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Variability and correlation studies in bacterial wilt resistant advanced tomato lines (*Solanum lycopersicum* L.)

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ABSTRACT

Twenty bacterial wilt resistant lines including recently developed lines at CSKHPKV, Palampur (08) were studied to ascertain the extent of genetic variability, the type and magnitude of correlation between component characters & marketable yield, as well as the direct and indirect impacts of every character on marketable yield. For all variables except plant survival, analysis of variance exhibited significant differences across genotypes. Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values for lycopene content (80.581%, 80.148%), titrable acidity (73.666%, 71.219%), marketable yield / plant (53.953%, 52.598%), marketable fruits / plant (34.994%, 34.050%), gross yield / plant (34.094%, 30.553%), average weight of fruit (30.558%, 29.13%), locules / fruit (28.549%, 25.050%), and ascorbic acid (23.641%, 20.919%) respectively, were found high across different parameters of variability. Marketable yield / plant (95.043%, 45.633%), marketable fruits /plant (94.68%, 68.252%), titrable acidity (93.467%, 48.838%), average weight of fruit (90.877%, 57.206%), gross yield / plant (80.305%, 56.402%), ascorbic acid (78.295%, 38.130%), and locules / fruit (76.985%, 45.276%) were found with high heritability and high genetic advance. Marketable yield / plant was significantly and positively associated with average weight of fruit (0.734, 0.795), gross yield / plant (0.774, 0.853), marketable fruits / plant (0.734, 0.742), pericarp thickness (0.693, 0.806), ascorbic acid (0.381, 0.469), titrable acidity (0.347, 0.364) and locules/ fruit (0.284, 0.345) at both phenotypic as well as genotypic levels, respectively. Path coefficient analysis showed that marketable fruits / plant (0.589, 0.608), gross yield / plant (0.278, 0.617) and average weight of fruit (0.382, 0.182) are the three main parameters that had the greatest positive direct impact on marketable yield / plant at the phenotypic and genotypic levels, respectively.

Introduction

Tomato is the third most widely grown vegetable crop in the world, after potato followed by sweet potato, but it ranks first among vegetables as a processing crop. Cultivation of off-season tomato crops during the peak rainy season has increased in Himachal Pradesh during the last three decades, particularly in the mid and low Hills. It is currently farmed on around 13794.98 hectares with an output of 577004.5 metric tonnes (Anonymous, 2020-21). Himachal Pradesh has emerged as a major supplier of fresh produced tomatoes to plain areas because increased temperatures and regular rains hamper production in these areas during the rainy season. The frequency of bacterial wilt caused by *Ralstonia solanacearum* has severely harmed tomato farming in numerous areas of state (low and mid hills). Because it is soil-borne, chemical management is neither efficient nor effective. As a result, genetic

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resistance in cultivars is important and appears to be a great option for successful tomato cultivation in wilt-prone areas. Some bacterial wilt resistant and high yielding lines have recently been developed at CSKHPKV, Palampur, appropriate for growing in the local conditions of low and mid hill areas of the state receiving considerable rainfall, particularly during the rainy season. Continuous researchon different parameters of variability alongwith interrelationship in newly developed genotypes are important for selecting superior genotypes for future crop improvement programme.

Material and Methods

The data were analyzed using OPSTAT 6.8 software for variability, heritability, genetic advance, correlation and path analysis. Twenty bacterial wilt resistance tomato genotypes including two bacterial wilt resistant checks were tested in summer-rainy season, 2020 in Randomized Block Design with three replications. The observations were recorded on ten competitive plants on various parameters viz. plant survival/bacterial wilt disease incidence (%), days to 50 per cent flowering, days to first harvest, average weight of fruit (g), fruit shape index, thickness of pericarp (mm), locules / fruit, plant height (cm), harvest duration, total number of fruits / plant, marketable fruits / plant, gross yield /plant (kg), marketable yield / plant (kg), total soluble solids (°Brix), lycopene content (mg/100g), titrable acidity (%) and ascorbic acid content (mg/100g). For fruit shape index, standard protocol as suggested by Roy and Choudhury (1972) was followed. For lycopene content, acetone- ether extraction method suggested by Ranganna (2000); for titrable acidity, official method 942.15 (AOAC 2000); for ascorbic acid, 2,6-dichlorophenol-indophenol visual titration method as described by Ranganna (1979) were used.

Study Area

The research was conducted at Department of Vegetable Science and Floriculture Research Farm, CSK Himachal Pradesh Krishi Vishvavidyalaya Palampur (Figure 1). This Farm is located at 32°6' N latitude and 76°3' E longitude, at an elevation of 1,290.8 metres above mean sea level. It is located in mid-hill zone of Himachal Pradesh. The location has a humid climate, a sub-temperate climate, and a high rainfall of about 2332 mm per year, the majority of which (70-80 percent) falls between June and September.

Figure 1: Experimental location (32°6' N latitude, 76°3' E longitude)

Results and Discussion

For all variables except plant survival, analysis of variance (ANOVA) exhibited significant differences across genotypes (Table-1). PCV, GCV, heritability, and genetic advance were estimated for fruit yield and other traits in tomato genotypes (Table-2). PCV and GCV ranged from 5.110 (days to first harvest) to 80.581 percent (lycopene content) and 4.265 (days to first harvest) to 80.148 percent (lycopene content), respectively. Both PCV and GCV estimates were found high for lycopene content, titrable acidity, marketable yield / plant, marketable fruits / plant, gross yield / plant, average weight of fruit, number of locules / fruit and ascorbic acid content among different components of variability. High GCV and PCV defines greater variability among the genotypes and thus, better improvement is possible by selection. Harvest duration, thickness of pericarp, days to 50% flowering, fruit shape index, and plant height exhibited moderate level of PCV and GCV indicating that a moderate level of genetic variability is present in these traits, however days to first harvest had low PCV and GCV values indicating limited scope for improvement through this trait. The findings are consistent with previous findings for lycopene content (Rai *et al*., 2016), locules per fruit (Rai *et al.*, 2016), average fruit weight and total fruits per plant (Al-Aysh *et al.*, 2012), and plant height (Shweta *et al.*, 2016). High

Table 1: Analysis of variance (ANOVA) for various characters in tomato genotypes

Sr. No.	Traits		Mean sum of squares		
			Replications	Treatments	Error
		degree of freedom	2	19	38
1.	Plant survival percentage		0.066	1.911	0.277
2.	Days to 50 per cent flowering		18.200	72.052*	3.375
3.	Days to first harvest		5.217	31.575*	4.006
4.	Average fruit weight (g)		39.200	626.540*	20.288
5.	Fruit shape index		0.003	0.049*	0.005
6.	Pericarp thickness(mm)		0.977	2.599*	0.314
7.	Locules per fruit		0.253	2.122*	0.192
8.	Plant height (cm)		180.469	377.543*	114.750
9.	Duration of fruit harvest (days)		397.850	136.438*	28.411
10.	Total fruits / plant		22.467	47.596*	7.835
11.	Marketable fruits / plant		2.017	59.118*	1.087
12.	Gross yield / plant (kg)		0.012	0.310*	0.023
13.	Marketable yield / plant (kg)		0.015	0.348*	0.006
14.	Total soluble solids (˚Brix)		0.996	43.669*	19.757
15.	Titrable acidity (%)		0.001	0.090*	0.002
16.	Lycopene content (mg/100g)		0.113	8.462*	0.030
17.	Ascorbic acid (mg/100g)		0.263	10.422*	0.882

***level of significance at 5%**

PCV was also found for marketable yield per plant, marketable fruits per plant (Chadha and Walia, 2016) and ascorbic acid (Shankar *et al*., 2013). Similarly, days to first harvest was observed to have low PCV estimates (Chadha and Walia, 2016). PCV estimations for pericarp thickness (Khapte and Jansirani, 2014),fruit shape index (Khapte and Jansirani, 2014), and days to 50% flowering (Khapte and Jansirani, 2014) were moderate (Chadha and Walia, 2016).Researchers previously discovered comparable results for lycopene content (Rai *et al.*, 2016), average fruit weight (Al-Aysh *et al*., 2012), and locules per fruit (Rai *et al*., 2016). For marketable fruits per plant, (Chadha and Walia, 2016) found comparable results, as did (Sehgal, 2017) for marketable yield per plant. (Shankar *et al*., 2013) observed high GCV estimations for titrable acidity. (Shweta *et al*., 2016) found moderate GCV estimates for days to 50% flowering, and (Khapte and Jansirani, 2014) reported moderate GCV estimates for pericarp thickness.The heritability estimates alone fail to indicate the response to selection. Therefore, estimations of heritability seem to have more significance when combined with estimates of genetic advance. For different traits, heritability and genetic advance estimates varied from 43.291 (plant height) to 98.127 percent (lycopene content) and 7.331 (days to first harvest) to 68.252 percent (number of marketable fruits / plant), respectively. Marketable yield / plant, number of marketable fruits / plant, titrable acidity, average weight of fruit, gross yield / plant, ascorbic acid, and locules / fruit had high heritability and high genetic advance demonstrating that these traits are under the strong influence of additive gene action and hence simple selection based on phenotypic performance of these traits would be more efficient. Days to 50% flowering, fruit shape index, pericarp thickness, and total fruits / plant showed high heritability with moderate level of genetic advance indicating the influence of non-additive gene action and considerable influence of environment on the expression of these traits. This trait could be exploited through expression of dominance and epistatic components through heterosis. Fruit harvesting period, TSS, and plant height exhibited moderate level of heritability and genetic advance. Plant height, harvest duration and total soluble solids indicated moderate level of heritability with low genetic advance. High heritability estimates for marketable fruits per plant were reported (Chadha and Bhushan, 2013); for marketable yield per plant; for gross yield per plant (Chadha and Walia, 2016); and for average fruit weight (Meena *et al*., 2015). The characters with high heritability indicated that these traits are least influenced by the environmental effects, the selection for improvement of these traits may not be useful because broad sense heritability is

Table 2: PCV, GCV, heritability, and genetic advance estimates for fruit yield and other characters in tomato genotypes

Sr. No.	Characters	PCV (%)	GCV (%)	Heritability (%)	GA
1	Days to 50 per cent flowering	12.926 (M)	12.067(M)	87.150(H)	23.206(M)
2	Days to first harvest	5.110 (L)	4.265(L)	69.640(H)	7.331(L)
3	Average fruit weight (g)	30.558 (H)	29.13(H)	90.877(H)	57.206(H)
4	Fruit shape index	14.715(M)	12.64(M)	73.778(H)	22.365(M)
5	Pericarpthickness (mm)	17.446(M)	14.682(M)	70.822(H)	25.453(M)
6	Locules / fruit	28.549(H)	25.050(H)	76.985(H)	45.276(H)
7	Plant height (cm)	16.589(M)	10.915(M)	43.291(M)	14.794(M)
8	Duration of fruit harvest (days)	19.271(M)	14.408(M)	55.897(M)	22.190(M)
9	Total fruits / plant	21.850(H)	17.322(M)	62.847(H)	28.289(M)
10	Marketable fruits / plant	34.994(H)	34.050(H)	94.68(H)	68.252(H)
11	Gross yield / plant (kg)	34.094(H)	30.553(H)	80.305(H)	56.402(H)
12	Marketable yield / plant (kg)	53.953(H)	52.598(H)	95.043(H)	45.633(H)
13	Total soluble solids (°Brix)	22.030(H)	16.079(M)	53.275(M)	24.177(M)
14	Titrable acidity (%)	73.666(H)	71.219(H)	93.467(H)	48.838(H)
15	Lycopene content (mg/100g)	80.581(H)	80.148(H)	98.927(H)	50.217(H)
16	Ascorbic acid (mg/100g)	23.641(H)	20.919(H)	78.295(H)	38.130(H)

PCV range = {Low level (L) : < 10%, Moderate level (M): 10-20%, High level (H) :>20%}
GCV range= {Low level (L) : <10%, Moderate level (M): 10-20%, High level (H) :>20%}
Heritability = - {Low level (L) : <30%, Moderate level M): 30-60%, High level (H): >60%}
GA = - {Low level (L) :< 10%, Moderate level (M): 10-30%, High level (H) :>30%}

based on total genetic variance which includes both fixable (additive) and non-fixable variance (dominance and epistasis). (Rai *et al*., 2016) found high genetic advance for traits viz. average fruit weight, gross yield per plant, and locules per fruit. Correlation studies are useful for genetic breeding because they allow researchers to identify and quantify the proportion of phenotypic correlation that is due to genetic causes, confirm whether selection for one trait influences another, quantify indirect gains due to selection on correlated traits, and assess the traits complexity (Tiwari and Upadhyay, 2011). Correlation between various tomato traits at the phenotypic (P) and genotypic (G) levels was estimated (Table-3). Genotypic correlations were higher as compare to phenotypic exhibiting high degrees of genetic association among traits under consideration. Marketable yield / plant was found significantly and positively correlated with average weight of fruit, gross yield/plant, marketable fruits/ plant, thickness of pericarp, ascorbic acid content, titrable acidity, and number of locules / fruit at both phenotypic as well as genotypic levels which illustrated that marketable yield could be increased through selection in the component characters like average weight of fruit, gross yield / plant, marketable fruits / plant, thickness of pericarp, ascorbic acid content, titrable acidity, and number of locules / fruit. The present results are comparable with Chadha and Walia, 2016. Direct and indirect effects of different tomato characters on marketable yield were estimated(Table-4). At the phenotypic level, analysis of path coefficient showed number of marketable fruits / plant withhighestpositive direct impact on marketable yield / plant, afterwards average weight of fruit, gross yield per plant, pericarp thickness, titrable acidity, days to 50% blooming, and number of locules / fruit. On the other hand, TSS had the maximum negative direct effect which suggested that selection on the basis of this trait might lead to the loss in terms of fruit yield. The highest positive direct impact on marketable yield / plant at the genotypic level was of total yield / plant, marketable fruits / plant, average weight of fruit, titrable acidity, harvest duration, days to first harvest, fruit shape index and days to 50% blooming. Since yield is a polygenic and complex attribute that is influenced by many other factors, direct selection based solely on the association pattern between two variables may occasionally lead the breeder misled; as a result, it is split into direct and indirect effects

Table 4: Direct and indirect effects of component characters on marketable yield of tomato at both phenotypic as well as genotypic levels

Traits		Days to 50 % flowering	Days to first harvest	Average fruit weight (g)	Fruit shape index	Pericarp thickness (mm)	Locules per fruit	Plant height (cm)	Duration of fruit harvest (days)	Total fruits/ plant	Marketable fruits / plant	Gross yield/ plant (kg)	Total soluble solids (°Brix)	Titrable acidity (%)	Lycopene content (mg/100g)	Ascorbic acid (mg/100g)	Correlation with Marketable yield / plant
Days to 50% flowering	**P**	**0.028**	-0.009	-0.002	0.000	-0.006	-0.002	0.001	0.000	0.007	0.067	0.006	-0.002	-0.006	-0.011	-0.001	0.070
	G	**0.013**	0.043	-0.006	0.007	0.010	0.001	-0.041	-0.001	0.023	0.089	-0.015	-0.006	-0.015	-0.024	-0.003	0.076
Days to first harvest	**P**	0.018	**-0.013**	0.007	0.000	0.001	0.002	0.000	0.000	-0.006	0.098	0.020	-0.001	0.001	-0.006	0.000	0.249
	G	0.014	**0.040**	-0.016	0.001	-0.007	-0.003	-0.029	-0.006	-0.056	0.124	0.073	-0.005	0.001	-0.019	-0.006	0.303*
Average fruit weight (g)	**P**	0.000	0.000	**0.382**	0.000	0.031	0.005	0.000	0.001	0.036	0.111	0.222	-0.001	0.015	-0.002	-0.006	0.792**
	G	0.000	-0.003	**0.182**	-0.002	-0.047	-0.005	-0.008	-0.024	0.078	0.122	0.524	-0.004	0.041	-0.005	-0.053	0.795**
Fruit shape index	**P**	0.005	0.001	-0.025	**-0.001**	-0.019	0.001	0.000	0.000	0.027	-0.196	-0.033	0.002	-0.021	0.007	0.001	-0.249
	G	0.002	0.001	-0.010	**0.039**	0.031	-0.001	-0.029	-0.008	0.083	-0.227	-0.110	0.007	-0.060	0.018	0.005	-0.257*
Pericarp thickness (mm)	**P**	-0.003	0.000	0.209	0.000	**0.056**	0.007	0.000	0.000	-0.025	0.267	0.172	0.001	0.012	-0.001	-0.002	0.693**
	G	-0.002	0.004	0.121	-0.017	**-0.070**	-0.006	0.019	-0.006	-0.058	0.294	0.517	0.002	0.034	-0.002	-0.025	0.806**
Locules per fruit	**P**	-0.002	-0.001	0.071	0.000	0.014	**0.026**	0.000	0.000	-0.032	0.106	0.098	0.000	0.008	-0.005	-0.001	0.284*
	G	-0.001	0.005	0.044	0.001	-0.021	**-0.020**	0.012	-0.012	-0.083	0.126	0.289	-0.001	0.025	-0.011	-0.008	0.345**
Plant height (cm)	**P**	0.007	-0.001	0.037	0.000	-0.005	-0.004	**0.002**	0.000	0.050	0.051	-0.025	-0.001	-0.005	0.001	0.002	0.108
	G	0.008	0.016	0.020	0.016	0.019	0.004	**-0.070**	0.014	0.142	0.012	-0.074	-0.005	-0.018	0.002	0.002	0.089
Duration of fruit harvest (days)	**P**	-0.002	0.001	-0.138	0.000	0.004	-0.005	0.000	**-0.001**	-0.024	0.128	-0.072	0.002	-0.005	-0.006	0.004	-0.116
	G	0.000	-0.005	-0.081	-0.006	0.007	0.004	-0.019	**0.053**	-0.048	0.127	-0.191	0.004	-0.021	-0.017	0.033	-0.159
Total fruits / plant	**P**	-0.001	0.000	-0.078	0.000	0.008	0.005	-0.001	0.000	**-0.174**	0.213	0.109	0.001	-0.005	-0.001	0.001	0.076
	G	-0.001	0.008	-0.048	-0.011	-0.014	-0.006	0.034	0.009	**-0.291**	0.285	0.155	-0.002	-0.016	-0.001	0.013	0.113
Marketable fruits /plant	**P**	0.003	-0.002	0.072	0.000	0.026	0.005	0.000	0.000	-0.063	**0.589**	0.101	-0.003	0.003	0.005	0.000	0.734**
	G	0.002	0.008	0.036	-0.015	-0.034	-0.004	-0.001	0.011	-0.137	**0.608**	0.267	-0.008	0.006	0.010	-0.007	0.742**
Gross yield / plant (kg)	**P**	0.001	-0.001	0.304	0.000	0.035	0.009	0.000	0.000	-0.068	0.215	**0.278**	-0.001	0.011	-0.004	-0.005	0.774**
	G	0.000	0.005	0.154	-0.007	-0.059	-0.009	0.008	-0.016	-0.073	0.263	**0.617**	-0.004	0.032	-0.009	-0.048	0.853**
Total soluble solids(°Brix)	**P**	-0.007	0.001	-0.060	0.000	0.005	0.000	0.000	0.000	-0.013	-0.214	-0.021	**0.009**	-0.010	0.007	0.003	-0.299*
	G	-0.005	-0.011	-0.047	0.017	-0.007	0.001	0.022	0.012	0.030	-0.312	-0.168	**0.016**	-0.033	0.021	0.036	-0.428**
Titrable acidity (%)	**P**	-0.005	-0.001	0.160	0.000	0.019	0.006	0.000	0.000	0.024	0.042	0.083	-0.002	**0.036**	-0.012	-0.004	0.347**
	G	-0.002	0.000	0.082	-0.026	-0.027	-0.006	0.014	-0.012	0.052	0.042	0.216	-0.006	**0.091**	-0.025	-0.031	0.364**
Lycopene content (mg/100g)	**P**	0.008	-0.002	0.020	0.000	0.002	0.003	0.000	0.000	-0.003	-0.070	0.028	-0.002	0.011	**-0.039**	0.000	-0.045
	G	0.004	0.010	0.011	-0.009	-0.002	-0.003	0.002	0.011	-0.002	-0.074	0.071	-0.004	0.028	**-0.080**	-0.003	-0.040
Ascorbic acid content (mg/100g)	**P**	0.001	0.000	0.204	0.000	0.012	0.002	0.000	0.001	0.013	0.020	0.132	-0.003	0.012	-0.002	**-0.011**	0.381**
	G	0.000	0.003	0.116	-0.003	-0.021	-0.002	0.002	-0.021	0.045	0.050	0.357	-0.007	0.035	-0.003	**-0.083**	0.469**

*** indicates significance at P ≤ 0.05** **** indicates significance at P ≤ 0.01** **Residual effect (P): 0.00868; (G): 0.00343**

for successful selection. It turned out that traits with a direct impact on marketable yield per plant were a major factor in yield. Therefore, should be regarded as a crucial selection criterion for increasing tomato yield.

Conclusion

For all characters except plant survival, analysis of variance exhibited significant differences across genotypes. The presence of high PCV and GCV estimates indicated that the provided genetic stock had a lot of variability for that trait. This information will aid in the development of an effective breeding programme. The majority of the characters made contribution towards marketable yield / plant via gross yield / plant, marketable fruits / plant and average weight of fruit as per path coefficient analysis. All of these characters are positively correlated with marketable yield / plant. As a result, these characters must be considered in order to increase marketable yield / plant. The residual effect (0.00343) in this investigation was extremely small, implying that all of the primary yield components had been taken into account.

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Conflict of interest

The authors declare that they have no conflict of interest.

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