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

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Abstract
Thirty tomato genotypes were studied for correlation and path co-efficient analysis of fruit yield and yield attributes in tomato (*Solanum lycopersicum* L.) at Vegetable Research Farm, College of Horticulture, Rajendranagar, SKLTSHU, Hyderabad, Telangana during *Rabi*, 2015-16. Fruit yield had positive and significant correlation with plant height, average fruit weight, fruit yield per hectare, lycopene and beta carotene. It was observed that with increase in plant height, there was corresponding increase in average fruit weight and fruit yield per hectare. Path coefficient analysis of different yield and yield contributing traits on fruit yield per plant revealed with number of branches per plant, days to first flowering, days to 50% flowering, average fruit weight, number of fruits per plant, fruit yield per hectare, acidity and TSS: Acid ratio exhibited positive direct effects on fruit yield these characters play a major role in recombination breeding and suggested that direct selection based on these traits will be rewarded for crop improvement of tomato.

Keywords: Tomato, yield and yield attributes, correlation, path co-efficient analysis.

Introduction
Tomato (*Solanum lycopersicum* L.) is one of the most important solanaceous vegetable crops grown widely all over the world. It is a very versatile vegetable for culinary purposes. Ripe fresh tomato fruit is consumed fresh as salads, consumed after cooking and utilized in the preparation of range of processed products such as puree, paste, powder, ketchup, sauce, soup and canned whole fruits. Unripe green fruits are used for preparation of pickles and chutney. Tomatoes are important source of lycopene (an antioxidant), ascorbic acid and beta carotene and valued for their colour and flavour.

Tomato belongs to the family solanaceae and is native of Peru Equador region (Rick, 1969) [11]. Tomato is a typical day neutral plant and is mainly self-pollinated, but a certain percentage of cross-pollination also occurs. It is a warm season crop reasonably resistant to heat and drought and grows under wide range of soil and climatic conditions.

The study on genotypic and phenotypic correlations is an important approach in crop improvement as Galtan (1988) emphasized the use of this index to describe the degree of association between two or more characters. It gives the total mutual relationship between two characters. Plant yield is a very complex character dependent on a number of components. Therefore, knowledge of magnitude of correlation of yield with its attributes is of immense practical utility and has profound significance in the field of crop improvement. The knowledge of association that exists between important traits may facilitate interpretation of the result and provide basis for planning more efficient improvement programme for the future.

Path analysis developed by Wright (1921) [15] is standardized partial regression coefficient and as such measures the direct influence of one variable upon another and permits the partitioning of correlation coefficient into component of direct and indirect effect (Dewey and Lu, 1959) [3]. It is apparent that many of the yield components have mutual association either positive or negative amongst each other. As more variables are considered in correlation studies indirect association become more complex and less obvious. The direct and indirect causes of association permits a critical examination of specific forces acting to produce relative importance of each of the causal factors. In the calculation of correlation coefficient a prime knowledge available regarding the relationship between the multiple variants is not made use of significant correlation and is therefore no proof of direct causal relationship. Hence it appear desirable to employ a method of analysis which will take into account the knowledge to have in regard to the causal relation between the variable in addition to that provided on the degree of relationship between the characters by correlation analysis which can be easily done by utilizing the technique of path coefficient analysis.

With the above objectives, an attempt was made to study the genotypic and phenotypic correlation coefficient between all possible combinations of the characters and path coefficient analysis also.

Materials and methods

The field experiment was conducted at Vegetable Research Farm, College of Horticulture, Rajendranagar, SKLTSHU, Hyderabad, Telangana during *Rabi* season of 2015-16. Thirty tomato genotypes were evaluated for correlation and Path co efficient analysis of fruit yield and it's attributing traits in tomato. The experiment was laid out in a Randomized Block Design (RBD) with three replications. Appropriate agronomic practices were followed to raise a good crop. Ten randomly taken plants were used to record observations on yield and yield attributed traits as plant height, number of branches, days to first flowering, days to 50% flowering, days to fruit set, number of fruits per plant, average fruit weight, fruit yield per plant, fruit yield per hectare, TSS, Acidity, TSS :Acid ratio, ascorbic acid, lycopene and beta carotene which included correlation co-efficient calculated for all quantitative and qualitative character combinations at phenotypic and genotypic levels correlation analysis by the formula given by Al-Jibouri *et al.* (1958) [1] and path co-efficient analysis developed by Wright (1921) [15] and elaborated by Dewey and Lu (1959) [3].

Results and discussion

Interrelationship study in growth and yield parameters

The results of phenotypic correlation and genotypic correlation (Table 1) revealed that plant height exhibited positive significant correlation with number of branches per plant and fruit yield per hectare along with negative significant correlation was noticed with TSS: Acid ratio. The number of primary branches per plant recorded positive, significant correlation with days to first flowering, days to 50% flowering, days to fruit set, number of fruits per plant, TSS, acidity, beta carotene, plant height and negative and significant correlation with average fruit weight, fruit yield per hectare and lycopene. Days to first flowering recorded both phenotypic and genotypic correlation exhibited significant positive correlation with days to 50% flowering, days to fruit set, number of fruits per plant, TSS, acidity, TSS :Acid ratio and plant height and number of branches per plant. Significant negative correlation was recorded with average fruit weight, fruit yield per hectare, lycopene and beta carotene. Days to 50 per cent flowering recorded both phenotypic and genotypic correlation exhibited significant positive correlation with days to 50% flowering days to fruit set, number of fruits per plant, TSS, acidity, plant height, number of branches per plant and days to first flowering. The average fruit weight, fruit yield per hectare, lycopene and beta carotene recorded significant negative correlation for the trait. Days to fruit set showed both phenotypic and genotypic correlation exhibited significant positive correlation with number of fruits per plant, TSS, acidity, plant height, number of branches per plant, days to first flowering and days to 50% flowering and Significant negative correlation with average fruit weight, fruit yield per hectare, lycopene and beta carotene.

Number of fruit per plant showed positive significant correlation with TSS, acidity, plant height, number of branches per plant, days to first flowering, days to 50% flowering and days to fruit set and negative significant correlation with average fruit weight, lycopene and beta carotene. Average fruit weight showed positive and significant correlation with fruit yield per hectare, acidity, lycopene, beta carotene, plant height, number of branches per plant, days to first flowering, days to 50% flowering, days to fruit set and number of fruits per plant. This trait recorded negative significant association with TSS. Fruit yield per ha recorded positive and significant correlation with lycopene, plant height, number of branches per plant, days to first flowering, days to 50% flowering, days to fruit set and number of fruits per plant, average fruit weight and negative, significant correlation with TSS and TSS: Acid ratio.

Total soluble solids recorded positive and significant correlation with TSS: Acid ratio (0.628 P, 0.630 G), plant height, number of branches per plant, days to first flowering, days to 50% flowering, days to fruit set and number of fruits per plant, average fruit weight, Fruit yield per hectare. Acidity showed positive and significant correlation with plant height, number of branches per plant, days to first flowering, days to 50% flowering, days to fruit set and number of fruits per plant, average fruit weight, Fruit yield per hectare, total soluble solids. The correlation between TSS: Acid ratio and fruit yield per plant was not significant as well as with all the other characters also. Ascorbic acid showed positive significant correlation with lycopene, beta carotene, plant height, number of branches per plant, days to first flowering, days to 50% flowering, days to fruit set and number of fruits per plant, average fruit weight, fruit yield per hectare, total soluble solids and TSS: Acid ratio. Lycopene showed positive and significant correlation with beta carotene, plant height, number of branches per plant, days to first flowering, days to 50% flowering, days to fruit set and number of fruits per plant, average fruit weight, fruit yield per hectare, total soluble solids, TSS: Acid ratio and ascorbic acid. The correlation between beta carotene and fruit yield per plant was significant as well as with all the other characters. These results are in consonance with the finding of Nandapuri *et al*. (1974) [9], Verma *et al*. (1974) [14], Anitha *et al*. (2007) [2] and Golani *et al*. (2007) [4]. The trend of association observed in this study is mostly based upon the genetic contribution. Therefore, the value of 'r' for genotypic correlation between yield, yield contributing characters and quality characters should be considered for selecting the suitable characters for improvement.

Fruit yield per plant showed positive and significant correlation with characters plant height, average fruit weight, fruit yield per hectare, lycopene, beta carotene and ascorbic acid. It also registered significant negative correlation with number of branches per plant, days to first flowering, days to 50% flowering, days to fruit set, number of fruits per plant and TSS. These results are in consonance with the finding of Singh *et al.,* (1990) [12], Patil and Bojappa (1993) [10], Singh *et al.,* (2004) [13], Mohanty (2003) [6]. The present study further indicated that yield per plant can be improved by improving the characters like number of fruits per plant and weight of fruit.

Table 1: Phenotypic (P) and genotypic (G) correlation coefficients among yield and yield attributes in 30 genotypes of tomato.

Characters		Plant height (cm)	No. of branches per plant	Days to first flowering	Days to 50 per cent flowering	Days to fruit set	No. of fruits per plant	Av. fruit weight (g)	Fruit yield per ha (t)	TSS (°Brix)	Acidity (%)	TSS: Acid ratio	Ascorbic acid (mg/100g of fruit)	Lycopene (mg/100g)	Beta carotene (mg/100g	Fruit yield /plant(kg)
Plant height (cm)	P	1.000	0.373**	-0.084	-0.941	-0.101	0.122	-0.086	0.241*	0.082	0.171	-0.265*	0.089	-0.151	0.089	0.233 **
	G	1.000	0.379**	-0.085	-0.095	-0.102	0.123	-0.088	0.245*	-0.084	0.172	-0.266*	0.091	-0.152	0.092	0.237 **
No. of branches per plant	P		1.000	0.576**	0.681**	0.579**	0.463**	-0.535**	-0.181	0.348**	0.311**	-0.028	-0.120	-0.507**	-0.311**	-0.185**
	G		1.000	0.586**	0.703**	0.588**	0.469**	-0.545**	-0.189	0.353**	0.318**	-0.032	-0.127	-0.514**	0.340**	-0.194**
Days to first flowering	P			1.000	0.914**	0.886**	0.513**	-0.696**	-0.562**	0.615**	0.218*	0.250*	-0.125	-0.767**	-0.459**	-0.559**
	G			1.000	0.925**	0.887**	0.514**	-0.698**	-0.571**	0.618**	0.219*	0.251*	-0.127	-0.769**	-0.477**	-0.569**
Days to 50 per cent flowering	P				1.000	0.904**	0.535**	-0.701**	-0.547**	0.585**	0.238*	0.191	-0.095	-0.736**	-0.419***	-0.545**
	G				1.000	0.915**	0.542**	-0.709**	-0.557**	0.592**	0.242*	0.193	-0.097	-0.745**	0.446**	-0.558**
Days to fruit set	P					1.000	0.606**	-0.767**	-0.579**	0.641**	0.253*	0.219	-0.123	-0.813**	-0.475**	-0.578**
	G					1.000	0.607**	-0.769**	-0.587**	0.642**	0.254*	0.220	-0.125	-0.814**	-0.494**	-0.589**
No. offruits per plant	P						1.000	-0.754**	-0.050	0.428**	0.628**	-0.189	-0.042	-0.656**	-0.356**	-0.056**
	G						1.000	-0.756**	-0.054	0.429**	0.629**	0.190	-0.043	-0.657**	-0.372**	-0.059**
Av. fruit weight(g)	P							1.000	0.603**	-0.620**	0.472**	-0.029	0.001	0.779**	0.318**	0.612**
	G							1.000	0.608**	-0.624**	-0.474	-0.030	0.002	0.781**	0.331**	0.618**
Fruit yield per ha (t)	P								1.000	-0.590**	-0.014	-0.389**	0.010	0.452**	0.186**	0.998**
	G								1.000	-0.602**	-0.015	-0.398**	0.013	0.460**	0.191**	1.000**
TSS (°Brix)	P									1.000	0.094	0.628**	0.030	-0.644**	-0.337**	-0.589**
	G									1.000	0.095	0.630**	0.031	-0.645**	-0.353**	-0.603**
Acidity (%)	P										1.000	-0.637**	0.002	-0.207*	-0.054	-0.023
	G										1.000	-0.638**	0.003	-0.208*	-0.058	-0.022
TSS: Acid ratio	P											1.000	-0.052	-0.193	-0.170	-0.379
	G											1.000	-0.056	-0.194	-0.179	-0.389
Ascorbic acid (mg/100g of fruit)	P												1.000	0.260*	0.466**	-0.002**
	G												1.000	0.263*	0.485**	0.001**
Lycopene (mg/100g)	P													1.000	0.676**	0.451**
	G													1.000	0.704**	0.461**
B-carotene (mg/100g	P														1.000	0.177**
	G														1.000	0.183**
Fruit yield /plant(kg)	P															1.000
	G															1.000

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

Path co-efficient analyses

From the results, it was observed that genotypic direct and indirect effects (Table 2) were higher than their corresponding phenotypic values.

Table 2: Phenotypic (P) and genotypic (G) path coefficient analysis indicating direct and indirect effects of components characters on fruit yield in 30 genotypes of tomato.

Characters		Plant height (cm)	No. of branches per plant	Days to first flowering	Days to 50 per cent flowering	Days to fruit set	No. of fruits per plant	Av. fruit weight(g)	Fruit yield per ha (t)	TSS (ºBrix)	Acidity (%)	TSS: Acid ratio	Ascorbic acid (mg/100g of fruit)	Lycopene (mg/100g)	Beta carotene (mg/100g	Correlation coefficient
Plant height (cm)	P	-0.0015	-0.0006	0.0001	0.0001	0.0002	-0.0002	0.0001	-0.0004	0.0001	-0.0003	0.0004	-0.0001	0.0002	-0.0001	0.233**
	G	0.0002	0.0001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.0001	0.000	0.000	0.000	0.237**
No. of branches per plant	P	0.0007	0.0020	0.0011	0.0013	0.0011	0.0009	-0.0010	-0.0004	0.0007	0.0006	-0.0001	-0.0002	-0.0010	-0.0006	-0.185**
	G	0.0006	0.0017	0.0010	0.0012	0.0010	0.0008	-0.0009	-0.0003	0.0006	0.0005	-0.0001	-0.0002	-0.0009	-0.0006	-0.194**
Days to first flowering	P	-0.0004	0.0031	0.0053	0.0048	0.0047	0.0027	-0.0037	-0.003	0.0033	0.0012	0.0013	-0.0007	-0.0041	-0.0024	-0.559**
	G	-0.0009	0.0065	0.0111	0.0103	0.0099	0.0057	-0.0078	-0.0063	0.0069	0.0024	0.0028	-0.0014	-0.0085	-0.0053	-0.569**
Days to 50 per cent flowering	P	0.0005	0.0033	0.0044	0.0048	0.0044	0.0026	-0.0034	-0.0026	0.0028	0.0012	0.0009	-0.0005	-0.0036	-0.002	-0.545**
	G	0.000	-0.0003	-0.0004	-0.0004	-0.0004	-0.0002	0.0003	0.0002	-0.0002	-0.0001	-0.0001	0.000	0.0003	0.0002	-0.558**
Days to fruit set	P	0.001	-0.0059	-0.009	-0.0092	-0.0102	-0.0062	0.0078	0.0059	-0.0065	-0.0026	-0.0022	0.0013	0.0083	0.0048	-0.578**
	G	0.0011	-0.0063	-0.0096	-0.0099	-0.0108	-0.0066	0.0083	0.0064	-0.0069	-0.0027	-0.0024	0.0014	0.0088	0.0053	-0.589**
No. offruits per plant	P	0.0029	0.0109	0.0121	0.0126	0.0143	0.0236	-0.0178	-0.0012	0.0101	0.0148	-0.0045	-0.0010	-0.0155	-0.0084	-0.056**
	G	0.0036	0.0139	0.0152	0.016	0.0179	0.0296	-0.0224	-0.0016	0.0127	0.0186	-0.0056	-0.0013	-0.0194	-0.011	-0.059**
Av. fruit weight(g)	P	-0.0036	-0.0228	-0.0296	-0.0298	-0.0326	-0.0321	0.0426	0.0257	-0.0264	-0.0201	-0.0012	0.0001	0.0331	0.0135	0.612**
	G	-0.0038	-0.0242	-0.031	-0.0315	-0.0341	-0.0335	0.0444	0.0270	-0.0277	-0.0210	-0.0013	0.0001	0.0346	0.0147	0.618**
Fruit yield per ha (t)	P	0.2353	-0.1771	-0.5494	-0.5346	-0.5656	-0.0493	0.5899	0.9776	-0.5768	-0.0137	-0.3806	0.0100	0.4417	0.1816	0.998**
	G	0.2385	-0.1843	-0.5562	-0.5428	-0.5724	-0.0523	0.5923	0.9737	-0.5857	-0.0128	-0.3871	0.0128	0.4481	0.1861	1.000**
TSS (ºBrix)	P	0.0018	-0.0075	-0.0132	-0.0126	-0.0138	-0.0092	0.0133	0.0127	-0.0215	-0.002	-0.0135	-0.0007	0.0139	0.0073	-0.589**
	G	0.0011	-0.0047	-0.0083	-0.0079	-0.0086	-0.0058	0.0084	0.0081	-0.0134	-0.0013	-0.0085	-0.0004	0.0087	0.0047	-0.603**
Acidity (%)	P	0.0018	0.0032	0.0023	0.0025	0.0026	0.0065	-0.0049	-0.0001	0.001	0.0103	-0.0066	0.000	-0.0021	-0.0006	-0.023
	G	0.0002	0.0003	0.0002	0.0002	0.0002	0.0006	-0.0004	0.000	0.0001	0.0009	-0.0006	0.000	-0.0002	-0.0001	-0.022
TSS: Acid ratio	P	-0.0064	-0.0007	0.006	0.0046	0.0053	-0.0045	-0.0007	-0.0094	0.0151	-0.0153	0.0241	-0.0013	-0.0047	-0.0041	-0.379
	G	-0.0031	-0.0004	0.0029	0.0022	0.0025	-0.0022	-0.0003	-0.0046	0.0072	-0.0073	0.0115	-0.0006	-0.0022	-0.002	-0.389
Ascorbic acid (mg/100g of fruit)	P	-0.0004	0.0066	0.0006	0.0005	0.0006	0.0002	0.000	0.000	-0.0002	0.000	0.0003	-0.0048	-0.0013	-0.0022	-0.002**
	G	-0.0006	0.0008	0.0008	0.0006	0.0008	0.0003	0.000	-0.0001	-0.0002	0.000	0.0004	-0.0064	-0.0017	-0.0031	0.001**
Lycopene (mg/100g)	P	0.002	0.0066	0.01	0.0095	0.0106	0.0085	-0.0101	-0.0059	0.0084	0.0027	0.0025	-0.0034	-0.0130	-0.0088	0.451**
	G	0.0006	0.002	0.003	0.003	0.0032	0.0026	-0.0031	-0.0018	0.0026	0.0008	0.0008	-0.001	-0.0040	-0.0028	0.461**
B-carotene (mg/100g	P	-0.0001	0.0003	0.0004	0.0004	0.0004	0.0003	-0.003	-0.0002	0.0003	0.000	0.0002	-0.0004	-0.0006	-0.0009	0.177**
	G	-0.0003	0.0012	0.0017	0.0016	0.0018	0.0013	-0.0012	-0.0007	0.0013	0.0002	0.0006	-0.0017	-0.0025	-0.0036	0.183**

Phenotypic Residual effect = 0.044; Genotypic Residual effect= 0.0004; Diagonal (under lined) values indicate direct effects

Direct effects

Path coefficient analysis showed that the characters plant height, number of branches per plant, days to first flowering, days to 50% flowering, average fruit weight, number of fruits per plant, fruit yield per hectare, acidity and TSS : Acid ratio exhibited positive direct effects on fruit yield. This suggested that direct selection based on these traits will be rewarding for crop yield improvement. These results were conformity with Singh *et al*. (2004) [13] and Haydar *et.al.* (2007) [5].

Indirect effects on growth and yield parameters

Number of branches per plant showed negligible positive indirect effect through days to 50% flowering on fruit yield. The days to first flowering also exhibited negligible positive indirect effect through days to 50% flowering and days to fruit set on fruit yield. Number of fruits per plant showed negligible positive indirect effect through acidity and days to fruit set on fruit yield. Average fruit weight also exhibited negligible positive indirect effect through lycopene and fruit yield per hectare on fruit yield. Fruit yield per hectare exhibited high positive indirect effect through average fruit weight on fruit yield. This suggested that indirect selection based on number of branches per plant, days to first flowering, number of fruits per plant, average fruit weight and fruit yield per hectare will be effective in yield improvement. Similar result was observed by Golani *et al.* (2007) [4] who reported that yield can be improved directly by improving fruit weight and Mohanty (2002^a and 2002^b) [7-8] reported that yield can be improved directly by improving fruits per plant and fruit weight.

Conclusion

Fruit yield had a positive and highly significant association with number of fruit per plant, average fruit weight, strong association of these traits revealed that the selection based on these traits would ultimately improve the fruit yield were positive and significant correlated with fruit yield plant per plant. Hence, due weightage should be given to these characters while selecting the germplasm in crop improvement. The path coefficient revealed that the improvement of yield by improving the characters days to first flower, length of fruit, fruits per plant and weight of fruit. 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.

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