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Correlation and path coefficient analysis in tomato (*Solanum lycopersicum* L.)

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Abstract
Forty genotypes of tomato were used to study the correlation and path coefficient analysis of thirteen yield and yield related traits during *Kharif*, 2017-18. Fruit yield per plant exhibited high significant positive correlations with average fruit weight, yield per hectare, beta carotene and lycopene. It also registered significant negative correlation with plant height, number of primary branches per plant, days to fruit set, number of fruits per plant, ascorbic acid and TSS. Path analysis revealed that the traits like number of fruits per plant and average fruit weight exhibited positive direct effects on fruit yield and these traits also recorded positive correlation with yield. This suggested that direct selection based on these traits will be rewarding for crop yield improvement.

Keywords: Correlation, path coefficient analysis, tomato, yield and yield related traits.

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) [1]. 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) [2]. 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) [3]. 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.

Material and methods
The investigation was carried out at the experimental farm of College of Horticulture, Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad, Telangana during *kharif*, 2017-18. Forty genotypes of tomato were utilized for the study in randomized block design with three replications. Five plants were selected in each genotype to record the observations on plant height (cm), number of primary branches per plant, days to first flowering, days to 50% flowering, days to fruit set, number of fruits per plant, average fruit weight (g), fruit yield per plant (kg), fruit yield (t/ha), T.S.S. (°Brix), ascorbic acid content (mg/100 g), lycopene content (mg/100g) and beta carotene (mg/100g). Correlation coefficient analysis was done as per Al-Jibouri *et al.* (1958) and the path coefficient analysis was estimated according to the formulae suggested by Dewey and Lu (1959).

Results and discussion
The estimates of correlation coefficient presented in (Table 1) described that fruit yield per plant recorded positive and significant correlations with average fruit weight (0.7125 P, 0.7274 G), yield per hectare (0.9883 P, 1.0057 G), beta carotene (0.3144 P, 0.3213 G) and lycopene (0.2501 P, 0.2523 G). It also registered significant negative correlation with plant height (-0.4706 P, -0.4845 G) number of primary branches per plant (-0.5788 P, -0.5924 G), days to

Fruit set (- 0.2865 P, -0.3661 G), number of fruits per plant (-0.5831 P, -0.5905 G), ascorbic acid (-0.6254 P, -0.6396 G) and TSS (-0.5045 P, -0.5142 G). Yield being a complex character is governed by a large number of genes. The influence of each character on yield could be known through correlation studies with a view to determine the extent and nature of relationships prevailing among yield and yield attributing characters. Fruit yield per plant exhibited high significant positive association with average fruit weight, fruit yield per hectare, lycopene and beta carotene indicating the importance of these traits in selection for yield. Direct selection based on these traits would result in simultaneous improvement of aforesaid traits and yield per se in tomato. Similar results were reported in tomato for different components *viz.*, lycopene (Nair and Thamburaj, 1995) [4]; fruit weight (Brar and Singh, 1998) [5]; lycopene (Kumar and Tewari, 1999) [2]; plant height and fruit weight (Prasad and Rai, 1999) [7]; fruit weight (Mayavel *et al.*, 2005) [8], Ullah *et al*. (2015) for fruit weight and fruit yield per hectare; for average fruit weight (Monisha Rawat *et al*., 2017) [9].

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). Plant height had negligible direct and negative effects on fruit yield per plant at genotypic level (-0.0070) and negligible positive direct effect at phenotypic level (0.0039). Further, negligible indirect negative effect on fruit yield per plant at genotypic level (-0.0046) and negligible positive effect on fruit yield per plant at phenotypic level (0.0025) was exhibited through number of fruits per plant. Number of primary branches per plant showed negligible positive direct effect on fruit yield per plant at genotypic level (0.0157) as well as at phenotypic level (0.0083). Further, negligible positive indirect effects on fruit yield were exhibited through number of fruits per plant at both genotypic and phenotypic level with values 0.0103 and 0.0054 respectively. At both genotypic and phenotypic level, days to first flowering exhibited negligible negative direct effect on fruit yield per plant (-0.2296 and -0.0137 respectively). Further, negligible negative indirect effect on fruit yield was exhibited through days to 50% flowering followed by days to fruit set at both phenotypic level (-0.0092) and (-0.0047) respectively and genotypic level (-0.2137) and (-0.1000) respectively. Days to 50 % flowering showed negligible positive direct effects on fruit yield per plant at genotypic level (0.0685) and phenotypic level (0.0104), respectively. At both genotypic and phenotypic level, days to fruit set exhibited negligible positive direct effect per plant fruit yield (0.3128 and 0.0235), respectively. Further, negligible positive indirect effect on fruit yield was exhibited through number of fruits per plant at both genotypic and phenotypic level (0.2619 and 0.0130), respectively. At both genotypic and phenotypic level, number of fruits per plant recorded negligible negative direct effect (-0.3323 and -0.0165), respectively on fruit yield per plant. Further, indirect negligible negative effect was noticed through total soluble solids followed by ascorbic acid at both genotypic (-0.2461 and -0.2354), respectively and phenotypic level (-0.0121 and -0.0116), respectively. This character showed negligible negative direct effect on fruit yield per plant at genotypic level (-0.0484) and showed negligible positive direct effect on phenotypic level (0.0123) on fruit yield. Further, indirect negligible negative effect at genotypic level (-0.0351) and indirect negligible positive effect at phenotypic level (0.0088) on fruit yield was exhibited through yield per hectare. At both genotypic and phenotypic level, yield per hectare recorded high positive direct effect on fruit yield per plant (0.9750 and 0.9711) respectively. Further, indirect high positive effect was recorded through average fruit weight at genotypic and phenotypic level (0.7071 and 0.6945), respectively. Ascorbic acid content recorded negligible negative direct effect at both the genotypic and phenotypic level, on fruit yield per plant (-0.0501) and (-0.0131), respectively. Total soluble solids (^{o}Brix) showed negligible positive direct effect on fruit yield per plant at genotypic level (0.0176) and showed negligible negative direct effect on fruit yield per plant at phenotypic level (-0.0061), respectively. Beta carotene content recorded negligible negative direct effects on fruit yield per plant at genotypic level (-0.0207) and showed negligible positive direct effect on fruit yield per plant at phenotypic level (0.0004) respectively. Lycopene content recorded negligible positive direct effect at both the genotypic and phenotypic level (0.0042 and 0.0081), respectively on fruit yield per plant.

Results of the path coefficient analysis revealed the improvement of yield by improving the characters days to first flowering, fruits per plant and weight of fruit. Similarly to this result, Golani *et al.* (2007) [10] reported that yield can be improved directly by improving fruit weight and Mohanty (2002) [11] reported that yield can be improved directly by improving fruits per plant and fruit weight. The traits like number of fruits per plant and average fruit weight exhibited positive direct effects on fruit yield and these traits also recorded positive correlation with yield. This suggested that direct selection based on these traits will be rewarding for crop yield improvement, similar results were also reported in tomato by Prasad and Rai (1999) [7], Mohanty (2003) [12] and Singh *et al.* (2004) [14]. In this study, yield per plant of tomato can also be increased indirectly through number of primary branches, days to fruit set and also through number of fruits per plant and average weight of fruit.

Table 1: Phenotypic (P) and genotypic (G) correlation coefficients among yield and yield attributes in forty genotypes of tomato

Characters		Plant height (cm)	Number of primary branches per plant	Days to first flowering	Days to 50 per cent flowering	Days to fruit set	No. of fruits per plant	Average fruit weight(g)	Yield/ha(t)	Ascorbic acid (mg/100)	TSS (^{o}Brix)	Beta-carotene (mg/100g)	Lycopene content (mg/100g)	Fruit yield per plant (kg)
Plant height (cm)	P	1.0000	0.5174**	-.2532**	-0.0898	0.3650**	0.6381**	-0.4623**	-0.4743**	0.5668**	0.4382**	-0.1979*	-0.3538**	-0.4706**
	G	1.0000	0.5225**	-.2904**	-0.1007	0.4491**	0.6504**	-0.4726**	-0.4863**	0.5829**	0.4526**	-0.2023*	-0.3613**	-0.4845**
Number of primary branches per plant	P		1.0000	-0.0864	0.0513	0.3513**	0.6468**	-0.7337**	-0.5823**	0.6029**	0.5687**	-0.2876**	-0.2892**	-0.5788**
	G		1.0000	-0.1283	0.0437	0.4470**	0.6555**	-0.7467**	-0.5945**	0.6100**	0.5874**	-0.2956**	-0.2944**	-0.5924**
Days to first flowering	P			1.0000	0.6745**	0.2897**	-0.0837	-0.0275	0.0927	0.0622	0.1346	0.0846	0.0348	0.0881
	G			1.0000	0.9307**	0.4356**	-0.1086	-0.0402	0.1350	0.0777	0.1667	0.1054	0.0486	0.1371
Days to 50 per cent flowering	P				1.0000	0.5571**	0.2210*	-0.0663	0.0214	0.2276*	0.3296**	-0.0423	-0.1708	0.0242

	G				1.0000	0.7257**	0.2433*	-0.0604	0.0321	0.2587*	0.3686**	-0.0512	-0.1887	0.0304
Days to fruit set	P					1.0000	0.6817**	-0.3608**	-0.2948**	0.5562**	0.5878**	-0.0756	-0.3995**	-0.2865**
	G					1.0000	0.8372**	-0.4397**	-0.3622**	0.6960**	0.7260**	-0.0844	-0.4817**	-0.3661**
Number of fruits per plant	P						1.0000	-0.5732**	-0.5855**	0.6993**	0.7305**	-0.2689**	-0.5465**	-0.5831**
	G						1.0000	-0.5764**	-0.5909**	0.7083**	0.7407**	-0.2722**	-0.5507**	-0.5905**
Average fruit weight(g)	P							1.0000	0.7152**	-0.6336**	-.5052**	0.2909**	0.1662	0.7125**
	G							1.0000	0.7252**	-0.6456**	-.5115**	0.2940**	0.1677	0.7274**
Yield /ha (t)	P								1.0000	-0.6265**	-.5067**	0.3140**	0.2477**	0.9883**
	G								1.0000	-0.6394**	-.5156**	0.3197**	0.2519**	1.0057**
Ascorbic acid (mg/100g)	P									1.0000	0.6036**	-0.2608**	-0.3184**	-0.6254**
	G									1.0000	0.6193**	-0.2658**	-0.3256**	-0.6396**
TSS(^{0}Brix)	P										1.0000	-0.1948*	-0.2314*	-0.5045**
	G										1.0000	-0.2007*	-0.2322*	-0.5142**
Beta-carotene (mg/100g)	P											1.0000	0.3774**	0.3144**
	G											1.0000	0.3797**	0.3213**
Lycopene content(mg/100g)	P												1.0000	0.2501**
	G												1.0000	0.2523**
Fruit yield /plant(kg)	P													1.0000
	G													1.0000

*Significant at 5 per cent level; ** Significant at 1 per cent level

Table 2: Phenotypic (P) and genotypic (G) path coefficients indicating direct and indirect effects of components characters on fruit yield in forty genotypes of tomato

Characters		Plant height (cm)	Number of primary branches per plant	Days to first flowering	Days to 50 per cent flowering	Days to fruit set	Number of fruits per plant	Average fruit weight (g)	Yield/ha (t)	Ascorbic acid (mg/100)	TSS (^{o}Brix)	Betacarotene (mg/ 100g)	Lycopene content (mg/100g)	Correlation coefficient
Plant height (cm)	P	0.0039	0.0020	-0.0010	-0.0004	0.0014	0.0025	-0.0018	-0.0019	0.0022	0.0017	-0.0008	-0.0014	-0.4706**
	G	-0.0070	-0.0037	0.0020	0.0007	-0.0032	-0.0046	0.0033	-0.0034	-0.0041	-0.0032	0.0014	0.0025	-0.4845**
Number of primary branches per plant	P	0.0043	0.0083	-0.0007	0.0004	0.0029	0.0054	-0.0061	-0.0048	0.0050	0.0047	-0.0024	-0.0024	-0.5788**
	G	0.0082	0.0157	-0.0020	0.0007	0.0070	0.0103	-0.0117	-0.0093	0.0096	0.0092	-0.0046	-0.0046	-0.5924**
Days to first flowering	P	0.0035	0.0012	-0.0137	-0.0092	-0.0040	0.0011	0.0004	-0.0013	-0.0009	-0.0018	-0.0012	-0.0005	0.0881
	G	0.0667	0.0295	-0.2296	-0.2137	-0.1000	0.0249	0.0092	-0.0310	-0.0178	-0.0383	-0.0242	-0.0112	0.1371
Days to 50 per cent flowering	P	-0.0009	0.0005	0.0070	0.0104	0.0058	0.0023	-0.0007	0.0002	0.0024	0.0034	-0.0004	-0.0018	0.0242
	G	-0.0069	0.0030	0.0637	0.0685	0.0497	0.0167	-0.0041	0.0022	0.0177	0.0252	-0.0035	-0.0129	0.0304
Days to fruit set	P	0.0086	0.0082	0.0068	0.0131	0.0235	0.0160	-0.0085	-0.0069	0.0130	0.0138	-0.0018	-0.0094	-0.2865**
	G	0.1405	0.1398	0.1362	0.2270	0.3128	0.2619	-0.1375	-0.1133	0.2177	0.2271	-0.0264	-0.1507	-0.3661**
Number of fruits per plant	P	-0.0105	-0.0107	0.0014	-0.0037	-0.0113	-0.0165	0.0095	0.0097	-0.0116	-0.0121	0.0044	0.0090	-0.5831**
	G	-0.2161	-0.2178	0.0361	-0.0808	-0.2782	-0.3323	0.1915	0.1963	-0.2354	-0.2461	0.0905	0.1830	-0.5905**
Average fruit weight(g)	P	-0.0057	-0.0091	-0.0003	-0.0008	-0.0045	-0.0071	0.0123	0.0088	-0.0078	-0.0062	0.0036	0.0020	0.7125**
	G	0.0229	0.0361	0.0019	0.0029	0.0213	0.0279	-0.0484	-0.0351	0.0312	0.0247	-0.0142	-0.0081	0.7274**
Yield /ha (t)	P	-0.4606	-0.5655	0.0900	0.0208	-0.2863	-0.5686	0.6945	0.9711	-0.6084	-0.4920	0.3049	0.2406	0.9883**
	G	-0.4741	-0.5797	0.1316	0.0313	-0.3531	-0.5761	0.7071	0.9750	-0.6235	-0.5027	0.3117	0.2456	1.0057**
Ascorbic acid (mg/100g)	P	-0.0074	-0.0079	-0.0008	-0.0030	-0.0073	-0.0091	0.0083	0.0082	-0.0131	-0.0079	0.0034	0.0042	-0.6254**
	G	-0.0292	-0.0306	-0.0039	-0.0130	-0.0349	-0.0355	0.0324	0.0320	-0.0501	-0.0310	0.0133	0.0163	-0.6396**
TSS(^{0}Brix)	P	-0.0027	-0.0035	-0.0008	-0.0020	-0.0036	-0.0045	0.0031	0.0031	-0.0037	-0.0061	0.0012	0.0014	-0.5045**
	G	0.0080	0.0104	0.0029	0.0065	0.0128	0.0131	-0.0090	-0.0091	0.0109	0.0176	-0.0035	-0.0041	-0.5142**
Beta-carotene (mg/100g)	P	-0.0001	-0.0001	0.0000	0.0000	-0.0000	-0.0001	0.0001	0.0001	-0.0001	-0.0001	0.0004	0.0002	0.3144**
	G	0.0042	0.0061	-0.0022	0.0011	0.0017	0.0056	-0.0061	-0.0066	0.0055	0.0041	-0.0207	-0.0078	0.3213**
Lycopene content(mg/100g)	P	-0.0029	-0.0023	0.0003	-0.0014	-0.0032	-0.0044	0.0013	0.0020	-0.0026	-0.0019	0.0031	0.0081	0.2501**
	G	-0.0015	-0.0012	0.0002	-0.0008	-0.0020	-0.0023	0.0007	0.0011	-0.0014	-0.0010	0.0016	0.0042	0.2523**

Phenotypic Residual effect = 0.151; Genotypic Residual effect= 0.0092; Diagonal (under lined) values indicate direct effects

Conclusion

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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