The Pharma Innovation Journal 2023; 12(6): 1627-1634

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(6): 1627-1634

www.thepharmajournal.com
Received: 27-03-2023
Accepted: 28-04-2023

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Association analysis of yield and fruit quality traits in Tomato (*Solanum lycopersicon* L.)

Bhavesh Verma, Dhananjay Sharma and Jhanendra Kumar Patel

Abstract
Tomato is one of the most significant vegetable crops, which provides several important dietary components. The present study aimed to investigate association analysis for yield and yield-related traits and quality traits in tomatoes. For this purpose, fifteen tomato genotypes were evaluated in the field of AICRP on vegetable crops, Horticultural Research cum Instructional Farm, Department of Vegetable Sciences, Indira Gandhi Krishi Vishwavidyalaya, Raipur during 2019-20 in randomized complete block design with three-replication to study the association analysis between relevant traits. The genotypic correlation analysis revealed that the yield per plant was significantly and positively associated with plant height, number of primary branches, number of secondary branches, days to first flowering, flowers per cluster, fruit weight, polar diameter, equatorial diameter, number of fruits per cluster and pericarp thickness, pulp juice ratio, yield per plot. Path analysis was performed to know the direct and indirect effects of related traits on yield and fruit yield was used as a dependent variable while other characters are considered as independent variables. The findings depicted that the plant height, primary branches, days to first flowering, days to 50% flowering, flowers per cluster, polar diameter, fruit weight, calyx length TSS pericarp thickness, and acidity showed that it was a positive direct effect on the yield per hectare. Hence, it may be suggested that these are the most effective and reliable parameters for genetic improvement in the fruit yield of tomato genotypes. The genotypes in this experiment can be used as parents for future studies on hybridization programme to enhance the yield and quality of tomato.

Keywords: Correlation, path analysis, tomato, yield, direct effect

Introduction
Tomato (*Solanum lycopersicon* L.) with chromosome number 2n=24 belongs to the nightshade family Solanaceae. It is a herbaceous, annual to perennial, sexually propagated, prostrate, and typically day-neutral plant. This crop is self-pollinated, but there is also a certain proportion of cross-pollination occurs. It has determinate or indeterminate growth habits. Scientific evidence suggests that the cultivated tomato originated in the Peru-Ecuador-Bolivia area of the Andes (South American). The cherry species (*Lycopersicon esculantum var. creasiforme*) is the most probable ancestor of the cultivated tomato. Among many tomato varieties, only two species (*Lycopersicon esculantum* and *L. pimpinellifolium*) are commonly edible. Even if the origin of the tomato is South America, it is produced in a wide area of the world. Especially, China, India, Türkiye and the USA are globally shining out for tomato production (FAO, 2021) [6].
Ripe fresh tomatoes are used to make purées, pastes, powders, k*etc*hup, sauces, soups, and canned whole fruit. Unripe green fruits are used for pickles and chutney preparation uses. Tomato pulp and juice are Digestible moderate aperients and gastric secretion promoters and blood purifiers. The red color of the tomato is due to the presence of a pigment called "Lycopene" varying from 30 to 50 mg/100 g of the edible part. The yellow and orange color of tomato fruit is due to the presence of carotene and prolycopene (tangerine) pigments; both are anti-oxidants, respectively.
Although the tomatoes are self-pollinated crops, there is a genetic diversity was found not only in morphological features but also in quality attributes (Abushita *et al*., 1997).
In India, the yield of tomato (*Solanum lycopersicon* L.) is lower than the global average. So, the development of superior varieties/hybrids is needed to boost productivity. Because yield is a complex character, its direct improvement is difficult. Therefore, the evaluation of tomato germplasm is of great importance for crop agronomic and genetic enhancement in the current and future time (Ramzan *et al.*, 2014) [22]. Tomato yield is a multigenic trait and is greatly affected by environmental factors (Wang *et al.*, 2021) [27]. The breeders used potential hybridization techniques to obtain tomatoes with high-yield potential.

Many yield components have a mutual association either positive or negative among each other. As more variable is considered in correlation studies indirect association becomes more complex and less obvious. The direct and indirect causes of association permit a critical examination of specific forces acting to produce relative importance to each other of the causal factors. Therefore, the present study on tomato breeding program was carried out to determine factors having significant effects on the yield by using correlation and path coefficient analyses (Ibrahim *et al*., 2023) [7].

Materials and Methods

The experimental materials consisted of fifteen determinate tomato genotypes that were spread out in a three-replication randomized block design (RBD). Crops are shown in plot size 3.6 x 3.0 m. Firstly, prepared the nursery beds to get the seedlings of tomato crops and then transplanted them in the main plot. For transplanting different treatments, a plot size of 3.6 × 3m was prepared. Healthy seedlings were selected from the nursery and were transplanted on 20/11/2020 with a spacing of 60×40 cm, respectively. Newly planted tomatoes were irrigated lightly to keep the soil moist. During the early growing period, watering was done daily in the early morning. During severe temperatures, the plants were watered daily twice.

All the 15 determinate types of genotypes are from entries of AICRP on Vegetable Crops, IGKV, Raipur, Chhattisgarh.

Table 1: List of tomato (*Solanum lycopersicon* L.) genotypes and their sources

S. No.	Treatments	Source
1.	2018/TODVAR-1	AICRP on Vegetable Crops, Raipur, Chhattisgarh
2.	2018/TODVAR-2	AICRP on Vegetable Crops, Raipur, Chhattisgarh
3.	2018/TODVAR-3	AICRP on Vegetable Crops, Raipur, Chhattisgarh
4.	2018/TODVAR-5	AICRP on Vegetable Crops, Raipur, Chhattisgarh
5.	2018/TODVAR-6	AICRP on Vegetable Crops, Raipur, Chhattisgarh
6.	2019/TODVAR-1	AICRP on Vegetable Crops, Raipur, Chhattisgarh
7.	2019/TODVAR-2	AICRP on Vegetable Crops, Raipur, Chhattisgarh
8.	2019/TODVAR-3	AICRP on Vegetable Crops, Raipur, Chhattisgarh
9.	2019/TODVAR-4	AICRP on Vegetable Crops, Raipur, Chhattisgarh
10.	2019/TODVAR-5	AICRP on Vegetable Crops, Raipur, Chhattisgarh
11.	2019/TODVAR-6	AICRP on Vegetable Crops, Raipur, Chhattisgarh
12.	2019/TODVAR-7	AICRP on Vegetable Crops, Raipur, Chhattisgarh
13.	2019/TODVAR-8	AICRP on Vegetable Crops, Raipur, Chhattisgarh
14.	2019/TODVAR-9	AICRP on Vegetable Crops, Raipur, Chhattisgarh
15.	PANT Tomato-3	AICRP on Vegetable Crops, Raipur, Chhattisgarh

A field experiment was conducted at AICRP on vegetable crops, Horticultural Research cum Instructional Farm, Department of Vegetable Sciences, Indira Gandhi Krishi Vishwavidyalaya, Raipur, during 2019-20. Raipur is located between 22˚33’ N to 21˚14’ N latitude and 82˚6’ E to 81˚38’ E longitude in the Middle Eastern part of Chhattisgarh state. As per the observations recorded at Agro-meteorological Observatory, IGKV, Raipur, the Maximum temperature varied between 21.3 °C to 39.0 °C as against the normal of 29.63 °C. Similarly, the minimum temperature varied between 10.8 °C to 23.0 °C as against the normal of 16.70 °C. Around 1080.8 mm of rainfall was recorded during session 2019-20.

The fertilizer application depends on the soil requirement. Full doses of P_2O_5 and K_2O are applied and half of the N fertilizer was applied as a basal dose and the rest of the N fertilizer was applied 30 and 60 days after transplanting as a top dressing. The intercultural operations *viz*., hoeing, earthing up, irrigation, fertigation, weeding, cutting, training, pruning, and staking were carried out following recommended package of practices to ensure a healthy crop development.

Observations were recorded on a single-plant basis from five randomly tagged competitive plants of each genotype for all the traits separately. The fruit picking was done during the coolest period on each genotype and the number of pickings counted and cumulative yield was taken.

For statistical analysis, average values of each genotype in each replication were used for every trait of interest. The Path-coefficient analysis is equipped for further partitioning of the genotypic correlation coefficient into direct and indirect effects as suggested by Wright (1934) [28] and elaborated by Dewey and Lu (1959) [5]. For all the important characters which consider yield as a dependent variable, the path coefficient was calculated separately for them.

Results and Discussion

Correlation coefficient analysis

Correlation coefficient analysis measures the mutual relationship between various characters. The correlation coefficient for all the possible combinations of characters at the genotypic and phenotypic levels was calculated by using the procedure given by Searle (1961) [24]. The number of primary branches, number of secondary branches, days to first flowering, number of flowers per cluster, fruit weight, polar diameter, equatorial diameter, number of fruits per cluster, pericarp thickness, calyx length TSS, acidity, yield per plant yield per plot and yield per hectare recorded significant correlation at genotypic correlation.

Genotypic correlation

The genotypic correlation says that the yield was positively associated with plant height (0.24), number of primary branches (0.965), number of secondary branches (0.914), days to first flowering (0.466), flowers per cluster (0.768), fruit weight (0.705), polar diameter (0.550), equatorial diameter (0.791), number of fruits per cluster (0.696) and pericarp thickness (0.388), pulp juice ratio(0.039), yield per plot (1.000) and was negatively correlated with days to first fruiting (-0.004), days to fruit maturity (-0.281), calyx length (-0.074), days to 50% flowering (-0.245), TSS (-0.297) and acidity (-0.390). The genotypic correlation matrix is presented in Table 2.

Table 2: Genotypic correlation for fruit yield and its contributing characters in tomato genotypes

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Plant height (cm)	1.00	0.214	-0.065	0.359*	0.179	0.294*	0.044	0.16	0.1	0.117	0.108	-0.051	0.453**	-0.451**	-0.568**	-0.172	0.149	0.239	0.222	0.24
Number of primary branches		1.00	1.000**	0.478**	-0.069	0.678**	-0.154	-0.115	0.631**	0.436**	0.825**	0.611**	0.323*	0.035	-0.131	-0.366*	-0.045	0.965**	0.967**	0.965**
Number of secondary branches			1.00	0.458**	-0.07	0.650**	-0.228	-0.108	0.642**	0.373*	0.827**	0.613**	0.327*	0.07	-0.114	-0.328*	-0.196	0.913**	0.915**	0.914**
Days to first flowering				1.00	0.324*	0.068	-0.448**	0.346*	0.361*	0.234	0.605**	0.171	0.551**	-0.074	0.353*	-0.097	0.14	0.466**	0.464**	0.466**
Days to fifty percent flowering					1.00	-0.630**	-0.131	1.001**	-0.302*	-0.409**	-0.089	-0.568**	0.035	0.023	0.351*	0.421**	-0.157	-0.243	-0.248	-0.245
No. of flowers per cluster						1.00	-0.034	-0.672**	0.601**	0.618**	0.432**	1.097**	0.402**	-0.011	-0.715**	-0.712**	0.390**	0.769**	0.772**	0.768**
Days to1st fruit setting							1.00	-0.122	-0.464**	-0.167	-0.352*	-0.263	-0.479**	0.07	-0.122	0.085	0.19	-0.003	-0.001	-0.004
Days to fruit maturity								1.00	-0.319*	-0.406**	-0.105	-0.605**	0.021	0.043	0.309*	0.415**	-0.157	-0.279	-0.283	-0.281
Fruit weight									1.00	0.789**	0.774**	0.738**	0.712**	-0.273	0.136	-0.337*	-0.179	0.703**	0.700**	0.705**
Polar diameter of fruit										1.00	0.517**	0.666**	0.544**	-0.458**	-0.884**	-0.148	0.188	0.550**	0.555**	0.550**
Equatorial diameter of fruit											1.00	0.578**	0.523**	-0.225	0.326*	-0.062	0.034	0.791**	0.792**	0.791**
No. of fruit per cluster												1.00	0.529**	-0.031	-0.761**	-0.601**	0.529**	0.696**	0.701**	0.696**
Pericarp thickness													1.00	-0.427**	-0.451**	-0.05	-0.049	0.387**	0.380*	0.388**
Calyx length														1.00	0.274	-0.644**	-0.005	-0.076	-0.073	-0.074
T.S.S.															1.00	0.143	-1.248**	-0.311*	-0.314*	-0.297*
Acidity																1.00	-0.156	-0.387**	-0.386**	-0.390**
Pulp juice ratio																	1.00	0.045	0.053	0.039
Number of fruit per plant																		1.00	1.000**	1.000**
Number of fruit per plot																			1.00	1.000**
yield per hectare																				1.00

Table 3: Phenotypic correlation for fruit yield and its contributing characters in tomato genotypes

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Plant height (cm)	1.00	0.142	-0.05	0.213	0.119	0.041	-0.061	0.09	-0.039	0.112	0.091	0.038	0.193	-0.254	0.287	-0.062	0.205	0.135	0.121	0.133
Number of primary branches		1.00	0.887**	0.420**	-0.052	0.455**	-0.139	-0.085	0.480**	0.362*	0.747**	0.526**	0.275	0.031	-0.071	-0.344*	-0.049	0.847**	0.846**	0.846**
Number of secondary branches			1.00	0.445**	-0.069	0.362*	-0.196	-0.102	0.560**	0.299*	0.773**	0.499**	0.311*	0.105	-0.058	-0.287	-0.122	0.840**	0.843**	0.840**
Days to first flowering				1.00	0.291	0.036	-0.389**	0.303*	0.325*	0.215	0.570**	0.161	0.501**	-0.014	0.036	-0.075	0.076	0.431**	0.432**	0.430**
Days to fifty percent flowering					1.00	-0.332*	-0.091	0.983**	-0.272	-0.370*	-0.067	-0.521**	0.011	-0.006	-0.03	0.358*	-0.03	-0.233	-0.239	-0.235
No. of flowers per cluster						1.00	0.066	-0.384**	0.427**	0.354*	0.258	0.686**	0.253	-0.011	-0.216	-0.524**	0.355*	0.522**	0.521**	0.521**
Days to1st fruit setting							1.00	-0.092	-0.349*	-0.197	-0.323*	-0.193	-0.439**	0.117	-0.16	0.074	0.112	-0.015	-0.015	-0.016
Days to fruit maturity								1.00	-0.294*	-0.382**	-0.089	-0.562**	0.025	0.013	0.003	0.376*	-0.046	-0.274	-0.28	-0.276
Fruit weight									1.00	0.677**	0.676**	0.583**	0.609**	-0.214	-0.073	-0.268	-0.099	0.639**	0.638**	0.641**
Polar diameter of fruit										1.00	0.494**	0.504**	0.499**	-0.407**	-0.18	-0.107	0.082	0.517**	0.525**	0.517**
Equatorial diameter of fruit											1.00	0.467**	0.510**	-0.195	0.075	-0.059	0	0.734**	0.735**	0.734**
No. of fruit per cluster												1.00	0.414**	0.049	-0.158	-0.469**	0.17	0.576**	0.580**	0.575**
Pericarp thickness													1.00	-0.363*	-0.075	-0.018	-0.055	0.359*	0.353*	0.360*
Calyx length														1.00	-0.123	-0.533**	-0.023	-0.102	-0.099	-0.1
T.S.S.															1.00	0.027	-0.072	-0.059	-0.068	-0.057
Acidity																1.00	-0.084	-0.361*	-0.355*	-0.363*
Pulp juice ratio																	1.00	-0.021	-0.019	-0.027
Fruit yield per plant																		1.00	0.999**	1.000**
Fruit yield per plot																			1.00	0.999**
Yield per hectare																				1.00

Phenotypic correlation

The number of primary branches, number of secondary branches, days to first flowering, number of flowers per cluster, fruit weight, polar diameter, equatorial diameter, number of fruits per cluster, pericarp thickness, TSS, acidity, yield per plant, yield per plot and yield per hectare recorded significant correlation at phenotypic correlation matrix.

The phenotypic correlation with yield parameter was positively correlated with plant height (0.133), number of primary branches (0.846), number of secondary branches (0.840), days to first flowering (0.430), flowers per cluster (0.521), fruit weight (0.641), polar diameter (0.517), equatorial diameter (0.734), number of fruits per cluster (0.575), yield per plant (1.000), yield per plot (1.000) and pericarp thickness (0.360) were significantly correlated and it was negatively associated with days to fifty percent flowering (-0.235), days to first fruiting (-0.016), days to fruit maturity (-0.276), calyx length (-0.10), acidity (-0.363) TSS (-0.057) and pulp juice ratio (-0.027) (Table 3).

Association studies of different components in the present investigation showed that the attributes such as the number of fruits per plant, the weight of fruit, and the number of flowers per cluster are important yield-contributing characteristics. The results are the findings of Mohanty (2003) [14], Singh *et al.* (2006) [26], Prashanth *et al.* (2008) [19], Sharma and Singh (2012) [25], Mahapatra *et al.* (2013) [11], Meena and Bahadur (2014) [13], Namdev and Dongre (2018) [16], Alam and Paul (2019) [2] and Yadav *et al.* (2020) [29].

Path coefficient analysis

Path coefficient analysis is an important and valuable statistical method, which is commonly used to distinguish the correlation coefficient into direct and indirect effects of independent variables on a dependent variable. Wright (1921) introduced the concept of path analysis and Dewey and Lu (1959) [5] first used the methodology of path analysis that helps in determining yield attributing characters, which is also useful for indirect selection. Correlation coefficients, as well as path coefficients, provide more accurate knowledge that can be predicted effectively in the programme for crop improvement.

In the present investigation, genotypic path coefficient was performed and fruit yield was used as a dependent variable while, other characters *viz*. plant height, number of branches per plant, days to first flowering, days to 50% flowering, number of flowers per cluster, number of fruits per cluster, days to first fruiting, days to first harvesting, polar diameter, equatorial diameter, the weight of fruit, pericarp thickness, calyx length, TSS, acidity, pulp juice ratio considered as independent variables. The findings derived from direct and indirect effects are summarized in Table 4 and described below.

The plant height (0.0061), primary branches (0.13312), days to first flowering (0.00838), days to 50% flowering (0.28893), flowers per cluster (0.01085), polar diameter (0.01032), fruit weight (0.0126), calyx length (0.005171) TSS (0.01813) pericarp thickness (0.03732) and acidity (0.04429) showed that it was a positive direct effect on the yield per hectare. Similarly, the secondary branches (-0.14372), first fruiting (-0.00768), days to fruit maturity (-0.31144), equatorial diameter (-0.3698), number of fruits per cluster (-0.01381), pericarp thickness (-0.02208) and pulp juice ratio (-0.00972), yield per plot (-0.58573) showed a negative direct effect on yield per hectare.

Plant height showed positive and indirect effects on primary branches (0.02853), secondary branches (0.00931), days to first flowering (0.00301), days to 50% flowering (0.05172), number of flowers per cluster (0.00319), fruit weight (0.00126), polar diameter (0.00121), number of fruits per cluster (0.0007), pericarp thickness (0.0169) and yield per plot (0.35426) whereas, the remaining characters had indirect negative values.

The number of primary branches recorded positive and indirect effects on days to first flowering (0.00401), the number of flowers per cluster (0.00735), days to first fruiting (0.00118), days to fruit maturity (0.03571), fruit weight (0.00795), polar diameter (0.0045), pericarp thickness (0.01206), calyx length (0.00179), pulp juice ratio (0.00043)and yield per plot (1.54225).

A secondary number of branches showed positive and indirect effects on days to first flowering (0.00384), flowers per cluster (0.00705), days to first fruiting (0.00175), days to fruit maturity (0.03361), fruit weight (0.00808), polar diameter (0.00385), pericarp thickness (0.0122), calyx length (0.00362), pulp juice ratio (0.0019) and yield per plot (1.45918).

Days to first flowering recorded positive and indirect effects on days to 50% flowering (0.09369), the number of flowers per cluster (0.00073), days to first fruiting (0.00344), fruit weight (0.00454), polar diameter (0.00242), pericarp thickness (0.02055), TSS content (0.00641)and yield per plot (0.00389).

Days to 50% flowering showed positive and direct effects on days to first fruiting (0.00101), equatorial diameter (0.00329), number of fruits per cluster (0.00785), pericarp thickness (0.00131), calyx length (0.00119), TSS (0.00363), acidity (0.01865), pulp juice ratio (0.00152) and yield per plant (0.14239).

Flowers per cluster showed positive and indirect effects on days to first fruiting (0.00026), days to fruit maturity (0.20916), fruit weight (0.00758), polar diameter (0.00638), pericarp thickness (0.01502) and yield per plot (1.23169).

Days to first fruiting recorded positive and indirect effects on days to fruit maturity (0.003798), equatorial diameter (0.01302), number of fruits per cluster (0.00363), calyx length (0.00364), acidity (0.00378) and yield per plant (0.00154).

Days to fruit maturity showed positive and indirect effects on equatorial diameter (0.00388), number of fruits per cluster (0.00836), calyx length (0.00222), TSS (0.00561), acidity (0.01837), pulp juice ratio (0.00153) and yield per plant (0.16321).

Fruit weight showed positive and indirect effects on polar diameter (0.00815), pericarp thickness (0.02658), TSS (0.00246), pulp juice ratio (0.0017), and yield per plot (1.11601).

Polar diameter showed a positive and indirect effect on pericarp thickness (0.02029) and yield per plot (0.88474).

Equatorial diameter showed positive and indirect effects on pericarp thickness (0.01952), TSS (0.00591), and yield per plot (1.26319).

The number of fruits per cluster showed a positive and indirect effect on pericarp thickness (0.01974) and yield per plot (1.11797).

Pericarp thickness showed a positive and indirect effect on pulp juice ratio (0.00048) and yield per plot (0.60635).

Calyx length showed a positive and indirect effect on TSS

Table 4: Genotypic path coefficient analysis for fruit yield & its components in tomato genotype

	Plant height	Number of Primary Branches	Number of Sec Branches	1st Flowering	50% Flowering	Flowers per cluster	1st Fruiting	Days to fruit maturity	Fruit Weight	Polar Dia	Equatorial Dia	No of fruits per cluster	Pericarp thickness	Calyx length	TSS	Acidity	P/J Ratio	Yield per plant	Yield per plot
Plant height	0.006	0.029	0.009	0.003	0.052	0.003	0.000	-0.050	0.001	0.001	-0.004	0.001	0.017	-0.023	-0.010	-0.008	-0.001	-0.140	0.354
Number of primary Branches	0.001	0.133	-0.144	0.004	-0.020	0.007	0.001	0.036	0.008	0.005	-0.031	-0.008	0.012	0.002	-0.002	-0.016	0.000	-0.565	1.542
Number of sec Branches	0.000	0.133	-0.144	0.004	-0.020	0.007	0.002	0.034	0.008	0.004	-0.031	-0.008	0.012	0.004	-0.002	-0.015	0.002	-0.535	1.459
1st Flowering	0.002	0.064	-0.066	0.008	0.094	0.001	0.003	-0.108	0.005	0.002	-0.022	-0.002	0.021	-0.004	0.006	-0.004	-0.001	-0.273	0.740
50% Flowering	0.001	-0.009	0.010	0.003	0.289	-0.007	0.001	-0.312	-0.004	-0.004	0.003	0.008	0.001	0.001	0.006	0.019	0.002	0.142	-0.396
Flowers per cluster	0.002	0.090	-0.093	0.001	-0.182	0.011	0.000	0.209	0.008	0.006	-0.016	-0.015	0.015	-0.001	-0.013	-0.032	-0.004	-0.450	1.232
1st Fruting	0.000	-0.021	0.033	-0.004	-0.038	0.000	-0.008	0.038	-0.006	-0.002	0.013	0.004	-0.018	0.004	-0.002	0.004	-0.002	0.002	-0.001
Days to fruit maturity	0.001	-0.015	0.016	0.003	0.289	-0.007	0.001	-0.311	-0.004	-0.004	0.004	0.008	0.001	0.002	0.006	0.018	0.002	0.163	-0.452
Fruit Weight	0.001	0.084	-0.092	0.003	-0.087	0.007	0.004	0.099	0.013	0.008	-0.029	-0.010	0.027	-0.014	0.002	-0.015	0.002	-0.412	1.116
Polar Dia	0.001	0.058	-0.054	0.002	-0.118	0.007	0.001	0.126	0.010	0.010	-0.019	-0.009	0.020	-0.024	-0.016	-0.007	-0.002	-0.322	0.885
Equatorial Dia	0.001	0.110	-0.119	0.005	-0.026	0.005	0.003	0.033	0.010	0.005	-0.037	-0.008	0.020	-0.012	0.006	-0.003	0.000	-0.464	1.263
No of fruits per cluster	0.000	0.081	-0.088	0.001	-0.164	0.012	0.002	0.188	0.009	0.007	-0.021	-0.014	0.020	-0.002	-0.014	-0.027	-0.005	-0.408	1.118
Pericarp thickness	0.003	0.043	-0.047	0.005	0.010	0.004	0.004	-0.007	0.009	0.006	-0.019	-0.007	0.037	-0.022	-0.008	-0.002	0.000	-0.227	0.606
Calyx length	-0.003	0.005	-0.010	-0.001	0.007	0.000	-0.001	-0.013	-0.003	-0.005	0.008	0.000	-0.016	0.052	0.005	-0.029	0.000	0.045	-0.116
TSS	-0.003	-0.017	0.016	0.003	0.101	-0.008	0.001	-0.096	0.002	-0.009	-0.012	0.011	-0.017	0.014	0.018	0.006	0.012	0.182	-0.501
Acidity	-0.001	-0.049	0.047	-0.001	0.122	-0.008	-0.001	-0.129	-0.004	-0.002	0.002	0.008	-0.002	-0.033	0.003	0.044	0.002	0.227	-0.615
P/J Ratio	0.001	-0.006	0.028	0.001	-0.045	0.004	-0.001	0.049	-0.002	0.002	-0.001	-0.007	-0.002	0.000	-0.023	-0.007	-0.010	-0.026	0.085
Yield per plant	0.001	0.128	-0.131	0.004	-0.070	0.008	0.000	0.087	0.009	0.006	-0.029	-0.010	0.014	-0.004	-0.006	-0.017	0.000	-0.586	1.595
Yield per plot	0.001	0.129	-0.131	0.004	-0.072	0.008	0.000	0.088	0.009	0.006	-0.029	-0.010	0.014	-0.004	-0.006	-0.017	-0.001	-0.586	1.595

(0.00497), pulp juice ratio (0.00005), and yield per plant (0.04479).

TSS content recorded positive and indirect effects on acidity (0.00632), pulp juice ratio (0.01212), and yield per plant (0.18236).

Acidity showed a positive and indirect effect on the pulp juice ratio (0.00151) and yield per plant (0.22672). The pulp juice ratio showed a positive and indirect effect on yield per plot (0.08458). Yield per plant recorded a direct and positive effect on yield per plot (1.59529).

In the current study, various traits like the volume of fruit, number of fruits per plant, the weight of fruit, days to first flowering, specific gravity, number of fruits per cluster, fruit diameter, and number of locules per fruit showed a positive direct effect on fruit yield. Hence, it may be suggested that these are the most effective and reliable parameters for genetic improvement in the fruit yield of tomato genotypes.

Similar results were obtained by Islam *et al.* (2010) [8], Narolia *et al.* (2012) [17], Sharma and Singh (2012) [25], Kumar *et al.* (2013) [10], Chernet *et al.* (2014) [4], Kapte and Jansirani (2014) [9], Premalakshmi *et al.* (2014) [20], Nagariya *et al.* (2015) [15], Naveen *et al.* (2017) [18], Rajolli *et al.* (2017) [21], Rawat *et al.* (2017) [23], Anuradha *et al.* (2018) [3], Alma and Paul (2019) [2] and Maurya *et al.* (2020) [12].

Conclusions

The fruit yield exhibited significant and positive correlation associated with plant height, primary branches, secondary branches, days to first flowering, flowers per cluster, fruit weight, polar diameter, equatorial diameter, number of fruits per cluster, pericarp thickness, pulp juice ratio, yield per plant, yield per plot at the genotypic and phenotypic level. Through path analysis, it can be concluded that direct selection for the parameters such as plant height, primary branches, days to first flowering, days to 50% flowering, flowers per cluster, polar diameter, fruit weight, pericarp thickness, calyx length, TSS content and acidity are the main contributing parameters to the fruit yield. Thus, for Chhattisgarh plains the above-mentioned genotypes can be recommended for better yield. More genotypes may be collected from various agro-climatic conditions in various locations to select promising genotypes for greater adaptability. More quality parameters like reducing and non-reducing sugars (%) and processing quality should be included in future research. In addition to the present study, these genotypes were evaluated with resistance to various biotic and abiotic stresses. Different biotechnological tools *i.e.* molecular markers may be used for molecular diversity. The genotypes in this experiment can be used as parents for future studies on hybridization programme. The genotypes may also compare with other established varieties and hybrids for their yield potential.

Acknowledgment

We would like to thank AICRP on Vegetable Science, Department of Horticulture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) for providing funds for the research experiment and also thankful Dr. Anita Kerketta for guiding and supporting during the research work.

References

1. Abushita AA, Daood HG, Biacs PA. Change in carotenoids and antioxidant vitamins in tomato as a function of varietal and technological factors central food research institute. J Agric. Food Chem. 2000;48:2075-2081.
2. Alam B, Paul A. Path analysis of the relationships between fruit yield and some yield components in tomato (*Solanum lycopersicon* L.). Journal of Pharmacognosy and Phytochemistry. 2019;8(3):4666-4671.
3. Anuradha B, Saidaiah P, Sudini H, Geetha A, Ravinder Reddy K. Correlation and path coefficient analysis in tomato (*Solanum lycopersicon* L.). Journal of Pharmacognosy and Phytochemistry. 2018;7(5):2748-2751.
4. Chernet S, Belew D, Abay F. Performance evaluation and path analysis studies in tomato (*Solanum lycopersicon* L.) genotypes under Humera, Northern Ethiopia Condition. World J of Agricultural Res. 2014;2(6):267-271.
5. Dewey DR, Lu K. A correlation and path-coefficient analysis of components of crested wheatgrass seed production. Agronomy journal. 1959;51(9):515-518.
6. FAO. Agriculture Production Data, 2021. https://www.fao.org/faostat/en/#data. Date accessed: February 28, 2023.
7. Ibrahim C, Serekan A, Halim Can K, Abdullah U, Emine G, Nejla C, *et al*. Evaluation of the Relations between Yield and Yield Components of Tomato (*Solanum lycopersicum* L.) Hybrids by Correlation and Path Analysis, Horticultural studies. 2023;40(2):49-54.
8. Islam BMR, Ivy NA, Rasul MG, Zakaria M. Character association and path analysis of exotic tomato (*Solanum lycopersicon* L.) genotypes. Bangladesh J Plant Breed. Genet. 2010;23(1):13-18.
9. Khapte PS, Jansirani P. Correlation and path coefficient analysis in tomato (*Solanum lycopersicon* L.). Electronic Journal of Plant Breeding. 2014;5(2):300-304.
10. Kumar D, Kumar R, Kumar S, Bhardwaj ML, Thakur MC, Kumar R, *et al*. Genetic variability, correlation and path coefficient analysis in tomato International journal of vegetable science. 2013;19(4):313-323.
11. Mahapatra AS, Singh AK, Vani VM, Ramanand M, Harit K, Rajkumar BV. Inter-relationship for various components and path coefficient analysis in tomato (*Lycopersicon esculentum* Mill). International journal of current microbiology and applied sciences. 2013;2(9):147-152.
12. Maurya S, Singh AK, Rai SK, Kumar U, Prakash O. Studies on genetic variability, heritability and genetic advance for yield and quality traits in Tomato (*Solanum lycopersicon* L.). Journal of Pharmacognosy and Phytochemistry. 2020;9(1):1683-1686.
13. Meena OP, Bahadur V. Assessment of genetic variability, heritability and genetic advance among tomato (*Solanum lycopersicon* L.) germplasm. The bioscan. 2014;9(4):1619-1623.
14. Mohanty BK. Genetic variability, correlation and path coefficient studies in tomato. Indian Journal of Agricultural Research. 2003;37(1):68-71.
15. Nagariya NK, Bhardwaj R, Sharma N, Mukherjee S. Correlation and path analysis in tomato (*Solanum lycopersicon* L.). International Journal of Farm Sciences. 2015;5(4):111-117.
16. Namdev SK, Dongre R. Correlation and path analysis in tomato. Research Journal of Agricultural Sciences. 2018;9(3):588-590.

17. Narolia RK, Reddy RVSK, Padma M. Correlation and path coefficient analysis of growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.). Indian Journal of Tropical Biodiversity. 2012;(1):65-69.
18. Naveen BL, Saidaiah P, Ravinderreddy K, Geetha A. Correlation and path coefficient analysis of yield and yield attributes in tomato (*Solanum lycopersicon* L.). Journal of Pharmacognosy and Phytochemistry. 2017;6(6):665-669.
19. Prashanth SJ, Jaiprakashnarayan RP, Ravindra M, Madalageri MB. Correlation and path analysis in tomato (*Lycopersicon esculentum* Mill.). Asian Journal of Horticulture. 2008;3(2):403-408.
20. Premalakshmi V, Kumar SR, Arumugam, T. Evaluation and genetic studies in tomato genotypes. Trends in Biosciences. 2014;7(13):1407-1410.
21. Rajolli GM, Lingaiah BH, Malashetti RI, Bhat SA, Kumar SJA. Correlation and path co-efficient studies in tomato (*Solanum lycopersicon* L.). Int. J Pure App. Bio Sci. 2017;5(6):913-917.
22. Ramzan A, Khan TN, Nawab NN, Hina A, Noor T, Jillani G. Estimation of genetic components in f 1 hybrids and their parents in determinate tomato (*Solanum lycopersicon* L.). J Agricul. Res., 2014, 52.
23. Rawat M, Singh D, Singh N, Kathayat K. Character association and path coefficient analysis in tomato (*Solanum lycopersicon* L.). International Journal of Current Microbiology and Applied Sciences. 2017;6(8):1966-1972.
24. Searle SR. Phenotypic, genetic and environmental correlations. Biometrics. 1961;17(3):474-480.
25. Sharma B, Singh JP. Correlation and path coefficient analysis for quantitative and qualitative traits for fruit yield and seed yield in tomato genotypes. Indian journal of Horticulture. 2012;69(4):540-544.
26. Singh PK, Singh B, Pandey S. Genetic variability and character association analysis in tomato. Indian Journal of Plant Genetic Resources. 2006;19(2):196-199.
27. Wang Y, Xiao R, Yin Y, Liu T. Prediction of tomato yield in Chinese-style solar greenhouses based on wavelet neural networks and genetic algorithms. Information. 2021;12:336.
28. Wright S. The method of path coefficients. Annals of Mathematical Statistics. 1934;5:614-617.
29. Yadav MK, Ram CN, Yadav GC, Maurya N, Prasad D. Character association and path analysis in tomato (*Solanum lycopersicon* [Mill.] Wettsd.). Journal of Pharmacognosy and Phytochemistry. 2020;9(1):1323-1325.