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Character Association and Path Coefficient Analysis in Tomato (*Solanum lycopersicum* L.)

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A B S T R A C T

Fifty nine genotypes of tomato were used to study the association and path coefficient analysis of fourteen yield related quantitative traits during the year 2014 and 2015 (January to June). Fruit yield was found significantly and positively correlated with number of fruits per plant (0.630, 0.558) followed by average fruit weight (0.291, 0.215) while it was significantly and negatively correlated with days to first fruit ripening (-0.539, -0.382) and days to 50% flowering (-0.399, -0.248) for both the years respectively. Path analysis confirmed that the number of fruits per plant had highest positive direct effect (0.753, 0.855) on fruit yield followed by average fruit weight (0.661, 0.464). The average fruit weight and number of fruits per plant exhibiting significant positive correlation and direct effect on fruit yield, emerged as the important components that contributed to fruit yield. Hence, these characters should be given due weightage during the selection of genotypes as selection primarily based on these traits may result in the development of high yielding varieties.

Introduction

The cultivated tomato (*Solanum lycopersicum* L.), belonging to the family Solanaceae, is one of the most consumed vegetable worldwide and a well-studied crop species in terms of genetics, genomics and breeding (Foolad, 2007). It has multipurpose uses in fresh as well as processed food industries and is one of the most nutritive vegetable rich in Vitamin A, Vitamin C, protein, fat, carbohydrates as well as other essential minerals and food elements (Mahapatra *et al.*, 2013). Systematic study and evaluation of germplasm is of great importance for current and future agronomic and genetic improvement of the crop (Reddy *et al.*, 2013).

Correlation coefficient helps a breeder to select an efficient trait in breeding programme and to allocate appropriate weightage for obtaining optimal results. Path analysis facilitates the partitioning of correlation coefficients into direct and indirect effects of various characters on yield or any other attributes and also permits critical examination of specific factors that provide a given correlation. As yield is a complex character, its direct improvement is difficult. The knowledge of the relationship among yield and other plant characters and their relative contribution to yield is very useful while formulating the selection scheme with

the target to improve yield. Therefore, in order to formulate a sound breeding plan for its improvement, the present experiment was conducted to determine the correlation and direct and indirect effect of various traits on fruit yield of tomato through path coefficient analysis.

Materials and Methods

The experiment was conducted at Vegetable Research Centre (V.R.C.), Govind Ballabh Pant University of Agriculture and Technology, Pantnagar during the year 2014 and 2015 (January to June). The experimental material comprised of fifty nine genotypes of tomato including three checks, namely, PT 3, Arka Vikas and Roma which were evaluated in Augmented Block Design-II.

Thirty days old seedlings were transplanted at a spacing of 50 x 50 cm. Each block had eleven rows of different genotypes including three checks of 5 m length. There were ten plants per genotype. Recommended practices were followed to raise the crop. Five plants were selected in each genotype to record the observations on plant height (cm), number of primary branches per plant, days to 50% flowering**,** days to first fruit ripening**,** number of fruits per cluster**,** average fruit weight (g)**,** number of fruits per plant**,** number of locules per fruit**,** equatorial fruit diameter (cm)**,** polar fruit diameter (cm), pericarp thickness (mm), fruit yield (q/ha), T.S.S. (°B) and ascorbic acid content (mg/100 g). Correlation coefficient analysis was done as per Searle (1961) and the path coefficient analysis was estimated according to the formulae suggested by Dewey and Lu (1959).

Results and Discussion

Most of the characters studied during both the years showed highly significant differences among check varieties except days to 50% flowering, number of fruits per cluster, equatorial fruit diameter and TSS which showed non-significant differences.

The estimates of correlation coefficient presented in table 1 described that fruit yield was highly significant and positively correlated with number of fruits per plant (0.630, 0.558), positively correlated with average fruit weight (0.291, 0.215) but showed highly significant negative correlation with days to first fruit ripening (-0.539, -0.382) and negative correlation with days to 50% flowering (-0.399, -0.248) during the years 2014 and 2015 respectively. Number of fruits per plant showed highly significant and positive correlation with number of fruits per cluster (0.391, 0.304), plant height (0.360, 0.479) but highly significant and negative correlation with days to first fruit ripening (-0.587, -0.439) and average fruit weight (-0.394, -0.494). On the other hand, average fruit weight showed highly significant and positive correlation with equatorial fruit diameter (0.440, 0.800) and pericarp thickness (0.352, 0.618). Pericarp thickness showed highly significant and positive correlation with equatorial fruit diameter (0.465, 0.668) and polar fruit diameter (0.399, 0.698). Equatorial fruit diameter had highly significant and positive correlation with number of locules per fruit (0.550, 0.630) during both the years. Number of primary branches per plant had highly significant and positive correlation with plant height (0.433, 0.397).

Similarly, positive correlation of fruit yield with number of fruits per plant has also been reported by Dhankhar and Dhankar (2006), Singh *et al.,* (2007), Dar *et al.,* (2011), Shashikanth *et al.,* (2010), Patel *et al.,* (2013), Iqbal *et al.,* (2014) and Emami (2014) and with average fruit weight by Singh *et al.,* (2007), Dar *et al.,* (2011), Sharma and Singh (2012), Patel *et al.,* (2013), Iqbal *et al.,* (2014), Henareh *et al.,* (2015) and Wali and Kabura (2014).

Table.1 Simple correlation coefficient between different characters of tomato genotypes during the years 2014 and 2015

Characters	Years	Plant height (cm)	No. of primary branches per plant	Days to 50% flowering	Days to 1st fruit ripening	No. of fruits per cluster	No. of locules per fruit	Equatorial fruit diameter (cm)	Polar fruit diameter (cm)	Pericarp thickness (mm)	TSS (^{0}B)	Ascorbic acid (mg/100g)	Average fruit weight (g)	No. of fruits per plant	Fruit yield (q/ha)
Plant height (cm)	2014	1.000													
	2015	1.000													
No. of primary branches per plant	2014	0.433**	1.000												
	2015	0.397**	1.000												
Days to 50% flowering	2014	-0.218	0.112	1.000											
	2015	-0.062	-0.075	1.000											
Days to 1st fruit ripening	2014	-0.200	0.143	0.429**	1.000										
	2015	-0.143	-0.106	0.277*	1.000										
No. of fruits per cluster	2014	0.176	-0.041	-0.365**	-0.369**	1.000									
	2015	0.246	0.025	-0.003	-0.240	1.000									
No. of locules per fruit	2014	-0.131	-0.044	-0.043	0.068	-0.024	1.000								
	2015	0.013	0.006	0.075	0.099	-0.221	1.000								
Equatorial fruit diameter (cm)	2014	-0.402**	-0.154	-0.025	0.123	-0.071	0.550**	1.000							
	2015	-0.249	-0.131	-0.006	0.282*	-0.404**	0.630**	1.000							
Polar fruit diameter (cm)	2014	-0.463**	-0.311*	0.055	0.145	-0.108	0.137	0.704**	1.000						
	2015	-0.172	-0.172	0.110	0.222	-0.177	0.171	0.655**	1.000						
Pericarp thickness (mm)	2014	-0.313*	-0.439**	0.039	0.125	0.023	0.150	0.465**	0.399**	1.000					
	2015	-0.162	-0.196	-0.117	0.207	-0.290*	0.236	0.668**	0.698**	1.000					
TSS (^{0}B)	2014	0.159	0.087	0.125	0.048	-0.143	-0.136	-0.255	-0.392**	-0.311*	1.000				
	2015	-0.076	-0.097	0.009	-0.202	0.301*	-0.111	-0.357**	-0.224	-0.264*	1.000				
Ascorbic acid (mg/100g)	2014	0.001	0.128	0.032	0.131	-0.114	-0.070	-0.040	-0.101	-0.039	0.051	1.000			
	2015	-0.107	0.180	0.045	0.102	-0.156	-0.037	-0.095	-0.179	-0.044	0.125	1.000			
Average fruit weight (g)	2014	-0.241	-0.299*	0.071	0.124	-0.207	0.215	0.440**	0.238	0.352**	-0.068	-0.139	1.000		
	2015	-0.245	-0.226	-0.059	0.133	-0.358**	0.413**	0.800**	0.578**	0.618**	-0.261*	-0.225	1.000		
No. of fruits per plant	2014	0.360**	0.048	-0.359**	-0.587**	0.391**	-0.173	-0.264*	-0.173	-0.177	-0.050	0.094	-0.394**	1.000	
	2015	0.479**	0.341**	-0.117	-0.439**	0.304*	-0.099	-0.458**	-0.394**	-0.336**	0.314*	0.234	-0.494**	1.000	
Fruit yield (q/ha)	2014	0.191	-0.137	-0.399**	-0.539**	0.284*	-0.081	-0.003	-0.049	-0.012	-0.107	-0.064	0.291*	0.630**	1.000
	2015	0.179	0.166	-0.248	-0.382**	0.098	0.253	0.169	-0.048	0.101	0.174	-0.019	0.215	0.558**	1.000

*, ** Significant at 5% and 1% level of probability, respectively

Table.2 Path coefficient analysis showing the direct and indirect effect of different characters on fruit yield of tomato during the years 2014 and 2015

Characters	Years	Plant height (cm)	No. of primary branches per plant	Days to 50% flowering	Days to 1st fruit ripening	No. of fruits per cluster	No. of locules per fruit	Equatorial fruit diameter (cm)	Polar fruit diameter (cm)	Pericarp thickness (mm)	TSS (^{0}B)	Ascorbic acid (mg/100g)	Average fruit weight (g)	No. of fruits per plant
Plant height (cm)	2014	**-0.025**	0.008	0.026	0.018	0.007	0.012	-0.009	0.022	0.028	-0.008	0.000	-0.159	0.271
	2015	**-0.124**	0.027	0.004	0.010	0.022	0.000	-0.091	0.042	-0.013	-0.007	0.014	-0.114	0.409
No. of primary branches per plant	2014	-0.011	**0.018**	-0.013	-0.013	-0.002	0.004	-0.004	0.015	0.039	-0.004	-0.005	-0.197	0.036
	2015	-0.049	**0.069**	0.004	0.008	0.002	0.000	-0.048	0.042	-0.016	-0.009	-0.024	-0.105	0.292
Days to 50% flowering	2014	0.006	0.002	**-0.119**	-0.040	-0.014	0.004	-0.001	-0.003	-0.003	-0.006	-0.001	0.047	-0.270
	2015	0.008	-0.005	**-0.057**	-0.020	0.000	-0.002	-0.002	-0.027	-0.010	0.001	-0.006	-0.027	-0.100
Days to 1st fruit ripening	2014	0.005	0.003	-0.051	**-0.093**	-0.014	-0.007	0.003	-0.007	-0.011	-0.002	-0.005	0.082	-0.442
	2015	0.018	-0.007	-0.016	**-0.072**	-0.021	-0.002	0.103	-0.055	0.017	-0.019	-0.014	0.062	-0.376
No. of fruits per cluster	2014	-0.004	-0.001	0.043	0.034	**0.039**	0.002	-0.002	0.005	-0.002	0.007	0.004	-0.137	0.294
	2015	-0.031	0.002	0.000	0.017	**0.088**	0.005	-0.147	0.044	-0.024	0.028	0.021	-0.166	0.260
No. of locules per fruit	2014	0.003	-0.001	0.005	-0.006	-0.001	**-0.095**	0.013	-0.007	-0.013	0.007	0.003	0.142	-0.130
	2015	-0.002	0.000	-0.004	-0.007	-0.020	**-0.024**	0.229	-0.042	0.020	-0.010	0.005	0.191	-0.084
Equatorial fruit diameter (cm)	2014	0.010	-0.003	0.003	-0.011	-0.003	-0.052	**0.023**	-0.034	-0.042	0.012	0.001	0.291	-0.199
	2015	0.031	-0.009	0.000	-0.020	-0.036	-0.015	**0.364**	-0.161	0.056	-0.034	0.013	0.371	-0.391
Polar fruit diameter (cm)	2014	0.012	-0.006	-0.007	-0.013	-0.004	-0.013	0.016	**-0.048**	-0.036	0.019	0.004	0.157	-0.131
	2015	0.021	-0.012	-0.006	-0.016	-0.016	-0.004	0.238	**-0.246**	0.058	-0.021	0.024	0.268	-0.337
Pericarp thickness (mm)	2014	0.008	-0.008	-0.005	-0.012	0.001	-0.014	0.011	-0.019	**-0.089**	0.015	0.001	0.233	-0.134
	2015	0.020	-0.014	0.007	-0.015	-0.026	-0.006	0.243	-0.172	**0.083**	-0.025	0.006	0.287	-0.288
TSS (^{0}B)	2014	-0.004	0.002	-0.015	-0.004	-0.006	0.013	-0.006	0.019	0.028	**-0.049**	-0.002	-0.045	-0.038
	2015	0.009	-0.007	-0.001	0.014	0.027	0.003	-0.130	0.055	-0.022	**0.094**	-0.017	-0.121	0.268
Ascorbic acid (mg/100g)	2014	0.000	0.002	-0.004	-0.012	-0.004	0.007	-0.001	0.005	0.004	-0.002	**-0.037**	-0.092	0.071
	2015	0.013	0.012	-0.003	-0.007	-0.014	0.001	-0.035	0.044	-0.004	0.012	**-0.135**	-0.105	0.200
Average fruit weight (g)	2014	0.006	-0.005	-0.008	-0.012	-0.008	-0.020	0.010	-0.011	-0.032	0.003	0.005	**0.661**	-0.297
	2015	0.030	-0.016	0.003	-0.010	-0.032	-0.010	0.291	-0.142	0.051	-0.025	0.030	**0.464**	-0.422
No. of fruits per plant	2014	-0.009	0.001	0.043	0.054	0.015	0.016	-0.006	0.008	0.016	0.002	-0.003	-0.260	**0.753**
	2015	-0.059	0.024	0.007	0.031	0.027	0.002	-0.167	0.097	-0.028	0.029	-0.032	-0.229	**0.855**

Residual factor = 0.2129 and 0.2891 for the years 2014 and 2015, respectively

Positive correlation of primary branches with plant height was also reported by Singh *et al.*, (2007). Positive and significant correlation of pericarp thickness with polar fruit diameter was also reported by Chattopadhyay *et al.*, (2013). Positive and significant correlation of equatorial fruit diameter with number of locules per fruit was also obtained by Chattopadhyay *et al.,* (2013). Significant negative correlation of fruit yield with days to 50% flowering was also recorded by Wali and Kabura (2014). Average fruit weight was negatively correlated with number of fruits per plant as reported by Patel *et al.,* (2013).

Path coefficient analysis gives an idea about the contribution of each independent character on the dependent character. Since the mutual relationship of component characters might vary both in magnitude and direction, it may tend to vitiate the association of fruit yield with other attributes. Therefore, it is necessary to partition the correlation into direct and indirect effects of each other (Table 2).

The number of fruits per plant (0.753, 0.855) had highest positive direct effect on the fruit yield followed by average fruit weight (0.661, 0.464), number of fruits per cluster (0.039, 0.088), equatorial fruit diameter (0.023, 0.364) and number of primary branches per plant (0.018, 0.069). However, days to 50% flowering (-0.119, -0.057), number of locules per fruit (-0.095, -0.024), days to first fruit ripening (-0.093, -0.072), polar fruit diameter (-0.048, -0.246), ascorbic acid content (-0.037, -0.135) and plant height (-0.025, -0.124) exerted negative direct effect towards the fruit yield for the years 2014 and 2015, respectively. Plant height exhibited positive indirect effect on fruit yield through number of fruits per plant (0.271, 0.409) while it exhibited negative indirect effect on fruit yield through average fruit weight (-0.159, -0.114). Number of fruits per cluster exhibited positive indirect effect on fruit yield through number of fruits per plant (0.294, 0.260). Number of locules per fruit exhibited positive indirect effect on fruit yield through average fruit weight (0.142, 0.191) while it exhibited negative indirect effect on fruit yield through number of fruits per plant (-0.130, -0.084). Equatorial fruit diameter exhibited positive indirect effect on fruit yield through average fruit weight (0.291, 0.371). Pericarp thickness exhibited positive indirect effect on fruit yield through average fruit weight (0.233, 0.287) while it exhibited negative indirect effect on fruit yield through number of fruits per plant (-0.134, -0.288). Average fruit weight exhibited negative indirect effect on fruit yield through number of fruits per plant (-0.297, -0.422). Number of fruits per plant exhibited negative indirect effect on fruit yield through average fruit weight (-0.260, -0.229). The residual factor obtained for the years 2014 and 2015 was 0.2129 and 0.2891 *i.e*., the unexplained variation in path was 21.29 per cent and 28.91 per cent for the years 2014 and 2015 respectively, which predicted that 78.71 per cent and 71.09 per cent variation in fruit yield had been determined due to the above characters studied. It further states the presence of some more factors, not considered here, which contribute to the fruit yield of tomato.

Number of fruits per plant exhibited positive direct effect on fruit yield as reported by Singh *et al.,* (2006), Ara *et al.,* (2009), Ghosh *et al.,* (2010) and Ullah *et al.,* (2015). Similarly, Singh *et al.,* (2006), Ara *et al.,* (2009), Dar *et al.,* (2011) and Tiwari *et al.,* (2013) also reported that average fruit weight exerted positive direct effect on fruit yield. Number of locules per fruit exhibited positive direct effect on fruit yield during the second year as reported by Tiwari *et al.,* (2013) while the contrasting results were obtained during the first year. Tiwari *et al.,* (2013) also recorded that plant height exhibited negative

direct effects on fruit yield. Fruit diameter had positive direct effect on fruit yield as reported by Ullah *et al.*, (2015).

The results obtained in this investigation revealed the occurrence of considerable positive as well as negative direct and indirect effects by various characters on the fruit yield of tomato through one or other characters. Thus, it can be concluded that the characters mentioned above should be duly considered at the time of formulation of selection strategy to develop high yielding varieties in tomato.

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