Ecology and Evolutionary Biology
2022; 7(3): 46-53
http://www.sciencepublishinggroup.com/j/eeb
doi: 10.11648/j.eeb.20220703.12
ISSN: 2575-3789 (Print); ISSN: 2575-3762 (Online)

Correlation and Path Analysis in Tomato (*Lycopersicon esculentum* MILL) Genotypes

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To cite this article:
Dasta Tsagaye, Andargachew Gadebo, Shimelis Aklilu. Correlation and Path Analysis in Tomato (*Lycopersicon esculentum* MILL) Genotypes. *Ecology and Evolutionary Biology.* Vol. 7, No. 3, 2022, pp. 46-53. doi: 10.11648/j.eeb.20220703.12

Received: May 17, 2022; **Accepted**: July 1, 2022; **Published**: August 17, 2022

Abstract: In Ethiopia, tomato is one of the most popular vegetables produced by small farmers and commercial growers for both local uses as well as processing industries. Considering the importance of tomato as one of the beneficial vegetables for both domestic consumption and export markets, it is important to increase its productivity along with desirable attributes through its genetic character. On the basis of its wide use and expansion potential the need for developing varieties that suite specific agro- ecological conditions and specific end use is clear. Thirty-six tomato genotypes were evaluated for yield contributing characters to observe their associations and direct and indirect effect on yield. Character association analysis among yield and yield contributing characters revealed that the genotypic correlation coefficient was higher than the respective phenotypic correlation coefficients in most cases. This indicated that the suppressive effect of the environment modified the phenotypic expression of these characters by reducing phenotypic correlation values. Also, narrow difference between phenotypic and genotypic correlation coefficient was noticed for almost all the pairs of characters studied showing that masking or modifying effects of the environment was little indicating the presence of an inherent association among these characters. Fruit diameter showed significant and positive association with yield/plant at genotypic level but all other characters had non-significant negative and positive association with yield/plant. Path coefficient analysis revealed that fruit shape index had the highest positive direct effects on fruit yield/plant suggesting their importance while imposing selection for correlation of yield in tomato.

Keywords: Correlation and Path Analysis, Tomato, Genotypes

1. Introduction

The tomato (*Lycopersicon esculentum* MILL) is the edible, often red berry-type fruit of the nightshade, commonly known as a tomato plant. Tomato species are diploid with twelve pairs of chromosomes (2n = 24) and is a self-pollinated annual crop which belongs to the family solanaceae.

The species originated in the South American Andes and its use as a food originated in Mexico, and spread throughout the world following the Spanish colonization of the Americas. It is the most frequently consumed vegetable in many countries, becoming the main supplier of several plant nutrients and providing an important nutritional value of human diet [1]. Besides tomato varieties are available with double the normal vitamin C, 40 times normal vitamin A, high levels of anthocyanin and two to four times the normal amount of lycopene. Tomato is also considered as an excellent model organism for both basic and applied plant research due to many reasons, including ease to culture under a wide range of environments, short life cycle, photoperiod insensitivity, high self-fertility and homozygosity, great reproductive potential, ease of controlled hybridization etc. [2].

Knowledge of inter relationships among different traits is very important in plant breeding to practice indirect selection for not easily measured characters and those that exhibit low

heritability. Sharma and Ahmad [3] pointed out the impotence of indirect selection when the attribute in selection has low heritability and /or is not easily or precisely measured. In such situations, some easy diagnosis criteria have to be developed to rationalize the selection in breeding programs. The aim of correlation study is primarily to know about the suitability of various characters for indirect selection because selection for one or more traits results in correlated response for several other traits. Ariyo *et al.* [4] indicated the importance of correlation study between characters in the determination of the most effective breeding procedure.

According to Bhatt G. M., inadequate knowledge of inter relationships among various traits and the practice of unilateral selection for agronomic traits frequently end up in retrograde or less than optimum result in plant breeding [5]. Correlation coefficient analysis helps to determine the nature and degree of relationship between any two measurable characters. It resolves a complex relationship between events in to simple form of association. According to [6] estimate of genotypic and phenotypic correlation among characters are useful in planning and evaluating breeding programs.

Path analysis was originally developed by [7], who defined the path coefficient as the ratio of the standard deviation of the effect due to a given cause (independent variable) to the total standard deviation of the effect (dependent variable). This technique, which aims to improve a dependent character like yield when the independent characters have a significant relationship in the desired direction and positive direct or indirect effect through other component traits on the dependent characters, became routine in plant breeding program only after its use [8].

Path coefficient is simply a standard partial regression coefficient partitioning the coefficient directly and indirectly [9]. The path coefficient analysis measures the direct influence upon another variable and permits the separation of correlation coefficient into components of direct and indirect effects [10]. Considering all the facts described above the present investigation was undertaken to estimate correlation and path coefficient analysis of tomato genotypes.

2. Materials and Methods

2.1. Description of the Study Areas

The experiment was conducted at Kulumsa and Melkassa Agricultural Research Centers in 2017/2018 (at the end of October to February) using furrow irrigation. Kulumsa Agricultural Research Center is found in Arsi, Zone Oromia Regional State, Ethiopia, is located 175km South East of Addis Ababa on the road from Adama to Asella. The geographical location of Kulumsa is 8°01' 10''N latitude and 39°09'13''E longitude and at an altitude of 2200 meter above sea level (m.a.s.l). The agro-ecology of the area is characterized by an average annual rain-fall of 850 mm, with short rain between March and April and long rain between June and September, and with annual mean minimum and maximum temperatures of 23.1°C and 7.9°C respectively. The area's soil types are clay and silt loam with pH of 5.6 [11]. The soil types of the area is clay and silt loamwith pH of 5.6 [11]. Melkassa Agricultural Research Center is situated in major tomato growing belts which is 117 km South East of Addis Ababa with geographic co-ordinate of 8° 24'N latitude and 39°12'E longitude at an altitude of 1550 m.a.s.l. The mean annual rainfall of the area is 763 mm and the mean annual maximum and minimum temperature is about 28.6°C and 13.8°C, respectively. The soil texture is dominantly loam and clay loam and is slightly alkaline ranging from 7.4 to 7.6 pH an optimum range for availability of major nutrients [12].

2.2. Experimental Materials

The experimental materials in the present study consisted of thirty six tomato genotypes obtained from Melkassa Agricultural Research Center.

2.3. Experimental Design and Experimental Procedures

Simple lattice design (6x6) was employed where each plot consisted of two rows with length of 4m and width 2m that makes a total area of $8m^2$. The spacing was 100cm and 30 cm between rows and plants respectively. Fertilizer rate of 200kg per ha of NPS and 150kg per ha of Urea was applied. All other necessary cultural practices were applied to all plots uniformly.

2.4. Data Collected

The following data were collected: days to first flowering, days to 50% flowering, days to fruit set, plant height, number of branches per plant, number of flowers per cluster, number of fruits per cluster, number of clusters per plant, number of fruits per plant, fruit length, fruit diameter, average fruit weight, fruit yield per plant, pericarp thickness, fruit shape index, pH, total soluble solid and juice volume.

2.5. Statistical Analysis

The correlation coefficients among all possible character combinations at phenotypic (r_p) and genotypic (r_g) level were estimated by employing the formulae given by [13]. Correlation analyses were done to determine traits that were correlated to yield genotypic and phenotypic correlation using SAS software version 9.2 [14] by Proc candisc.

$$\text{Genotypic correlations } r_{xy}(G) = \frac{\text{cov}_{g_{xy}}}{\sqrt{\sigma^2 g_x \sigma^2 g_y}}$$

$$\text{Phenotypic correlations } r_{xy}(P) = \frac{\text{covp}_{xy}}{\sqrt{\sigma^2 p_x \sigma^2 p_y}}$$

Where: rpxy = phenotypic correlation coefficient between traits x and y. Covpxy = phenotypic covariance between traits x and y, $\sigma^2 p_x$ = phenotypic variance of trait x, $\sigma^2 p_y$= phenotypic variance of trait y, rg x y = genotypic correlation coefficient between traits x and y, Covgxy = genotypic covariance between traits x and y, $\sigma^2 g_x$ = genotypic variance of trait x and $\sigma^2 p_y$ = phenotypic variance of trait y.

As suggested by Wright path coefficient analysis was conducted [7] and worked out according to [8] using both genotypic and phenotypic correlation coefficients to determine the direct and indirect effects of yield components on fruit yield based on the following relationship. Path coefficient analysis was done by using Microsoft Excel (2010).

$$R_{ij}=p_{ij}+\sum r_{ijk}p_{ij}$$

where, R_{ij} = mutual association between the independent character (i) and dependent character, fruit yield (j) as measured by the correlation coefficients, P_{ij} = components of direct effects of the independent character (i) as measured by the path coefficients and $\sum r_{ijk}p_{ij}$ = summation of components of indirect effects of a given independent character (i) on a given dependent character (j) via all other independent characters (k).

The contribution of the remaining unknown factor was measured as the residual factor (PR), which is calculated as:

$$PR=\sqrt{(1-\sum rij\ pij)}$$

3. Results and Discussion

As the genotypic associations are inherent, the correlation and path analysis is discussed at genotypic level only (Tables 1, 2, 3, 4 and 5). At Melkass days to first flowering had positive and highly significant association with days to 50% flowering (rg = 0.79**) and days to first fruit set (rg = 0.60**); positive and negative association with other characters and non-significant correlation with the rest of the characters. Days to 50% flowering date showed positive and highly significant correlation with the days to first fruit set (rg = 0.66**); positive and significant correlation with total soluble solid (rg = 0.42*); positive and negative association with other characters. Days to first fruit set had positive and significant correlation with fruit shape index (rg = 0.41*); negative and significant correlation with plant height (rg=-0.48*) and fruit diameter (rg = -0.4*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters.

Plant height showed positive and significant correlation with the number of flowers per cluster (rg = 0.34*), number of fruits per plant (rg = 0.41*); negative and significant correlation with the fruit length (rg = -0.5*); positive and negative association with other characters. Number of branches per plant showed highly significant correlation with the number of clusters per plant (rg = 0.65**); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Number of flowers per plant showed positive and significant correlation with the number of fruits per cluster (rg = 0.57) and number of fruits per plant (rg = 0.48*); negative and significant correlation with fruit average fruit weight (rg = -0.525) and juice volume (rg =-0.54*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters.

Number of fruits per cluster showed positive and significant correlation with number of clusters per plant (rg = 0.38*) and number fruits per plant (rg = 0.48*); negative and significant correlation with the average fruit weight (rg = -0.43*) and juice volume (rg = -0.41*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Number of clusters per plant showed positive and significant correlation with the number of fruits per plant (rg = 0.3*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Number of fruits per plant showed negative and significant correlation with the average fruit weight (rg = -0.49*); pericarp thickness (rg = -0.37*) and juice volume (rg = -0.43*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters.

Fruit length showed positive and highly significant correlation with pericarp thickness (rg = 0.49**) and fruit shape index (rg = 0.80**); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Fruit diameter showed positive and highly significant correlation with the average fruit weight (rg = 0.77**) and juice volume (rg = 0.79**); negative and highly significant correlation with fruit shape index (rg = -0.75**); positive and significant correlation with fruit yield per plant (rg = 0.37*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Average fruit weight showed positive and highly significant correlation with pericarp thickness (rg = 0.70**) and juice volume (rg = 0.95**); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Pericarp thickness showed positive and highly significant correlation with juice volume (rg = 0.72**). It had non-significant correlation with the rest of the characters. Fruit shape index had positive and negative association; non-significant correlation with the rest of the characters (Table 1).

At Kulumsa days to first flowering had positive and highly significant association with days to 50% flowering (rg = 0.68**) and days to first fruit set (rg = 0.73**); positive and significant correlation with the number of branches per plant (rg = 0.35*) and number of clusters per plant (rg=0.34); negative and significant correlation with plant height (rg = -0.35*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Days to 50% flowering showed positive and highly significant correlation with the days to first fruit set (rg = 0.67**); negative and significant correlation with the plant height (rg = -0.4*) and number of flowers per plant (rg = -0.37*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters.

Days to first fruit set had positive and significant

correlation with the number of branches per plant (rg = 0.35*) and number of clusters per plant (rg = 0.41*); negative and highly significant correlation with plant height (rg = -0.48**); negative and significant correlation with plant height (rg = -0.5*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Plant height showed positive and significant correlation with the number of flowers per clusters (rg = 0.56*) and number of fruits per cluster (rg = 0.42*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters.

Number of branches per plant showed positive and highly significant correlation with the number of clusters per plant (rg = 0.72**); positive and significant correlation with the number of fruit per cluster (rg = 0.40*) and number of fruits per plant (rg = 0.56*); negative and significant correlation with the average fruit weight (rg = -0.48) and juice volume (-0.45); positive and negative association with other characters. Number of flowers per plant showed positive and highly significant correlation with number of fruits per plant (rg = 0.46**); positive and significant correlation with number of fruits per cluster (rg = 0.55*); negative and significant correlation with pericarp thickness (rg = -0.43*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Number of fruits per cluster showed positive and highly significant correlation with the number of clusters per plant (rg = 0.69**); positive and significant correlation with number of clusters per plant (rg = 0.42*); negative and significant correlation with average fruit weight (rg = -0.44*), pericarp thickness (rg = -0.46*) and juice volume (rg = -0.37*); positive and negative association; non-significant correlation with the rest of the characters.

Number clusters per plant showed positive and highly significant correlation with the number of fruits per plant (rg = 0.8**); positive and significant correlation with the fruit yield per plant (rg = 0.34*); negative and significant correlation with average fruit weight (rg = -0.37*) and juice volume (rg = -0.5*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Number of fruits per plant showed negative and highly significant correlation with juice volume (r g =-0.52**); negative and significant correlation with average fruit weight (rg = -0.57*) and pericarp thickness (rg = -0.56*); and positive and significant correlation with fruit yield per plant (rg = 0.43*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters.

Fruit length showed positive and highly significant correlation with fruit shape index (rg = 0.49**); positive and significant correlation with fruit diameter (rg = 0.44*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Fruit diameter showed negative and significant correlation with fruit shape index (rg = -0.53*); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Average fruit weight showed positive and highly significant correlation with juice volume (rg = 0.81**); positive and significant correlation with pericarp thickness (rg = 0.55); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Pericarp thickness showed positive and highly significant correlation with juice volume (rg = 0.46**); positive and negative association with other characters. It had non-significant correlation with the rest of the characters. Fruit shape index showed positive and highly significant correlation with juice volume (rg = 0.46**); positive and negative association with other characters (Table 1).

Across location days to first flowering had positive and highly significant association with the days to 50% flowering (rg = 0.78) and days to first fruit set (rg = 0.63); negative and significant correlation with number of flowers per plant (rg = -0.17). Days to 50% flowering showed positive and highly significant correlation with the days to first fruit set (rg = 0.77) at genotypic. Days to first fruit set had positive and significant correlation with the number of branches per plant (rg = 0.46), number of clusters per plant (rg = 0.33), fruit length (rg = 0.35); negative and significant correlation with the plant height (rg = -0.49) at genotypic level.

Plant height showed positive and significant correlation with the number of flowers per cluster (rg = 0.56), number of fruits per cluster (rg = 0.42), number of fruits per plants (rg = 0.39) at genotypic level. The number of branches per plant showed a significant correlation with the number of clusters per plant (rg = 0.67) at the genotypic level; positive and highly significant with the number of clusters per plant (rp = 0.40). Number of flowers per plant showed positive and highly significant correlation with the number of fruits per cluster (rg = 0.73) and number of fruits per plant (rg = 0.61); negative and significant correlation with the average fruit weight (rg = -0.42), pericarp thickness (rg= -0.51) and total soluble solid (rg = -0.06). Number of fruits per cluster showed positive and highly significant correlation with the number of clusters per plant (rg = 0.45) and number fruits per plant (rg = 0.79); negative and highly significant correlation with the average fruit weight (rg = -0.64) and pericarp thickness (rg = -0.55) at genotypic level.

Number of clusters per plant showed positive and significant correlation with the number of fruit per plant (rg = 0.59); negative and significant correlation with the fruit diameter (rg = -0.34), average fruit weight (rg = -0.52), pericarp thickness (rg = -0.40) and juice volume (rg = -0.51) at genotypic level. Number of fruits per plant showed negative and highly significant correlation with the average fruit weight (rg = -0.64), pericarp thickness (rg = -0.62) and juice volume (rg = -0.60) at genotypic. Fruit length showed positive and significant correlation with the fruit shape index (rg = 0.4) at genotypic. Fruit diameter showed positive and highly significant correlation with the average fruit weight (rg = 0.58), fruit

yield per plant (rg = 0.36) and juice volume (rg = 0.46); negative and significant correlation with the fruit shape index (rg = -0.7) at genotypic level.

Average fruit weight showed positive and highly significant correlation with the pericarp thickness (rg = 0.62) and juice volume (rg = 0.9) at genotypic. Pericarp thickness showed positive and highly significant correlation with the juice volume (rg = 0.64) at genotypic. pH showed negative and significant correlation with juice volume (rg = -0.36) (Table 2). Mishra and Nandi (2018) reported that number of flowers per cluster had positive significant correlation with number of fruits per cluster both at genotypic and phenotypic level; Rani (2008) reported that association of plant height with yield per plant was positive, it was not significant at genotypic level and correlation coefficients between number of fruits per plant and fruit weight.

At Melkass genotypic path analysis of direct and indirect effects revealed that days to first flowering (0.205), plant height (0.231), number of branches per plant (0.208), number of fruits per cluster (0.132), number of clusters per plant (0.341), fruit shape index (0.504), pH (0.01), total soluble solid (0.04) and juice volume (0.44) exerted direct positive effect on fruit yield; whereas the direct effect of days to 50% flowering (-0.187), days to first fruit set (-0.287), number of flowers per cluster (-0.067), number of fruits per plant (-0.285), fruit length (-0.814), fruit diameter (-0157), average fruit weight (-0.093) and pericarp thickness (-0.38) were negative. Days to first flowering imparted highest positive indirect effect on fruit yield per plant via number of branches per plant and total soluble solid. However, indirect effect was visible to be highest negative via plant height fruit diameter and plant height. Genotypic path coefficient analyses results in the current study showed that the following components; days to first flowering, plant height, number of branches per plant, number of fruits per cluster, number of clusters per plant, fruit shape index, pH, total soluble solid and juice volume are potential selection criteria for improving tomato fruit yield (Table 3).

At Kulumsa the genotypic path analysis of direct and indirect effects revealed that days to first fruit set (0.51), plant height (0.16), number of branches per plant (0.31), number of fruits per cluster (017), number of fruit per plant (0.32), fruit diameter (0.102), average fruit weight (0.34), fruit shape index (0.61), pH (0.01), total soluble solid (0.04), juice volume (0.44) and number of clusters per plant (0.13) exerted direct positive effect on fruit yield; whereas the direct effect of days to first flowering (-0.44), days to 50% flowering (-0.26), number of flowers per cluster (-0.39), fruit length (-0.77) and pericarp thickness (-0.38) were negative.

Days to first fruit set imparted highest positive indirect effect on fruit yield per plant via number of branches per plant and number of cluster per plant. However, indirect effect was visible to be highest negative via plant height and fruit length. Genotypic path coefficient analyses results in the current study showed that at Kulumsa the following components; days to first fruit set, plant height, number of branches per plant, number of fruits per cluster, number of fruit per plant, fruit diameter, average fruit weight, fruit shape index, pH, total soluble solid, juice volume and number of clusters per plant are potential selection criteria for improving tomato fruit yield (Table 4).

Across location genotypic path analysis of the direct and indirect effects revealed that days to first flowering (0.102), days to first fruit set (0.683), plant height (0.324), number of fruits per cluster (0.509), number of clusters per plant (0.401), number of fruits per plant (0.2555), fruit diameter (0.662), average fruit weight (0.191), fruit shape index (0.106), total soluble solid (0.246) and juice volume (0.25) had positive direct effect on fruit yield. The direct effect of these characters on fruit yield indicates that, improvement on these traits will increase fruit yield; whereas, negative direct effect was observed for days to 50% flowering date (-0.692), number of branches per plant (-0.162), number of flowers per cluster (-0.588), pericarp thickness (-0.245), pH (-0.014) and fruit length (-0.117), indicating that the contribution of these traits for fruit yield is minimum. Days to first fruit set imparted highest positive indirect effect on fruit yield per plant via days to first flowering, days to 50% flowering, number of clusters per plant, fruit shape index and total soluble solid. However, indirect effect was visible to be highest negative via plant height and fruit diameter. Genotypic path coefficient analyses results in the current study showed that across locations the following components; days to first flowering, days to first fruit set, plant height, number of fruits per cluster, number of clusters per plant, number of fruits per plant, fruit diameter, average fruit weight, fruit shape index, total soluble solid and juice volume are potential selection criteria for improving tomato fruit yield (Table 5).

Islam reported that in path coefficient analysis days to first flowering showed negative direct effect on yield per plant [15]. The indirect effects via flowers per plant, plant height at first flowering, pericarp thickness and fruits per plant were positive and via fruit diameter and individual fruit weight were negative; [16] reported that at genotypic level, number of fruits per plant had the highest positive direct effect on yield per plant followed flowers per plant, number of branches, TSS and fruits weight. From genotypic path analysis the magnitude of residual effects of Melkassa, Kulumsa and across location (0.68, 0.62 and 0.60) respectively indicated that characters included in path analysis explained about (32%, 38% and 40%) of the variation in fruit yield. However, the remaining variation in fruit yield (68%, 62% and 60%) can be attained by incorporating in the path analysis as far as studies involving genetic variability and characters association is concerned.

Om Prakash Meena and Vijay Bahadur (2015) quoted in [17] reported that days to 50% flowering showed high direct effect on yield per plant and also Om Prakash Meena and Vijay Bahadur (2015) quoted in [17] revealed across locations that the number of fruits per cluster had negative

direct effect on fruit yield per plant and it showed positive direct contribution towards yield through number of branches per plant. Similarly, days to 50 per cent flowering had negative direct effect on fruit yield per plant.

Table 1. *Genotypic correlation coefficient at Kulumsa (above diagonal) and Melkassa (below diagonal) among the 18 traits of tomato genotypes tested in 2017/2018.*

Traits	DFF	D50F	DFFS	PLH	NBP	NFLC	NFC	NCPL	NFPL	FL	FD	AFW	PTH	FSHI	pH	TSS	JV	FYPL
DFF	1	0.68**	0.73**	-0.35*	0.35*	-0.19	0.04	0.34*	0.16	-0.25	-0.05	-0.01	-0.07	-0.15	0.21	0.14	-0.05	0.04
D50F	0.79**	1	0.67**	-0.41*	0.15	-0.37*	-0.22	0.17	-0.08	0.03	0.27	-0.03	0.10	-0.22	0.30	0.26	-0.13	-0.10
DFFS	0.60*	0.66**	1	-0.48**	0.35*	-0.30	-0.09	0.41*	0.18	0.01	-0.07	-0.09	0.15	0.08	0.26	0.14	-0.14	0.09
PLH	-0.32	-0.22	-0.48*	1	0.13	0.56*	0.42*	0.00	0.28	-0.16	0.08	-0.15	-0.17	-0.11	-0.12	-0.07	-0.18	0.23
NBP	0.11	0.08	0.31	-0.22	1	0.19	0.40*	0.72**	0.56*	-0.23	-0.24	-0.48*	-0.23	0.05	0.21	0.19	-0.45*	0.29
NFLC	0.03	0.09	0.11	0.34*	0.03	1	0.55*	0.19	0.46**	0.02	-0.01	-0.22	-0.43*	0.13	-0.18	-0.09	-0.28	0.07
NFC	0.12	0.08	-0.10	0.27	0.06	0.57*	1	0.42*	0.69**	-0.06	-0.03	-0.44*	-0.46*	0.03	-0.17	-0.11	-0.37*	0.32
NCPL	0.23	0.17	0.23	-0.17	0.65**	0.21	0.38*	1	0.79**	-0.08	-0.09	-0.58*	-0.37*	0.03	-0.07	0.12	-0.50*	0.34*
NFPL	-0.07	0.03	-0.24	0.41*	-0.10	0.55*	0.48*	0.3*	1	-0.01	-0.04	-0.57*	-0.56*	0.06	-0.13	-0.05	-0.52**	0.43*
FL	0.18	-0.05	0.30	-0.50*	0.07	-0.21	-0.26	0.08	-0.28	1	0.44*	0.04	0.19	0.49**	0.27	-0.24	0.04	-0.09
FD	-0.27	-0.24	-0.43*	0.05	-0.04	-0.41	-0.22	-0.21	-0.28	-0.26	1	0.13	0.08	-0.53*	-0.10	-0.04	0.00	0.20
AFW	-0.10	-0.16	-0.17	-0.26	0.04	-0.52*	-0.43*	-0.21	-0.49*	0.30	0.77**	1	0.55*	-0.14	-0.13	-0.27	0.81**	0.02
PTH	0.08	-0.09	0.01	-0.42	0.07	-0.31	-0.29	-0.05	-0.37*	0.49**	0.44*	0.70**	1	0.06	0.16	-0.10	0.46**	-0.18
FSHI	0.28	0.12	0.41*	-0.30	0.04	0.05	-0.03	0.15	-0.02	0.80**	-0.75**	-0.24	-0.03	1	0.43	-0.18	-0.04	-0.26
pH	-0.26	-0.30	-0.22*	0.01	-0.11	-0.06	0.03	-0.25	-0.03	0.12	0.15	0.23	0.05	0.06	1	-0.03	-0.12	-0.20
TSS	0.35	0.42*	0.29	0.27	-0.11	0.02	-0.05	-0.18	-0.10	-0.30	-0.18	-0.27	-0.45	-0.05	-0.10	1	-0.41	-0.16
JV	-0.09	-0.15	-0.17	-0.26	0.03	-0.54*	-0.41*	-0.19	-0.43*	0.29	0.79**	0.95**	0.71**	-0.26	0.22	-0.32	1	0.08
FYPL	-0.11	-0.19	-0.32	0.23	0.31	-0.16	0.15	0.20	-0.07	-0.23	0.37*	0.24	-0.01	-0.31	0.20	-0.04	0.27	1

Where ** = significant at 1%, * = significant at 5%, DFF = Days to first flowering, D50%F = Days to 50% flowering, DFFS = Days to fruit set, PLH = Plant height, NBPL = Number of branches per plant, NFLC = number flowers/cluster, NFC = number fruits/cluster, NCPL = number of clusters/plant, NFPLT = number fruits/plant, FL = fruit length, FD = fruit diameter, AFW = average fruit weight, FYPLT = fruit yield/plant, PTH = pericarp thickness, FSI = fruit shape index, pH= power of hydrogen, TSS = total soluble solid, JV = juice volume.

Table 2. *Genotypic correlation coefficient among the 18 traits of tomato genotypes tested across location in 2017/2018.*

Traits	DFF	D50F	DFFS	PLHC	NBPL	NFLC	NFC	NCPL	NFPT	FL	FD	AFW	PTH	FSI	pH	TSS	JV	FYPLT
DFF	1	0.78**	0.67**	-0.35	0.35*	-0.17*	0.09	0.29	-0.02	0.25	-0.14	0.01	-0.04	0.02	-0.31	0.22	-0.08	0.04
D50F		1	0.77**	-0.31	0.28	-0.32	-0.13	0.19	-0.12	0.26	0.00	-0.04	-0.05	-0.05	-0.21	0.34*	-0.17	-0.05
DFFS			1	-0.49*	0.46*	-0.24	-0.10	0.33*	-0.07	0.35*	-0.31	-0.11	0.04	0.23	-0.27	0.16	-0.15	-0.06
PLHC				1	-0.11	0.56*	0.42*	-0.10	0.39*	-0.32	0.06	-0.27	-0.32	-0.24	0.08	0.10	-0.27	0.17
NBPL					1	-0.02	0.19	0.68*	0.28	0.08	-0.31	-0.31	-0.20	-0.03	-0.19	0.24	-0.25	0.18
NFLC						1	0.73**	0.17	0.61**	-0.15	-0.21	-0.42*	-0.51*	0.02	-0.04	-0.06*	-0.40	0.04
NFC							1	0.45**	0.79**	-0.02	-0.26	-0.64**	-0.55**	-0.06	-0.09	-0.07	-0.52*	0.29
NCPL								1	0.59*	0.13	-0.34*	-0.52*	-0.40*	0.02	-0.31	0.08	-0.50*	0.32
NFPT									1	-0.02	-0.32	-0.64**	-0.62**	0.00	-0.18	-0.05	-0.60**	0.30
FL										1	-0.26	-0.08	0.03	0.4*	-0.03	0.18	-0.04	-0.15
FD											1	0.58**	0.24	-0.7*	0.19	-0.16	0.46**	0.36**
AFW												1	0.62**	-0.20	0.17	-0.23	0.90**	0.05
PTH													1	0.07	0.15	-0.32	0.64**	-0.20
FSI														1	0.23	0.02	-0.14	-0.39
pH															1	0.02	0.21	-0.02
TSS																1	-0.36*	-0.03
JV																	1	0.04
FYPLT																		1

Where ** = significant at 1%, * = significant at 5%, DFF = Days to first flowering, D50%F = Days to 50% flowering, DFFS = Days to fruit set, PLH = Plant height, NBPL = Number of branches per plant, NFLC = number flowers/cluster, NFC = number fruits/cluster, NCPL = number of clusters/plant, NFPLT = number fruits/plant, FL = fruit length, FD = fruit diameter, AFW = average fruit weight, FYPLT = fruit yield/plant, PTH = pericarp thickness, FSI = fruit shape index, pH= power of hydrogen, TSS = total soluble solid, JV = juice volume.

Table 3. *Path coefficient analysis of genotypic correlation studied at Melkassa in 2017/2018.*

Traits	DFF	D50%F	DFFS	PLH	NBPL	NFLC	NFC	NCPL	NFPT	FL	FD	AFW	PTH	FSI	pH	TSS	JV	r_g
DFF	0.205	-0.147	-0.167	-0.074	0.023	-0.002	0.016	0.077	0.021	-0.145	0.042	0.009	-0.004	0.140	-0.043	0.013	-0.074	-0.110
D50F	0.161	-0.187	-0.186	-0.051	0.017	-0.006	0.010	0.057	-0.008	0.038	0.038	0.015	0.005	0.062	-0.050	0.015	-0.119	-0.190
DFFS	0.122	-0.124	-0.281	-0.110	0.064	-0.008	-0.013	0.080	0.068	-0.243	0.067	0.016	0.000	0.207	-0.037	0.010	-0.135	-0.318
PLH	-0.066	0.041	0.134	0.231	-0.046	-0.023	0.035	-0.058	-0.117	0.409	-0.007	0.024	0.022	-0.152	0.002	0.010	-0.208	0.231
NBPL	0.023	-0.015	-0.086	-0.052	0.208	-0.002	0.008	0.222	0.030	-0.054	0.006	-0.004	-0.003	0.022	-0.018	-0.004	0.027	0.306
NFLC	0.005	-0.017	-0.032	0.078	0.006	-0.067	0.075	0.070	-0.158	0.174	0.064	0.049	0.016	0.027	-0.011	0.001	-0.437	-0.156
NFC	0.025	-0.014	0.028	0.061	0.012	-0.038	0.132	0.128	-0.136	0.211	0.034	0.039	0.015	-0.016	0.005	-0.002	-0.330	0.154
NCPL	0.046	-0.031	-0.066	-0.040	0.135	-0.014	0.050	0.341	-0.085	-0.068	0.034	0.020	0.002	0.075	-0.041	-0.007	-0.156	0.196

Traits	DFF	D50%F	DFFS	PLH	NBPL	NFLC	NFC	NCPL	NFPT	FL	FD	AFW	PTH	FSI	pH	TSS	JV	r_g
NFPT	-0.015	-0.005	0.067	0.095	-0.022	-0.037	0.063	0.102	-0.285	0.227	0.044	0.045	0.019	-0.008	-0.006	-0.003	-0.350	-0.069
FL	0.036	0.009	-0.084	-0.116	0.014	0.014	-0.034	0.028	0.080	-0.814	0.041	-0.027	-0.025	0.405	0.020	-0.011	0.236	-0.228
FD	-0.055	0.045	0.121	0.011	-0.008	0.028	-0.029	-0.073	0.079	0.215	-0.157	-0.072	-0.022	-0.376	0.024	-0.006	0.643	0.37*
AFW	-0.020	0.030	0.047	-0.060	0.009	0.035	-0.056	-0.072	0.139	-0.241	-0.122	-0.093	-0.036	-0.123	0.038	-0.010	0.772	0.238
PTH	0.017	0.017	-0.002	-0.098	0.014	0.021	-0.039	-0.016	0.105	-0.397	-0.069	-0.065	-0.051	-0.017	0.009	-0.016	0.581	-0.005
FSI	0.057	-0.023	-0.116	-0.070	0.009	-0.004	-0.004	0.051	0.005	-0.653	0.117	0.023	0.002	0.504	0.009	-0.002	-0.212	-0.307
pH	-0.053	0.057	0.063	0.002	-0.023	0.004	0.004	-0.084	0.010	-0.101	-0.023	-0.021	-0.003	0.028	0.165	-0.004	0.180	0.200
TSS	0.072	-0.079	-0.080	0.062	-0.024	-0.002	-0.007	-0.063	0.027	0.245	0.028	0.025	0.023	-0.024	-0.017	0.036	-0.259	-0.035
JV	-0.019	0.027	0.047	-0.059	0.007	0.036	-0.054	-0.065	0.123	-0.236	-0.124	-0.088	-0.037	-0.131	0.036	-0.011	0.814	0.267

Residual effect: 0.68, Where ** = significant at 1%, * = significant at 5%, DFF = Days to first flowering, D50%F = Days to 50% flowering, DFFS = Days to fruit set, PLH = Plant height, NBPL = Number of branches per plant, NFLC = number flowers/cluster, NFC = number fruits/cluster, NCPL = number of clusters/plant, NFPLT = number fruits/plant, FL = fruit length, FD = fruit diameter, AFW = average fruit weight, FYPLT = fruit yield/plant, PTH = pericarp thickness, FSI = fruit shape index, pH= power of hydrogen, TSS = total soluble solid, JV = juice volume.

Table 4. *Path coefficient analysis of genotypic correlation studied at Kulumsa in 2017/2018.*

Traits	DFF	D50%F	DFFS	PLH	NBP	NFLC	NFC	NCPL	NFPL	FL	FD	AFW	PTH	FSHI	pH	TSS	JV	r_g
DFF	-0.44	-0.18	0.37	-0.06	0.11	0.07	0.01	0.05	0.05	0.19	-0.05	0.00	0.03	-0.09	0.00	0.01	-0.02	0.04
D50%F	-0.30	-0.26	0.35	-0.07	0.05	0.14	-0.04	0.02	-0.02	-0.02	0.28	-0.01	-0.04	-0.13	0.00	0.01	-0.05	-0.10
DFFS	-0.32	-0.18	0.51	-0.08	0.11	0.12	-0.01	0.05	0.06	-0.01	-0.07	-0.03	-0.06	0.05	0.00	0.01	-0.06	0.09
PLH	0.15	0.11	-0.25	0.16	0.04	-0.22	0.07	0.00	0.09	0.12	0.09	-0.05	0.07	-0.07	0.00	0.00	-0.08	0.23
NBP	-0.15	-0.04	0.18	0.02	0.31	-0.07	0.07	0.10	0.18	0.18	-0.25	-0.16	0.09	0.03	0.00	0.01	-0.20	0.29
NFLC	0.08	0.10	-0.15	0.09	0.06	-0.39	0.10	0.03	0.14	-0.01	-0.01	-0.07	0.16	0.08	0.00	0.00	-0.12	0.07
NFC	-0.02	0.06	-0.04	0.07	0.13	-0.21	0.17	0.06	0.22	0.04	-0.03	-0.15	0.18	0.02	0.00	0.00	-0.16	0.32
NCPL	-0.15	-0.04	0.21	0.00	0.23	-0.07	0.07	0.13	0.25	0.06	-0.09	-0.19	0.14	0.02	0.00	0.00	-0.22	0.34*
NFPL	-0.07	0.02	0.09	0.05	0.18	-0.18	0.12	0.10	0.32	0.01	-0.04	-0.19	0.21	0.04	0.00	0.00	-0.23	0.43*
FL	0.11	-0.01	0.00	-0.03	-0.07	-0.01	-0.01	-0.01	0.00	-0.77	0.45	0.01	-0.07	0.30	0.00	-0.01	0.02	-0.09
FD	0.02	-0.07	-0.03	0.01	-0.08	0.00	0.00	-0.01	-0.01	-0.34	1.02	0.05	-0.03	-0.32	0.00	0.00	0.00	0.20
AFW	0.00	0.01	-0.05	-0.02	-0.15	0.09	-0.08	-0.08	-0.18	-0.03	0.14	0.34	-0.21	-0.09	0.00	-0.01	0.35	0.02
PTH	0.03	-0.03	0.08	-0.03	-0.07	0.16	-0.08	-0.05	-0.18	-0.14	0.08	0.19	-0.38	0.03	0.00	0.00	0.20	-0.18
FSHI	0.07	0.06	0.04	-0.02	0.02	-0.05	0.00	0.00	0.02	-0.38	-0.54	-0.05	-0.02	0.61	0.00	-0.01	-0.02	-0.26
pH	-0.09	-0.08	0.14	-0.02	0.07	0.07	-0.03	-0.01	-0.04	-0.21	-0.10	-0.04	-0.06	0.26	0.01	0.00	-0.05	-0.20
TSS	-0.06	-0.07	0.07	-0.01	0.06	0.04	-0.02	0.02	-0.02	0.19	-0.04	-0.09	0.04	-0.11	0.00	0.04	-0.18	-0.16
JV	0.02	0.03	-0.07	-0.03	-0.14	0.11	-0.06	-0.07	-0.17	-0.03	0.00	0.27	-0.18	-0.03	0.00	-0.01	0.44	0.08

R = 0.62, Where ** = significant at 1%, * = significant at 5%, DFF = Days to first flowering, D50%F = Days to 50% flowering, DFFS = Days to fruit set, PLH = Plant height, NBPL = Number of branches per plant, NFLC = number flowers/cluster, NFC = number fruits/cluster, NCPL = number of clusters/plant, NFPLT = number fruits/plant, FL = fruit length, FD = fruit diameter, AFW = average fruit weight, FYPLT = fruit yield/plant, PTH = pericarp thickness, FSI = fruit shape index, pH= power of hydrogen, TSS = total soluble solid, JV = juice volume.

Table 5. *Estimates of genotypic direct effects (bold and diagonal) and indirect effects (off-diagonal) of traits via other independent traits on fruit yield at across location in 2017/2018.*

Traits	DFF	D50%F	DFFS	PLH	NBPL	NFLC	NFC	NCPL	NFPT	FL	FD	AFW	PTH	FSI	pH	TSS	JV	r_g
DFF	0.102	-0.543	0.455	-0.114	-0.056	0.102	0.044	0.118	-0.004	-0.029	-0.090	0.002	0.010	0.002	0.005	0.053	-0.020	0.037
D50F	0.080	-0.692	0.525	-0.100	-0.046	0.188	-0.066	0.077	-0.030	-0.030	-0.001	-0.009	0.012	-0.006	0.003	0.085	-0.043	-0.054
DFFS	0.068	-0.531	0.683	-0.157	-0.075	0.143	-0.052	0.134	-0.019	-0.040	-0.208	-0.021	-0.010	0.024	0.004	0.038	-0.037	-0.056
PLH	-0.036	0.213	-0.332	0.324	0.018	-0.329	0.213	-0.038	0.101	0.037	0.042	-0.052	0.078	-0.026	-0.001	0.025	-0.068	0.169
NBPL	0.035	-0.196	0.316	-0.036	-0.162	0.009	0.094	0.272	0.071	-0.010	-0.203	-0.059	0.049	-0.003	0.003	0.060	-0.061	0.180
NFLC	-0.018	0.221	-0.166	0.182	0.003	-0.588	0.369	0.070	0.157	0.017	-0.142	-0.081	0.124	0.002	0.001	-0.014	-0.101	0.037
NFC	0.009	0.089	-0.070	0.136	-0.030	-0.426	0.509	0.179	0.201	0.003	-0.169	-0.122	0.135	-0.006	0.001	-0.016	-0.130	0.293
NCPL	0.030	-0.133	0.228	-0.031	-0.110	-0.102	0.227	0.401	0.150	-0.015	-0.228	-0.100	0.097	0.002	0.004	0.019	-0.125	0.317
NFPT	-0.002	0.083	-0.050	0.128	-0.045	-0.361	0.401	0.236	0.255	0.002	-0.212	-0.123	0.153	0.000	0.003	-0.012	-0.150	0.305
FL	0.025	-0.180	0.237	-0.103	-0.014	0.088	-0.011	0.050	-0.005	-0.117	-0.175	-0.016	-0.007	0.039	0.000	0.045	-0.009	-0.152
FD	-0.014	0.002	-0.214	0.021	0.050	0.126	-0.130	-0.138	-0.082	0.031	0.662	0.112	-0.059	-0.073	-0.003	-0.039	0.114	0.36*
AFW	0.001	0.031	-0.074	-0.089	0.050	0.248	-0.324	-0.210	-0.164	0.010	0.386	0.191	-0.152	-0.021	-0.002	-0.056	0.224	0.049
PTH	-0.004	0.034	0.027	-0.103	0.033	0.297	-0.281	-0.159	-0.159	-0.003	0.159	0.119	-0.245	0.007	-0.002	-0.078	0.159	-0.200
FSI	0.002	0.037	0.155	-0.078	0.005	-0.011	-0.029	0.008	-0.001	-0.043	-0.452	-0.038	-0.017	0.106	-0.003	0.006	-0.036	-0.389
pH	-0.032	0.147	-0.184	0.026	0.032	0.021	-0.048	-0.123	-0.045	0.003	0.123	0.032	-0.036	0.024	-0.014	0.005	0.053	-0.017
TSS	0.022	-0.237	0.106	0.032	-0.040	0.032	-0.034	0.032	-0.013	-0.021	-0.106	-0.043	0.078	0.002	0.000	0.246	-0.090	-0.033
JV	-0.008	0.120	-0.101	-0.088	0.040	0.237	-0.266	-0.201	-0.154	0.004	0.302	0.172	-0.156	-0.015	-0.003	-0.089	0.250	0.043

R = 0.60, Where ** = significant at 1%, * = significant at 5%, DFF = Days to first flowering, D50%F = Days to 50% flowering, DFFS = Days to fruit set, PLH = Plant height, NBPL = Number of branches per plant, NFLC = number flowers/cluster, NFC = number fruits/cluster, NCPL = number of clusters/plant, NFPLT = number fruits/plant, FL = fruit length, FD = fruit diameter, AFW = average fruit weight, FYPLT = fruit yield/plant, PTH = pericarp thickness, FSI = fruit shape index, pH= power of hydrogen, TSS = total soluble solid, JV = juice volume.

4. Conclusion

In Ethiopia, tomato is one of the most popular vegetables produced by small farmers and commercial growers for both local uses as well as processing industries. Considering the importance of tomato as one of the beneficial vegetables for both domestic consumption and export markets, it is important to increase its productivity along with desirable attributes through its genetic character. On the basis of its wide use and expansion potential the need for developing varieties that suite specific agro- ecological conditions and specific end use is clear. From the present study on correlation and path coefficient analysis in tomato, it may be concluded that improvement in fruit yield per plant could be brought by selecting component characters like number of flowers per cluster, days to first flowering and number of branches per plant.

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