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Genetic variability among bacterial wilt resistant genotypes of sweet pepper for yield and morpho-physiological traits under mid hill conditions of North Western Himalayas

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Abstract

The potential for improvement in crops is proportional to the magnitude of genetic variability present in the germplasm. Therefore, the present study was carried out with twenty six bacterial wilt resistant genotypes of sweet pepper (*Capsicum annuum* L. var. *grossum* Sendt.) to assess the extent of genetic variability, correlation and path analysis among yield and yield attributing traits. Significant variability was observed for all quantitative and quality traits studied. On the basis of mean performance, the genotype PCWR-1-3-08 was found to be promising for marketable yield. High phenotypic (PCV) and genotypic coefficients of variation (GCV) were observed for total number of fruits/plant, number of marketable fruits/plant, total yield/ plant, marketable yield/ plant and capsaicin content. High heritability coupled with high genetic advance was noted for pericarp thickness, number of marketable fruits/plant, marketable yield/plant and capsaicin content, which indicated the role of additive gene action for the inheritance of these traits. These traits are likely to respond better to selection. Correlation and path analysis studies indicated that number of marketable fruits/ plant, average fruit weight, fruit length and days to first harvest contributed to marketable yield. From the present study, it was concluded that the genotypes PCWR-1-3-08, PCWR-Cap-7-08, PCWR-Cap-4-08, PCWR-33-1-3-08 and PCWR-33-3-1-08 could be directly used after multi–location testing as these possessed inherent ability to high yield along with bacterial wilt resistance and superior horticultural and quality traits.

Key words: *Capsicum annuum,* Correlation, Heritability, Path analysis, Variability.

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Introduction

Sweet pepper (*Capsicum annuum* L. var. *grossum* Sendt.) is a cultivar group of the species *Capsicum annuum* belonging to nightshade family. It was introduced in India by the Britishers in the 19th century in Shimla hills and due to this reason it is also 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). In Himachal Pradesh, it enjoys the status of off-season vegetable, as during summer-rainy season large quantity of capsicum is transported to the distant markets in the plain areas which bring a boost in the economic conditions of the small and marginal farmers of the state. Mid hills of the state are leading suppliers of fresh market bell pepper. This produce is not only off-season for market in the plains, but is of excellent quality mainly because of genotype x environment interaction which produces big size blocky fruits with high flavour and shiny skin.

The potential for improvement in any crop is directly related to the magnitude of variability present in the germplasm (Kumari 2013). In sweet pepper, a wide range of variability is available, which provides possibilities to improve fruit yield through a breeding programme. When variability is partitioned into heritable and non-heritable components, efficiency of selection is better understood. Further, it is extremely important to study the interrelationships among various characters for success in crop improvement programmes (Babu et al. 2015). The relative importance of direct and indirect contributions of each trait on yield provides an opportunity for its improvement. The first step is the

evaluation of variability in germplasm to identify potential genotypes for use in future breeding programmes. Therefore, the present investigation was undertaken to assess the genetic variability and identification of yield contributing traits for genetic improvement of sweet pepper.

Materials and Methods

The experimental material constituted twenty six lines developed at CSK HPKV, Palampur and a cultivar (California Wonder) of capsicum which was taken from IARI, Regional Research Station, Katrain (Kullu, H.P.). The experiment was undertaken during the year 2014-15 at Experimental Farm of the Department of Vegetable and Floriculture CSK HPKV, Palampur situated at 32^0 6' N latitude and 76^0 3' E longitude at an elevation of 1290.8m above mean sea level. The location is characterized by humid and temperate climate with an annual rainfall of 2,500 mm of which 80% is received during June to September and represents the mid-hill zone of Himachal Pradesh. The experiment was conducted in a randomized complete block design with three replications.

Ten plants in each replication were taken at random from each treatment to determine days to 50% flowering, days to first harvest, fruit shape index, fruit length (cm), fruit width (cm), fruit pedicel length (cm), pericarp thickness (mm), number of locules/fruit, average fruit weight (g), total number of fruits/plant, number of marketable fruits/plant, total yield/plant (g), marketable yield/plant (g), number of seeds/fruit, number of branches/plant, plant height (cm), ascorbic acid (mg/100g), capsaicin content (%), TSS content (%) and moisture content (%). The parameters of variability were estimated following Burton and De Vane (1953). Heritability in broad sense (h^2_{bs}) and expected genetic advance (GA) resulting from the selection of 5 % superior individuals was calculated as per the formula given by Burton and De Vane (1953) and Johnson et al. (1955). The phenotypic and genotypic coefficients of correlation were computed following Al-Jibouri et al. (1958). The significance of phenotypic coefficients of correlation was tested against 'r' values as given by Fisher and Yates (1963) at n-2 degree of freedom, where 'n' is the number of genotypes. The path-coefficient analysis of important horticultural traits, as well as quality traits with yield was done following Dewey and Lu (1959).

Results and Discussion

The analysis of variance revealed significant differences among the genotypes for all the quantitative and quality traits studied. These differences indicated the presence of significant amount of variability and considerable scope for improvement. Sufficient genetic variability for many of the traits studied has also been reported by earlier workers with their genetic material under their environmental conditions (Sood et al. 2007; Rana et al. 2015).

A perusal of the results (Table 1) revealed that the values of PCV were higher than GCV for all the traits. Higher magnitude of PCV and GCV for pericarp thickness, number of fruits/plant, number of marketable fruits/plant, total yield/plant, marketable yield/plant and capsaicin content indicated the presence of substantial variability ensuring ample scope for improvement through selection of the traits. PCV and GCV were moderate for fruit shape index, plant height, fruit length, fruit width and number of locules/fruit and average fruit weight, suggesting that these traits have less potential for direct selection. Estimates of PCV and GCV were low for TSS content, moisture content, days to fruit harvest, days to 50% flowering, seeds/fruit, ascorbic acid content, number of branches/plant, and fruit pedicel length. These results further substantiate the findings of earlier workers for fruit yield (Sood et al. 2007), fruits/plant, average fruit weight (Verma et al. 2004) and fruit width (Sreelathakumary and Rajamony 2002).

Heritability is a measure of heritable variation, and it is helpful in predicting the expected amount of improvement to be achieved through selection together with the genotypic coefficient of variation (Burton and De Vane 1953). In this context, Capsaicin content, gross yield /plant, plant height, marketable yield/plant, days to first harvest, pericarp thickness, total number of fruits/plant, fruit length, number of marketable fruits/plant, days to 50% flowering and fruit width exhibited high heritability (Table 1), indicating that these traits were less influenced by the environment. This suggested that selection could be made for these traits on the basis of phenotypic expression. However, moderate heritability was recorded for number of seeds/fruit, TSS content, fruit shape index, fruit pedicel length, number of branches/ plant, average fruit weight and moisture content. Ascorbic acid and locules/fruit revealed low heritability. Higher estimates of heritability have also been reported by earlier workers for fruit yield/plant (Nehru et al. 2003), plant height (Sreelathakumary and Rajamony 2003), days to fruit harvest, fruit length, days to 50 % flowering (Verma et al. 2004), fruits /plant (Dipendra and Gautam 2002) and fruit width (Sreelathakumary and Rajamony 2002).

Johnson et al. (1955) stressed that for estimating the real effects of selection, heritability alone is not sufficient

Table 1: Estimates of parameters of variability for quantitative and quality traits in bell pepper

	Traits	Range	General mean ± SE(m)	Variance			Coefficient of variation			Heritability (h^2) (%)	Genetic Advance (K= 2.05)	Genetic Advance (% of mean)
				Pheno-typic	Geno-typic	Environmental	Phenotypic (PCV)	Genotypic (GCV)	Environmental (ECV)			
I	**Quantitative traits**											
	Days to 50 % flowering	47.00-50.00	48.03±0.37	1.14	0.99	0.14	2.22	2.08	0.78	87.74	1.93	4.02
	Days to first harvest	70.00-73.00	71.01±0.39	1.14	0.07	0.06	1.50	1.46	0.34	94.66	2.08	2.93
	Fruit shape index	1.07-2.12	1.43±0.08	0.07	0.06	0.02	19.12	16.41	9.81	73.70	0.42	29.03
	Fruit length (cm)	4.01-8.53	6.26±0.17	0.90	0.82	0.09	15.14	14.41	4.66	90.53	1.77	28.24
	Fruit width (cm)	3.74-6.96	4.47±0.20	0.67	0.55	0.12	18.31	16.62	7.70	82.32	1.39	31.07
	Fruit pedicel length (cm)	2.70-3.63	3.07±0.09	0.08	0.05	0.02	8.92	7.35	5.05	67.91	0.38	12.47
	Pericarp thickness (mm)	2.00-5.13	3.23±0.12	0.71	0.66	0.05	26.04	25.20	6.59	93.60	1.62	50.21
	Number of locules / fruit	2.67-3.67	3.33±0.31	0.33	0.30	0.03	17.25	16.53	4.94	8.19	0.10	2.91
	Average fruit weight (g)	41.75-64.67	46.66±1.95	34.60	22.74	11.85	12.61	10.22	7.38	65.74	7.97	17.07
	Total number of fruits / plant	5.59-15.66	10.67±0.41	7.23	6.70	0.53	25.18	24.25	6.82	92.68	5.13	48.08
	Number of marketable fruits /plant	4.75-13.31	8.21±0.60	5.44	4.90	0.53	28.40	26.98	8.88	90.23	4.33	52.79
	Total yield / plant	251.33-764.27	490.89±9.59	13109.83	12824.51	285.31	23.32	23.07	3.44	97.82	230.73	47.00
	Marketable yield / plant	213.56-575.94	377.98±14.20	9296.14	8993.53	302.60	25.51	25.09	4.60	96.74	192.15	50.84
	Number of seeds / fruit	108.60-124.20	115.65±3.29	17.78	13.99	3.79	3.64	3.23	1.68	78.69	6.84	5.91
	Number of branches / plant	3.80-5.30	4.43±0.12	0.14	0.09	0.04	8.55	6.96	4.95	66.48	0.52	11.72
	Plant height (cm)	39.11-83.77	63.23±1.06	135.17	131.69	3.48	18.36	18.15	2.95	97.43	23.33	36.90
II	**Quality traits**											
	Ascorbic acid (mg/100g)	101.62-122.24	109.26±2.92	135.17	33.81	26.56	5.32	4.72	2.46	21.44	2.57	2.35
	Capsaicin content (%)	0.014 -0.089	0.06±0.001	0.0005	0.0005	0.0000	40.45	40.31	3.37	99.30	0.05	82.75
	TSS content (%)	6.05-6.28	6.12±0.02	0.003	0.002	0.001	0.92	0.80	0.44	76.55	0.09	1.45
	Moisture content (%)	93.00-97.00	95.24±0.39	1.23	0.75	0.48	1.17	0.91	0.73	61.20	1.40	1.47

and genetic advance along with heritability is more useful. High heritability along with high genetic advance was recorded for pericarp thickness, number of marketable fruits/plant, marketable yield/plant and capsaicin content, whereas high to moderate heritability coupled with high to moderate genetic advance was recorded for fruit shape index, fruit length, fruit width, total number of fruits/plant, gross yield/plant and plant height. The results revealed that the inheritance of these characters is under the control of additive gene action (Panse 1957). Similar results have been reported earlier for fruit yield/plant (Sreelathakumary and Rajamony 2002), fruits/plant, fruit length (Verma et al. 2004), plant height (Ben-Chaim and Paran 2000), fruit width (Ibrahim et al. 2001) and capsaicin content (Khurana et al. 2003). High heritability along with low genetic advance was recorded for days to 50% flowering and days to first harvest, whereas low heritability associated with low genetic advance was noticed for vitamin C content. This indicated the preponderance of non-additive genes for its inheritance. These findings are in agreement with those of Ibrahim et al. (2001) and Verma et al. (2004).

In the present study, in general the genotypic correlation coefficients were higher than the corresponding phenotypic ones (Table 2), 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 the environment. Similar results have also been reported by Sood et al. (2007) in capsicum. Looking at these associations (Table 2), it appeared that marketable yield/plant had positive and highly significant correlations with gross yield/plant, number of marketable fruits/plant and total number of fruits/plant both at phenotypic and genotypic levels. Positive association of fruit yield with fruits/plant was also reported by Khurana et al. (2003) and Dipendra and Gautam (2003). Further, positive association was observed for moisture content with pericarp thickness; TSS content with average fruit weight, days to first harvest, days to 50% flowering, total fruits/plant and vitamin C content; capsaicin content with average fruit weight; vitamin C with fruit width and average fruit weight and seeds/fruit with fruit shape index. Fruit length and fruit shape index can be increased with the increase in plant height as these are positively correlated. Gross yield/plant increases with total number of fruits/plant and number of marketable fruits/plant due to positive correlation. Number of marketable fruits/plant was found to be positively correlated with total fruits/plant. The occurrence of positive correlation of average fruit weight with fruit length, fruit width and pericarp thickness revealed that the improvement in the average fruit weight is brought about by selecting the related traits. Similar results had been obtained by earlier workers for average fruit weight (Sharma et al. 2010).

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

Traits		Quantitative traits														Quality traits				
		Days to first harvest (days)	Fruit shape index	Fruit length (cm)	Fruit width (cm)	Fruit pedicel length (cm)	Pericarp thickness (mm)	Number of locules / fruit	Average fruit weight (g)	Total number of fruits /plant	Number of marketable fruits / plant	Total yield /plant	Number of seeds /fruit	Number of branches /plant	Plant height (cm)	Ascorbic acid (mg/100g)	Capsaicin content (%)	TSS content (%)	Moisture content (%)	Marketable yield / plant
Days to 50 % flowering (days)	P	**0.967***	0.015	**0.312***	**0.318***	**0.256***	0.088	-0.107	0.170	**-0.271***	-0.247	-0.208	0.137	-0.026	**-0.321***	0.082	0.196	**0.297***	0.151	-0.213
	G	1.001	0.014	0.359	0.394	0.335	0.090	-0.464	0.220	-0.302	-0.279	-0.219	0.165	0.035	-0.350	0.021	0.213	0.343	0.127	-0.227
Days to first harvest	P		0.033	**0.318***	**0.305***	**0.277***	0.057	-0.074	0.164	**-0.221***	-0.201	-0.154	0.098	0.010	**-0.319***	0.033	0.171	**0.316***	0.094	-0.162
	G		0.013	0.329	0.366	0.367	0.058	-0.356	0.213	-0.240	-0.222	-0.161	0.094	0.021	-0.337	-0.010	0.178	0.340	0.099	-0.172
Fruit shape index	P			**0.551***	**-0.597***	**0.269***	-0.014	0.097	0.059	-0.135	-0.090	-0.113	**0.269***	**-0.385***	**0.405***	-0.197	-0.002	-0.038	-0.208	-0.073
	G			0.573	-0.525	0.337	-0.023	0.478	0.039	-0.162	-0.110	-0.142	0.326	-0.530	0.491	-0.384	-0.002	-0.051	-0.303	-0.095
Fruit length (cm)	P				**0.327***	**0.249***	0.150	-0.078	**0.352***	**-0.291***	**-0.291***	-0.132	0.137	**-0.347***	**0.221***	0.067	0.139	0.035	-0.144	-0.086
	G				0.389	0.288	0.164	-0.260	0.468	-0.330	-0.256	-0.148	0.162	-0.413	0.241	0.138	0.145	0.043	-0.185	-0.103
Fruit width (cm)	P					-0.076	0.196	-0.207	**0.348***	-0.178	-0.163	-0.020	-0.172	0.106	**-0.310***	**0.293***	0.204	0.156	0.107	-0.030
	G					-0.093	0.233	-0.824	0.516	-0.209	-0.196	-0.020	-0.187	0.161	-0.350	0.616	0.222	0.200	0.154	-0.032
Fruit pedicel length (cm)	P						0.076	0.077	0.021	0.171	0.188	0.189	0.038	-0.164	0.133	-0.115	-0.132	-0.017	-0.111	0.206
	G						0.093	0.934	0.017	0.206	0.229	0.220	0.102	-0.237	0.158	-0.505	-0.165	-0.001	-0.187	0.242
Pericarp thickness (mm)	P							0.030	**0.341***	-0.174	**-0.229***	-0.056	0.070	0.064	0.011	0.177	0.182	0.205	**0.221***	-0.133
	G							0.187	0.463	-0.200	-0.264	-0.061	0.095	0.060	0.016	0.381	0.187	0.272	0.265	-0.148
Number of locules / fruit	P								-0.026	0.195	0.211	0.175	0.053	-0.152	0.037	0.069	-0.193	0.177	**-0.237***	0.199
	G								-0.671	1.001	1.120	0.676	0.011	-0.392	0.206	-0.712	-0.706	0.201	-0.288	0.861
Average fruit weight (g)	P									**-0.364***	**-0.389***	0.086	-0.143	**-0.269***	-0.180	**0.231***	**0.333***	**0.383***	0.167	-0.005
	G									-0.292	-0.302	0.087	-0.245	-0.305	-0.231	0.714	0.441	0.532	0.331	0.032
Total number of fruits / plant	P										**0.955***	**0.886***	-0.028	0.121	0.062	-0.134	-0.167	**0.281***	-0.046	**0.890***
	G										0.952	0.919	-0.009	-0.099	0.064	-0.254	-0.173	-0.329	-0.115	0.904
Number of marketable fruits / plant	P											**0.818***	-0.043	0.108	0.064	-0.112	-0.164	**-0.267***	-0.040	**0.918***
	G											0.856	0.005	0.014	0.128	-0.083	-0.237	-0.300	-0.202	0.940
Total yield / plant	P												-0.131	-0.025	0.008	-0.048	-0.004	-0.134	0.035	**0.942***
	G												-0.144	-0.042	0.006	-0.050	-0.004	-0.164	0.032	0.944
Number of seeds / fruit	P													0.176	0.097	0.061	-0.090	-0.012	-0.042	-0.110
	G													0.300	0.102	-0.060	-0.096	0.044	-0.109	-0.119
Number of branches /plant	P														-0.064	0.034	-0.129	-0.060	0.101	-0.071
	G														-0.102	0.119	-0.154	-0.051	0.166	-0.116
Plant height (cm)	P															**-0.224***	**-0.478***	**-0.314***	-0.140	0.074
	G															0.517	-0.487	-0.344	-0.194	0.073
Ascorbic acid (mg/100g)	P																0.055	**0.229***	0.072	0.015
	G																0.112	0.426	0.613	0.104
Capsaicin content (%)	P																	0.154	-0.157	-0.096
	G																	0.174	-0.195	-0.098
TSS content (%)	P																		0.014	-0.131
	G																		0.138	-0.158
Moisture content (%)	P																			-0.046
	G																			-0.091

* Significant at 5% level

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

Traits		Quantitative traits														Quality traits					
		Days to 50% flowering	Days to first harvest	Fruit shape index	Fruit length (cm)	Fruit width (cm)	Fruit pedicel length (cm)	Pericarp thickness (mm)	Number of locules / fruit	Average fruit weight (g)	Total number of fruits /plant	Number of marketable fruits /plant	Total yield /plant	Number of seeds /fruit	Number of branches /plant	Plant height (cm)	Ascorbic acid (mg/100g)	Capsaicin content (%)	TSS content (%)	Moisture content (%)	CC with Marketable yield / plant
Days to 50 % flowering	P	**-0.028**	0.015	-0.001	0.020	-0.020	-0.001	-0.001	0.002	0.032	0.117	-0.247	-0.101	-0.001	0.001	-0.001	0.000	-0.000	0.003	-0.001	-0.213
	G	**-0.084**	0.097	-0.010	0.199	-0.234	0.002	-0.004	0.005	0.071	0.034	-0.254	-0.049	0.005	-0.001	-0.017	0.000	0.007	0.007	-0.002	-0.227
Days to first harvest	P	-0.027	**0.016**	-0.003	0.021	-0.019	-0.001	-0.001	0.001	0.031	0.095	-0.201	-0.075	-0.000	-0.000	-0.001	0.000	-0.000	0.003	-0.001	-0.162
	G	-0.085	**0.097**	-0.009	0.182	-0.218	0.002	-0.002	0.004	0.069	0.027	-0.201	-0.036	0.003	-0.010	-0.016	0.000	0.006	0.007	-0.001	-0.172
Fruit shape index	P	-0.001	0.001	**-0.077**	0.037	-0.021	-0.001	0.000	-0.002	0.011	0.058	-0.090	-0.055	-0.001	0.007	0.002	-0.000	0.000	-0.000	0.002	-0.073
	G	-0.001	0.001	**-0.681**	0.318	0.313	0.002	0.010	-0.005	0.013	0.018	-0.100	-0.031	0.010	0.022	0.023	-0.000	-0.000	-0.001	0.004	-0.095
Fruit length (cm)	P	-0.009	0.005	-0.043	**0.066**	-0.021	-0.001	-0.002	0.001	0.066	0.125	-0.219	-0.064	-0.001	0.007	0.001	0.000	-0.000	0.000	0.001	-0.086
	G	-0.030	0.032	-0.390	**0.555**	-0.231	0.001	-0.007	0.003	0.152	0.037	-0.233	-0.033	0.005	0.017	0.011	0.000	0.005	0.001	0.002	-0.103
Fruit width (cm)	P	-0.009	0.005	0.046	0.022	**-0.063**	0.000	-0.002	0.003	0.066	0.076	-0.163	-0.010	0.001	-0.002	-0.001	0.000	-0.000	0.001	-0.001	-0.030
	G	-0.033	0.036	0.358	0.215	**-0.595**	-0.001	-0.010	0.008	0.167	0.024	-0.178	-0.004	-0.006	-0.007	-0.017	0.001	0.007	0.004	-0.002	-0.032
Fruit pedicel length (cm)	P	-0.007	0.004	-0.021	0.017	0.005	**-0.004**	-0.009	-0.001	0.004	-0.073	0.188	0.092	-0.000	0.003	0.001	-0.000	0.000	-0.000	0.001	0.206
	G	-0.028	0.036	-0.230	0.160	0.056	**0.005**	-0.004	-0.009	0.006	-0.023	0.208	0.049	0.003	0.010	0.007	-0.000	-0.005	0.000	0.003	0.242
Pericarp thickness (mm)	P	-0.002	0.001	0.001	0.010	-0.012	-0.000	**-0.011**	-0.006	0.064	0.075	-0.229	-0.027	-0.000	-0.001	0.000	0.000	-0.000	0.002	-0.002	-0.133
	G	-0.008	0.006	0.015	0.091	-0.138	0.001	**-0.041**	-0.002	0.150	0.023	-0.240	0.014	0.003	-0.003	0.001	0.000	0.006	0.005	-0.004	-0.148
Number of locules / fruit	P	0.003	-0.001	-0.008	-0.005	0.013	-0.000	-0.000	**-0.017**	-0.005	-0.084	0.211	0.085	-0.000	0.003	0.000	0.000	0.000	0.002	0.002	0.199
	G	0.039	-0.035	-0.325	-0.144	0.490	0.005	-0.008	**-0.010**	-0.218	-0.113	1.018	0.150	0.000	0.016	0.010	-0.001	-0.023	0.004	0.004	0.861
Average fruit weight (g)	P	-0.005	0.003	-0.005	0.023	-0.022	-0.000	-0.003	0.000	**0.189**	0.156	-0.389	0.042	0.001	0.005	-0.001	-0.000	-0.001	0.003	-0.001	-0.005
	G	-0.019	0.021	-0.026	0.260	-0.307	0.000	-0.019	0.006	**0.324**	0.033	-0.274	0.019	-0.008	0.013	-0.011	0.001	0.013	0.010	-0.004	0.032
Total number of fruits / plant	P	0.008	-0.004	0.010	-0.019	0.011	0.001	0.002	-0.003	-0.069	**-0.430**	0.956	0.432	0.000	-0.002	0.000	-0.000	0.000	-0.002	0.000	0.890*
	G	0.026	-0.023	0.111	-0.183	0.125	0.001	0.008	-0.010	-0.095	**-0.013**	0.865	0.204	-0.000	-0.004	0.003	-0.000	-0.006	-0.006	0.002	0.904
Number of marketable fruits / plant	P	0.007	-0.003	0.007	-0.015	-0.010	-0.001	0.003	-0.004	-0.073	-0.411	**1.000**	0.399	0.000	-0.001	0.001	-0.000	0.000	-0.002	0.001	0.918*
	G	0.024	-0.022	0.075	-0.142	0.117	0.001	0.011	-0.011	-0.098	-0.107	**0.909**	0.190	0.000	-0.001	0.006	-0.000	-0.008	-0.006	0.003	0.940
Total yield /plant	P	0.006	-0.002	0.009	-0.009	0.001	-0.001	0.001	-0.003	0.016	-0.381	0.818	**0.484**	0.001	0.001	0.000	-0.000	0.000	-0.001	-0.000	0.942*
	G	0.019	-0.016	0.096	-0.082	0.012	0.001	0.003	-0.007	0.028	-0.103	0.778	**0.222**	-0.005	0.002	0.000	0.000	-0.000	-0.003	-0.000	0.944
Number of seeds / fruit	P	-0.004	0.002	-0.021	0.009	0.011	-0.000	-0.001	-0.001	-0.027	0.012	0.019	-0.064	**-0.004**	-0.003	0.000	0.000	0.000	-0.000	0.000	-0.110
	G	-0.014	0.009	-0.222	0.090	0.011	0.001	-0.004	-0.000	-0.079	0.001	0.004	-0.032	**0.032**	-0.013	0.005	0.000	-0.003	0.010	0.001	-0.119
Number of branches / plant	P	0.001	0.000	0.030	-0.023	-0.007	0.001	-0.001	0.003	-0.051	-0.052	0.061	-0.012	-0.001	**-0.019**	0.000	0.000	0.000	-0.001	-0.001	-0.071
	G	0.003	0.002	0.361	-0.229	-0.096	-0.001	-0.003	0.004	-0.009	-0.011	0.013	-0.009	0.010	**-0.042**	-0.005	0.000	-0.005	-0.001	-0.002	-0.116
Plant height (cm)	P	0.009	-0.006	-0.031	0.015	0.020	-0.001	-0.000	-0.001	-0.034	-0.027	0.122	0.004	-0.000	0.001	**0.004**	-0.000	0.001	-0.003	0.001	0.074
	G	0.030	-0.033	-0.334	0.134	0.209	0.001	-0.001	-0.002	-0.075	-0.007	0.117	0.001	0.003	0.004	**0.047**	0.000	-0.016	-0.007	0.003	0.073
Ascorbic acid (mg/100g)	P	-0.003	0.001	0.015	0.004	-0.018	0.001	-0.002	-0.001	0.044	0.058	-0.060	-0.023	-0.000	-0.001	-0.001	**0.001**	-0.000	0.002	-0.001	0.015
	G	-0.002	-0.001	0.262	0.076	-0.367	-0.003	-0.016	0.007	0.232	0.023	-0.075	-0.011	-0.002	-0.005	-0.004	**0.001**	0.004	0.008	-0.008	0.104
Capsaicin content (%)	P	-0.005	0.003	0.000	0.009	-0.013	0.001	-0.002	0.003	0.063	0.072	-0.226	-0.002	0.000	0.002	-0.002	0.000	**-0.002**	0.001	0.001	-0.096
	G	-0.018	0.017	0.001	0.080	-0.132	-0.001	-0.008	0.007	0.133	0.020	-0.216	-0.001	-0.003	0.006	-0.023	0.000	**0.033**	0.003	0.003	-0.098
TSS content (%)	P	-0.008	0.005	0.003	0.002	-0.010	0.000	-0.002	0.003	0.072	0.120	-0.254	-0.066	0.000	0.001	-0.001	0.000	-0.000	**0.009**	-0.000	-0.131
	G	-0.029	0.033	0.035	0.024	-0.119	0.000	-0.011	-0.002	0.172	0.037	-0.273	-0.036	0.001	0.002	-0.016	0.000	0.006	**0.019**	-0.002	-0.158
Moisture content (%)	P	-0.004	0.002	0.016	-0.010	-0.007	0.001	-0.003	0.004	0.032	0.020	-0.104	0.017	0.000	-0.002	-0.001	0.000	0.000	0.000	**-0.008**	-0.046
	G	-0.011	0.010	0.206	-0.103	-0.092	0.001	-0.011	0.003	0.107	0.013	-0.184	0.007	-0.004	-0.007	-0.009	0.001	-0.006	0.002	**-0.013**	-0.091

* Significant at 5% level Residual effect: P = 0.048 , G = 0.059 Bold values indicate direct effect

Positive association was observed for fruit pedicel length with days to fruit harvest, fruit shape index, days to 50% flowering and fruit length. Fruit width was positively associated with days to first harvest and fruit length. Similarly, fruit length increases with days to 50% flowering, days to first harvest and fruit shape index. A positive correlation of days to 50% flowering with days to first harvest suggested that early flowering would be an appropriate selection criterion to get early yield. Sreelathakumary and Rajamony (2002) reported positive inter-relationship of days to first picking with days to 50% flowering. Hence, it can be concluded that selection for gross yield/plant, number of marketable fruits/plant and total number of fruits/plant will be effective for isolating plants with higher marketable fruit yield in bell pepper.

It is evident from the present study (Table 3) that marketable fruits/plant had the maximum direct positive contribution towards the marketable yield/plant followed by gross yield/plant and average fruit weight at phenotypic level. At genotypic level, marketable fruits/plant had the highest positive direct effect on marketable yield/plant followed by fruit length, average fruit weight, gross yield/plant and days to first harvest, while negative direct effects were exhibited by for fruit shape index, fruit width, days to 50% flowering, number of branches/plant and pericarp thickness. Direct and positive effect for fruit yield were also observed by earlier workers for fruits/plant average fruit weight (Verma et al. 2004) and number of marketable fruits/plant (Nandadevi and Hosamani 2003). Therefore, attention should be given to improve these traits while making selection of high yielding genotypes. The low magnitude of residual effect (Table 3) indicated that the traits included in the present investigation accounted for most of the variation present in the dependent variables i.e. marketable yield/plant. In this view the direct and indirect contributions of component traits towards marketable yield, selection on the basis of horticultural traits *viz*., number of marketable fruits/plant, average fruit weight and gross yield/plant would be a paying preposition in the genotypes included in the study.

Lkkjka'k

फसल में सुधार की सम्भावना कार्बनप्लगैम में उपस्थित आनुवांशिक परिवर्तनशीलता के परिमाण के अनुपात में होता है। वर्तमान अध्ययन में 26 बैक्टीरियल विल्ट प्रतिरोधी (*कैप्सिकम एन्युअम* एल. वार *ग्रीसम* सेंडिट) की प्रभेदों आनुवांशिक विविधता, विभिन्न घटकों के बीच सह सम्बन्ध एवं उपज व उपज घटकों के मध्य पूथ विष्लेशण किया गया। औसत निष्पादन क्षमता के आधार पर प्रभेद पी सी डब्ल्यू आर–1–3–08 उपज के लिए उत्तम पाया गया। बाहय कार्यकीय (पी सी वी) व प्रभेद भिन्नता गुणांक प्रति पौध फलों की संख्या बाजार योग्य प्रति पौध फलों की संख्या, कुल उपज/पौध, बाजार योग्य उपज प्रति पोध तथा कैप्सिलीन की मात्रा के लिए उच्च पाया गया। उच्च वंशा गतित्व के साथ उच्च अनुवांशिक कैप्सिन की मात्रा से स्पष्ट हुआ कि योज्य जीन प्रक्रिया इन गुणों के वंशागतित्व की महत्वपूर्ण भूमिका है। इन गुणों का चयन में ज्यादा योगदान है। सह संबंध एवं पथ विश्लेषण अध्ययन से स्पष्ट हुआ कि बाजार योज्य फलों की प्रति पौध संख्या औसत फल भार, फल की लम्बाई एवं प्रथम कड़ाके के दिन न बाजार योज्य गुण में योगदान दिया। वर्तमान अध्ययन से स्पष्ट हुआ कि प्रभेद पी सी डब्ल्यू आर–1–3–08, पी सी डब्ल्यू आर–कैप–7–08, पी सी डब्ल्यू आर–कैप–4–08, पी सी डब्ल्यू आर–33–1–3–08 एवं पी सी डब्ल्यू आर–33–3–1–08 को बहुस्थानीय मूल्यांकन उपरान्त सीधे तौर उत्पादन हेतु उपयोग कर सकते हैं क्योंकि इसमें उच्च उपज के साथ जीवाणु उकठा प्रतिरोधी गुण, उच्च औद्यानिक गुण व गुणात्मक पहलु निहित है।

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