR-14-24-1, DPCBWR-14-25, DPCBWR-14-28, DPCBWR-14-29, DPCBWR-14-30, DPCBWR-14-31, DPCBWR-14-32, DPCBWR-14-35, DPCBWR-14-36, DPCBWR-14-38, DPCBWR-14-39, DPCBWR-14-40, L-22, L-4	Department of Vegetable Science & Floriculture, CSKHPKV, Palampur (HP), India
EC-464107, EC-464115 (Resistant Checks)	AVRDC, Taiwan
Kandaghat Selection (Moderately Resistant Check)	RRS, Kandaghat, UHF, Solan (HP), India
California Wonder (Susceptible Check)	ICAR - IARI Regional Station, Katrain (Kullu), HP, India

Table 2: Estimates of correlation coefficients at the phenotypic (P) and genotypic (G) levels for quantitative and quality traits in 43 genotypes of bell pepper

Traits		Quantitative Traits										Quality Traits			
		Phenological and Structural Traits				Fruit Yield Traits									
		Days to first picking	Plant height (cm)	Primary branches per plant	Harvest duration (days)	Fruit Length (cm)	Fruit Width (cm)	Pericarp Thickness (mm)	Lobes per fruit	Average fruit weight (g)	Marketable fruits per plant	Capsanthin content (ASTA units)	TSS (°Brix)	Ascorbic Acid (mg/100g)	Marketable fruit yield per plant (g)
Days to 50 per cent flowering	P	0.060	0.107	-0.100	0.041	-0.010	0.088	-0.039	0.026	-0.023	-0.167	-0.046	0.125	0.095	-0.186*
	G	0.089	0.182*	-0.227*	0.047	-0.010	0.191*	-0.064	0.053	0.020	-0.251*	-0.074	0.167	0.123	-0.263*
Days to first picking	P		0.019	-0.048	-0.134	0.004	-0.078	0.072	0.177*	-0.178*	-0.114	-0.050	0.207*	-0.124	-0.218*
	G		0.006	-0.064	-0.161	0.005	-0.087	0.052	0.200*	-0.196*	-0.128	-0.053	0.229*	-0.129	-0.251*
Plant height (cm)	P			0.166	0.211*	-0.011	0.009	-0.319*	-0.144	-0.095	0.132	-0.069	0.193*	-0.023	0.072
	G			0.211*	0.238*	-0.007	-0.018	-0.341*	-0.175*	-0.123	0.144	-0.075	0.227*	-0.028	0.079
Primary branches per plant	P				-0.120	0.030	-0.010	-0.071	0.117	-0.174*	0.143	-0.032	-0.007	-0.048	0.050
	G				-0.187*	0.021	0.018	-0.055	0.164	-0.246*	0.096	-0.038	-0.030	-0.056	-0.044
Harvest duration (days)	P					-0.053	0.049	0.012	-0.236*	0.195*	0.447*	0.084	-0.008	0.043	0.524*
	G					-0.067	0.032	0.006	-0.300*	0.267*	0.541*	0.086	-0.006	0.054	0.663*
Fruit Length (cm)	P						-0.619*	-0.360*	-0.529*	0.049	-0.185*	-0.025	0.282*	-0.041	-0.164
	G						-0.685*	-0.384*	-0.572*	0.066	-0.194*	-0.025	0.310*	-0.040	-0.176*
Fruit Width (cm)	P							0.091	0.267*	0.300*	0.045	-0.196*	-0.165	-0.061	0.180*
	G							0.066	0.303*	0.332*	0.066	-0.219*	-0.208*	-0.073	0.229*
Pericarp Thickness (mm)	P								0.214*	-0.231*	0.016	0.172	-0.388*	0.168	-0.080
	G								0.230*	-0.276*	0.012	0.195*	-0.446*	0.192*	-0.106
Lobes per fruit	P									-0.040	-0.140	-0.058	-0.130	0.170	-0.151
	G									-0.037	-0.174*	-0.063	-0.134	0.183*	-0.194*
Average fruit weight (g)	P										-0.180*	-0.194*	0.082	0.154	0.275*
	G										-0.244*	-0.215*	0.102	0.172	0.234*
Marketable fruits per plant	P											0.097	-0.089	-0.032	0.889*
	G											0.109	-0.069	-0.038	0.884*
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
Ascorbic Acid (mg/100g)	P														0.037
	G														0.039

*Significant at 5% level

Table 3: Estimates of direct and indirect effects of quantitative and quality traits on marketable fruit yield per plant at the phenotypic (P) and genotypic (G) levels in 43 genotypes of bell pepper

Traits		Quantitative traits											Quality traits			
		Phenological and Structural traits					Fruit yield traits									
		Days to 50% flowering	Days to first picking	Plant height (cm)	Primary branches per plant	Harvest duration (days)	Fruit length (cm)	Fruit width (cm)	Pericarp thickness (mm)	Lobes per fruit	Average fruit weight (g)	Marketable fruits per plant	Capsanthin content (ASTA units)	TSS (ºBrix)	Ascorbic acid content (mg/100 g)	Marketable fruit yield per plant (g)
Days to 50% flowering	P	-0.0123	-0.0017	-0.0009	0.0012	0.0003	0.0001	-0.0004	0.0000	0.0001	-0.0100	-0.1609	0.0004	-0.0014	-0.0003	-0.1858*
	G	-0.0304	-0.0033	0.0034	0.0095	-0.0007	0.0000	0.0019	-0.0010	0.0005	0.0093	-0.2505	-0.0003	-0.0002	-0.0013	-0.2631*
Days to first picking	P	-0.0007	-0.0281	-0.0002	0.0006	-0.0010	0.0000	0.0004	0.0000	0.0009	-0.0784	-0.1097	0.0004	-0.0023	0.0004	-0.2178*
	G	-0.0027	-0.0369	0.0001	0.0027	0.0025	0.0000	-0.0009	0.0008	0.0017	-0.0920	-0.1276	-0.0002	-0.0003	0.0014	-0.2514*
Plant height (cm)	P	-0.0013	-0.0005	-0.0080	-0.0020	0.0015	0.0001	0.0000	0.0001	-0.0007	-0.0420	0.1269	0.0005	-0.0021	0.0001	0.0724
	G	-0.0055	-0.0002	0.0187	-0.0088	-0.0038	0.0000	-0.0002	-0.0051	-0.0015	-0.0579	0.1439	-0.0003	-0.0003	0.0003	0.0792
Primary branches per plant	P	0.0012	0.0014	-0.0013	-0.0123	-0.0009	-0.0002	0.0001	0.0000	0.0006	-0.0767	0.1374	0.0002	0.0001	0.0001	0.0497
	G	0.0069	0.0024	0.0039	-0.0417	0.0030	0.0001	0.0002	-0.0008	0.0014	-0.1157	0.0960	-0.0002	0.0000	0.0006	-0.0439
Harvest duration (days	P	-0.0005	0.0038	-0.0017	0.0015	0.0073	0.0003	-0.0002	0.0000	-0.0012	0.0857	0.4296	-0.0006	0.0001	-0.0001	0.5238*
	G	-0.0014	0.0059	0.0045	0.0078	-0.0158	-0.0002	0.0003	0.0001	-0.0026	0.1256	0.5391	0.0003	0.0000	-0.0006	0.6631*
Fruit length (cm)	P	0.0001	-0.0001	0.0001	-0.0004	-0.0004	-0.0054	0.0031	0.0001	-0.0027	0.0217	-0.1775	0.0002	-0.0031	0.0001	-0.1641
	G	0.0003	-0.0002	-0.0001	-0.0009	0.0011	0.0035	-0.0069	-0.0057	-0.0049	0.0310	-0.1934	-0.0001	-0.0005	0.0004	-0.1763*
Fruit width (cm)	P	-0.0011	0.0022	-0.0001	0.0001	0.0004	0.0033	-0.0050	0.0000	0.0014	0.1320	0.0434	0.0015	0.0018	0.0002	0.1801*
	G	-0.0058	0.0032	-0.0003	-0.0008	-0.0005	-0.0024	0.0101	0.0010	0.0026	0.1562	0.0654	-0.0008	0.0003	0.0008	0.2288*
Pericarp thickness (mm	P	0.0005	-0.0020	0.0026	0.0009	0.0001	0.0019	-0.0005	-0.0002	0.0011	-0.1017	0.0151	-0.0013	0.0042	-0.0005	-0.0798
	G	0.0020	-0.0019	-0.0064	0.0023	-0.0001	-0.0014	0.0007	0.0149	0.0020	-0.1295	0.0122	0.0007	0.0007	-0.0020	-0.1059
Lobes per fruit	P	-0.0003	-0.0050	0.0012	-0.0015	-0.0017	0.0029	-0.0013	-0.0001	0.0051	-0.0174	-0.1347	0.0004	0.0014	-0.0005	-0.1515
	G	-0.0016	-0.0074	-0.0033	-0.0069	0.0047	-0.0020	0.0030	0.0034	0.0086	-0.0172	-0.1738	-0.0002	0.0002	-0.0019	-0.1943*
Average fruit weight (g)	P	0.0003	0.0050	0.0008	0.0022	0.0014	-0.0003	-0.0015	0.0001	-0.0002	0.4399	-0.1727	0.0015	-0.0009	-0.0005	0.2750*
	G	-0.0006	0.0072	-0.0023	0.0103	-0.0042	0.0002	0.0033	-0.0041	-0.0003	0.4701	-0.2433	-0.0008	-0.0002	-0.0018	0.2336*
Marketable fruits per plant	P	0.0021	0.0032	-0.0011	-0.0018	0.0032	0.0010	-0.0002	0.0000	-0.0007	-0.0790	0.9617	-0.0007	0.0010	0.0001	0.8888*
	G	0.0076	0.0047	0.0027	-0.0040	-0.0085	-0.0007	0.0007	0.0002	-0.0015	-0.1147	0.9969	0.0004	0.0001	0.0004	0.8843*
Capsanthin content (ASTA units)	P	0.0006	0.0014	0.0006	0.0004	0.0006	0.0001	0.0010	0.0000	-0.0003	-0.0852	0.0935	-0.0075	0.0023	-0.0007	0.0066
	G	0.0023	0.0020	-0.0014	0.0016	-0.0014	-0.0001	-0.0022	0.0029	-0.0005	-0.1009	0.1088	0.0038	0.0003	-0.0025	0.0127
TSS (ºBrix)	P	-0.0015	-0.0058	-0.0015	0.0001	-0.0001	-0.0015	0.0008	0.0001	-0.0007	0.0361	-0.0855	0.0016	-0.0109	0.0002	-0.0687
	G	-0.0051	-0.0084	0.0042	0.0012	0.0001	0.0011	-0.0021	-0.0066	-0.0012	0.0480	-0.0691	-0.0009	-0.0015	0.0008	-0.0393
Ascorbic acid content (mg/100 g)	P	-0.0012	0.0035	0.0002	0.0006	0.0003	0.0002	0.0003	0.0000	0.0009	0.0678	-0.0311	-0.0018	0.0007	-0.0029	0.0374
	G	-0.0037	0.0048	-0.0005	0.0023	-0.0009	-0.0001	-0.0007	0.0029	0.0016	0.0807	-0.0376	0.0009	0.0001	-0.0106	0.0391

Residual effect at phenotypic level (P) = 0.0135 and genotypic level (G) = 0.0004; Bold values indicate direct effects

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