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Character association studies in Tomato (*Solanum lycopersicum* L.) for growth, yield and quality traits

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Abstract
Correlation and path coefficients analysis was done over twenty-one genotypes of tomato to study the nature and magnitude of associations between yield and its various contributing characters. The genotypes were sown under randomized block design (RBD) in three replications at Regional Research Station Karnal, CCS Haryana Agricultural University, during the *spring summer* season of 2019-20. The observations were recorded for twenty-one parameters pertaining to the morpho-phenological, yield and quality traits in tomato. The correlation coefficients exhibited a significantly positive association, at both genotypic and phenotypic levels, for yield per hectare with number of branches per plant, plant height at maturity, days to 50% flowering, number of marketable fruits per plant, weight of marketable fruits per plant, total number of fruits per plant, pericarp thickness, polar diameter and fruit firmness. The statistics from path analysis revealed that the weight of marketable fruits per plant, total number of fruits per plant, yield per plant and equatorial diameter of fruits were the most propitious characters influencing the dependent variable *viz*. yield per hectare directly as well as indirectly.

Keywords: Genotypic correlation coefficient, phenotypic correlation coefficient and path analysis

1. Introduction

Tomato (*Solanum lycopersicum* L.) is a flowering plant of the nightshade family (Solanaceae) with chromosome number of 2n=24, cultivated extensively for its edible fruits. It ranks second in importance only next to potato and ranked first in preserved and processed vegetables at the global level. It occupies the most prestigious berth not only in the sophisticated, ultra-modern kitchen but also equally in the kitchen of the poor man, because of diverse nutritious and value-added products that can be prepared from it. It is rich in vitamin A (270 IU for green and up to 900 IU for ripe fruits), vitamin C (20 mg) and minerals like Phosphorus (27 mg), Calcium (13 mg), and Iron (0.5 mg).

Yield being a complex trait and multiplicative end product of large number of contributing characters and their interactions, have polygenic inheritance. Therefore, understanding the character association and their interaction with the environment becomes immensely important for any crop improvement programme to succeed.

The correlation coefficient analysis is a bivariate analysis that measures the strength of association between two variables and the direction of their relationship. Broadly correlation coefficient is studied into two groups namely, genotypic correlation coefficient and phenotypic correlation coefficient. The genotypic correlation coefficient measures the degree of dependency between two characters for expression of genetic traits suggesting the importance of traits which are to be focused in breeding programmes. Path analysis is typically a form of multiple regression statistical analysis which examines the relationship between a dependent variable and independent variables contributing towards the former. In context to present study, yield per hectare was considered as the dependent variable and rest of the plant characters were independent variables. Selection solely based on correlation coefficients may not be appropriate as it is only a bivariate analysis whereas, yield is dependent upon indefinite number of characters therefore, path analysis is required as it can measure relative importance of several characters contributing to yield at the same time. In simplified words, path analysis divides the magnitude of association between characters into direct and indirect effects.

Thereby, correlation and path coefficients assist a breeder in simultaneous selection of efficient traits for desired improvement and allocation of resources accordingly under a crop improvement or selection programme to result in the desired direction.

2. Materials and Methods

The present study was carried out at CCSHAU, Regional Research Station Karnal, during the *spring summer* season of 2019-20. The experimental location stands at 29º 43' in the North and 76º 58' East, at 243 meters elevation above mean sea level and the tract of research station is characterized by sub-tropical and semi-arid climate with mean maximum temperature ranging between 35 to 41ºC in summers and mean minimum temperature ranging between 6-9ºC in winters. And the fruit quality analysis was done in the laboratories of Department of Vegetable Science, CCS Haryana Agricultural University, Hisar.

The selected germplasm consists of twenty genotypes along with one standard check variety originating from various sources (Table-1). The crop was sown in randomized block design in three replications. The investigation involved twenty-one parameters which were observed and recorded, further categorised into 3 major groups' namely morpho-phenological traits, yield traits and quality traits. Five plants were randomly selected for recording of various plant characters and likewise five fruits were picked randomly to record fruit characters in every genotype for each replication.

Table 1: Genotypes constituting the evaluated germplasm along with their sources

Sr. No.	Name of Genotype	Growth Habit	Source
1	Arka Vikas	Semi-Determinate	IIHR, Bengaluru
2	Castle Rock	Determinate	PAU, Ludhiana
3	DVRT 1	Determinate	IIVR, Varanasi
4	DVRT 2	Determinate	IIVR, Varanasi
5	DVRT 3	Determinate	IIVR, Varanasi
6	DVRT 5	Determinate	IIVR, Varanasi
7	DVRT 6	Determinate	IIVR, Varanasi
8	H 86	Semi-Determinate	IIVR, Varanasi
9	Palam Pink	Determinate	CSKHPKV, Palampur
10	Punjab Kesari	Determinate	PAU, Ludhiana
11	Punjab Ratta	Determinate	PAU, Ludhiana
12	PHS	Determinate	IARI, New Delhi
13	PNR 7	Semi-Determinate	PAU, Ludhiana
14	Punjab Tropic	Determinate	PAU, Ludhiana
15	Punjab Chhuhara	Determinate	PAU, Ludhiana
16	Pusa Gaurav	Semi-Determinate	IARI, New Delhi
17	Pusa Ruby	Semi-Determinate	IARI, New Delhi
18	Pusa Sadabahar	Determinate	IARI, New Delhi
19	Pusa Sheetal	Determinate	IARI, New Delhi
20	Punjab Upma	Determinate	PAU, Ludhiana
21	Selection 7	Determinate	CCS HAU, Hisar

The data collected for various characters was statistically analyzed in order to find the nature and magnitude of association. Genotypic and phenotypic coefficients of correlation were determined by using the variance and covariance components as suggested by Al-Jibouri *et al.* (1958) [1] and path coefficient analysis as computed as per the method of Dewey and Lu (1959) [2].

3. Results

3.1 Correlation coefficient analysis

The values for correlation coefficients were figured at both phenotypic and genotypic levels for all the characters under study with fruit yield per hectare as well as among the characters themselves (Table-2). The comparison of values revealed that genotypic correlation coefficient estimates were relatively higher than their counterpart estimates of phenotypic correlation coefficient for almost all the characters, implying that the environmental influence reduced the phenotypic expression even under a strong inherent association of characters. The findings of this study were in accordance with Tiwari and Upadhyay (2011) [12], Tasisa *et al.* (2012) [11] and Meena and Bahadur (2015) [9]. This implies that there exists an impregnable genetic relationship between the characters, although their phenotypic expression was hindered by environmental factors. It was also evident from the results that nature and direction of genotypic and phenotypic correlation coefficients remained same for all the traits under consideration.

Fruit yield per hectare evinced a significant positively correlated relationship with number of branches per plant at harvesting stage (0.614, 0.532), plant height (0.330, 0.301), days to 50% flowering (0.345, 0.317), number of marketable fruits per plant (0.449, 0.445), weight of marketable fruits (0.893, 0.882), total number of fruits per plant (0.382, 0.377), yield of fruits per plant (0.994, 0.991), pericarp thickness (0.457, 0.433), polar diameter (0.359, 0.329) and fruit firmness (0.446, 0.422) at both the levels *viz* genotypic and phenotypic, respectively.

A positive association of number of branches was observed with number of marketable fruits per plant (0.288, 0.247), weight of marketable fruits (0.478, 0.414), weight of unmarketable fruits (0.658, 0.569), number of fruits per plant (0.306, 0.282) and yield of fruits per plant (0.614, 0.532) at both the levels, respectively, but it observed a significantly negative association with total soluble solid content (-0.433, -0.215). Days to 50% flowering observed a significantly positive correlation with days to first picking (0.807, 0.715), days to last picking (0.930, 0.820), weight of marketable fruits (0.371, 0.331), total number of fruits per plant (0.256, 0.247), yield of fruits per plant (0.299, 0.280), pericarp thickness (0.368, 0.361) and specific gravity of fruits (0.345, 0.278) while it had a significantly negative correlation with number of locules per fruit (-0.269, -0.253) and equatorial diameter of fruit (-0.284, -0.241) at both the levels *viz* genotypic and phenotypic, respectively.

Days to first picking had a significant positive correlation with days to 50% flowering (0.807, 0.715), days to last picking (0.941, 0.834), number of unmarketable fruits per plant (0.356, 0.324) and total number of fruits per plant (0.278, 0.255) but had a significant negative association with number of locules per fruit (-0.254, -0.232) and equatorial diameter of fruit (-0.293, -0.307) at both the levels *viz* genotypic and phenotypic, respectively.

Days to last picking observed a significantly positive association with days to 50% flowering (0.930, 0.820), days to first picking (0.941, 0.834), weight of marketable fruits(0.305, 0.273), number of unmarketable fruits per plant (0.334, 0.307) and total number of fruits per plant (0.326, 0.305) but it showed a significant negative association for number of locules per fruit (-0.404, -0.380) and equatorial diameter of fruit (-0.357, -0.294) at both the levels *viz* genotypic and phenotypic, respectively.

A significantly positive association of total number of fruits per plant was revealed with number of branches (0.306, 0.282), plant height (0.186, 0.272), days to 50% flowering (0.256, 0.247), number of marketable fruits per plant (0.938, 0.930), weight of marketable fruits (0.412, 0.431), number of unmarketable fruits per plant (0.588, 0.544), yield per plant (0.352, 0.368) and ascorbic acid content (0.730, 0.628) while it had a significantly negative correlation with number of locules per fruit (-0.308, -0.299).

Pericarp thickness had a significantly positive correlation with days to 50% flowering (0.368, 0.361), weight of marketable fruits (0.5220, 0.488), weight of unmarketable fruits (0.287, 0.266), yield per plant (0.490, 0.466), polar diameter (0.915, 0.837), equatorial diameter (0.315, 0.291), fruit firmness (0.635, 0.596) and titrable acidity (0.266, 0.262) while it had negative association with number of locules per fruit (-0.280, -0.281)and total soluble solid content (-0.399, -0.230).

A significantly positive association of polar diameter was revealed with days to 50% flowering (0.276, 0.268), weight of marketable fruits (0.366, 0.335), weight of unmarketable fruits (0.283, 0.257), yield per plant (0.384, 0.356), pericarp thickness (0.915, 0.837), equatorial diameter (0.467, 0.396) and fruit firmness (0.689, 0.632), whereas, it had a negative correlation with number of unmarketable fruits (-0.310, -0.290)and total number of fruits (-0.252, -0.237).

A significantly positive association of equatorial diameter was revealed with number of locules per fruit (0.328, 0.305), pericarp thickness (0.315, 0.291), polar diameter (0.467, 0.396) and fruit firmness (0.348, 0.313), whereas, it had a negative correlation with days to 50% flowering (-0.284, -0.241), days to first picking (-0.293, -0.307) and days to last picking (-0.357, -0.294).

Specific gravity observed a significantly positive association with days to 50% flowering (0.345, 0.378), days to first picking (0.300, 0.224), weight of unmarketable fruits (0.315, 0.258), pericarp thickness (0.250, 0.153) and acidity content (0.323, 0.264), while it had a significantly negative association with ascorbic acid content (-0.347, -0.285) at both the levels *viz* genotypic and phenotypic, respectively.

A significantly positive association of total soluble solids was found with plant height (0.487, 0.354) for both the levels and significantly negative association was there for number of branches per plant (-0.433), pericarp thickness (-0.399) and fruit firmness (-0.296) only at the genotypic level.

Based on the analysed observations, acidity content of fruits depicted a significant positively correlated relationship with pericarp thickness (0.266, 0.262) and specific gravity (0.323, 0.264) at both the levels and also there was a significantly negative correlation for number of locules (-0.264) at genotypic level only.

3.2 Path coefficient analysis

Path analysis is a standardized partial regression coefficient analysis which measures the influence of one variable upon another and facilitates the partitioning of correlation coefficients into direct and indirect effects of various characters on yield or any other attribute. The path coefficients were computed using the corresponding values of genotypic correlation coefficients taking the yield per hectare as dependent variable and rest all the characters as independent variable to evaluate and quantify direct as well as indirect effects of contributing characters on yield per hectare (Table-3). The observations recorded are in accordance with the results of Dhankar *et al.* (2001) [3] for total number of fruits per plant, Indu Rani *et al.* (2010) [5] for weight of fruits per plant, Sharma and Singh (2012) [10] for weight of fruits and yield per plant, Kaushal *et al.* (2017) [6] for yield per plant and equatorial diameter of fruits, Kumar (2018) [7] for weight of marketable and unmarketable fruits per plant, yield per plant, equatorial diameter and number of branches per plant and Madhavi *et al.* (2019) [8] for number of branches, equatorial diameter of fruits and yield per plant.

3.2.1 Direct effects

Results from path coefficient analysis showed that highest positive direct effect towards yield per hectare was contributed by weight of marketable fruits per plant (0.607) followed by total number of fruits per plant (0.408), weight of unmarketable fruits per plant (0.380), yield per plant (0.235), equatorial diameter (0.158) and days to first picking (0.074). However, highest negative direct effect towards yield per hectare was reported by number of marketable fruits per plant (-0.371) which was followed by number of locules per fruit (-0.214), pericarp thickness of fruits (-0.172), number of unmarketable fruits per plant (-0.168), fruit firmness (-0.162) and titrable acidity content (-0.088).

3.2.2 Indirect effects

The observations from analysis depicted that number of branches at harvesting stage had a positive indirect effect on yield per hectare via weight of marketable fruits per plant (0.290), weight of unmarketable fruits per plant (0.250), yield per plant (0.150) and total number of fruits per plant (0.125). It also showed negative indirect effect through number of marketable fruits per plant (-0.107).

Similarly, weight of marketable fruits per plant showed a positive indirect effect on yield per hectare via yield per plant (0.213), weight of unmarketable fruits per plant (0.180) and total number of fruits per plant (0.168). It also showed negative indirect effects through number of marketable fruits per plant (-0.172) and fruit firmness (-0.092).

Likewise, total number of fruits per plant showed a positive indirect effect on yield per hectare via weight of marketable fruits per plant (0.250) while, it also showed negative indirect effects through number of marketable fruits per plant (-0.348) and number of unmarketable fruits per plant (-0.092).

Similarly, pericarp thickness showed a positive indirect effect on yield per hectare via weight of marketable fruits per plant (0.315), yield per plant (0.115) and weight of unmarketable fruits per plant (0.109). It also showed negative indirect effects through fruit firmness (-0.103).

Further, polar diameter depicted a positive indirect effect on yield per hectare via weight of marketable fruits per plant (0.222) and weight of unmarketable fruits per plant (0.108). It also showed negative indirect effects through pericarp thickness (-0.157), fruit firmness (-0.112) and total number of fruits per plant (-0.103).

Likewise, fruit firmness showed a positive indirect effect on yield per hectare via weight of marketable fruits per plant (0.345) and yield per plant (0.113). However, it showed a negative indirect effect via pericarp thickness (-0.109).

Lastly ascorbic acid content also showed a positive indirect effect on yield per hectare via total number of fruits (0.287) and weight of marketable fruits per plant (0.135). However, it depicted a negative indirect effect via number of marketable fruits per plant (-0.256).

The characters like total soluble solids, specific gravity of fruits and acidity content of fruits showed very less values for indirect effect towards yield per hectare in both positive and negative direction.

Considering the spectrum of observations from path analysis it can be inferenced that weight of marketable fruits per plant, total number of fruits per plant, equatorial diameter of fruits and yield per plant are the most propitious characters influencing the yield directly as well as indirectly.

Table 2: Values of genotypic (below diagonal) and phenotypic (above diagonal) correlation coefficients for various traits under study

Traits	NB	PH	DFF	DFP	DLP	NMF	WMF	NUMF	WUMF	TNF	YPP	YPH	NL	PT	PD	ED	FF	SG	TSS	AA	Acidity
NB	1.00	-0.054^{NS}	-0.073^{NS}	-0.088^{NS}	-0.087^{NS}	0.247*	0.414**	0.190^{NS}	0.569**	0.282*	0.561**	0.532**	-0.074^{NS}	0.124^{NS}	-0.001^{NS}	-0.099^{NS}	0.117^{NS}	-0.103^{NS}	-0.215^{NS}	0.231^{NS}	-0.004^{NS}
PH	-0.187^{NS}	1.00	0.136^{NS}	-0.093^{NS}	0.019^{NS}	0.280*	0.364**	0.086^{NS}	0.111^{NS}	0.272*	0.305*	0.301*	0.011^{NS}	0.025^{NS}	0.104^{NS}	0.165^{NS}	0.230^{NS}	0.091^{NS}	0.354**	-0.152^{NS}	0.005^{NS}
DFF	-0.075^{NS}	0.196^{NS}	1.00	0.715**	0.820**	0.190^{NS}	0.331**	0.225^{NS}	0.107^{NS}	0.247*	0.280*	0.317*	-0.253*	0.361**	0.268*	-0.241^{NS}	0.227^{NS}	0.278*	0.010^{NS}	-0.075^{NS}	-0.156^{NS}
DFP	-0.108^{NS}	-0.050^{NS}	0.807**	1.00	0.834**	0.156^{NS}	0.096^{NS}	0.324**	0.013^{NS}	0.255*	0.073^{NS}	0.114^{NS}	-0.232^{NS}	0.202^{NS}	0.016^{NS}	-0.307*	-0.077^{NS}	0.224^{NS}	-0.133^{NS}	0.150^{NS}	-0.014^{NS}
DLP	-0.110^{NS}	0.071^{NS}	0.930**	0.941**	1.00	0.223^{NS}	0.273*	0.307*	0.000^{NS}	0.305*	0.189^{NS}	0.237^{NS}	-0.380**	0.218^{NS}	0.076^{NS}	-0.294*	0.110^{NS}	0.124^{NS}	-0.097^{NS}	0.140^{NS}	-0.111^{NS}
NMF	0.288*	0.174^{NS}	0.211^{NS}	0.178^{NS}	0.245*	1.00	0.490**	0.198^{NS}	0.183^{NS}	0.930**	0.427**	0.445**	-0.123^{NS}	-0.134^{NS}	-0.150^{NS}	0.172^{NS}	0.124^{NS}	-0.138^{NS}	0.163^{NS}	0.608**	-0.202^{NS}
WMF	0.478**	0.329**	0.371**	0.110^{NS}	0.305*	0.463**	1.00	0.030^{NS}	0.432**	0.431**	0.900**	0.882**	-0.154^{NS}	0.488**	0.335**	0.228^{NS}	0.520**	-0.051^{NS}	-0.079^{NS}	0.217^{NS}	0.115^{NS}
NUMF	0.178^{NS}	0.112^{NS}	0.219^{NS}	0.356**	0.334**	0.271*	0.062^{NS}	1.00	-0.031^{NS}	0.544**	0.006^{NS}	0.017^{NS}	-0.516**	-0.124^{NS}	-0.290*	-0.481**	-0.119^{NS}	0.022^{NS}	0.073^{NS}	0.286*	0.161^{NS}
WUMF	0.658**	0.175^{NS}	0.099^{NS}	0.007^{NS}	-0.009^{NS}	0.224^{NS}	0.475**	-0.098^{NS}	1.00	0.145^{NS}	0.781**	0.789**	0.218^{NS}	0.266*	0.257*	0.119^{NS}	0.186^{NS}	0.258*	-0.038^{NS}	-0.017^{NS}	0.131^{NS}
TNF	0.306*	0.186^{NS}	0.256*	0.278*	0.326**	0.938**	0.412**	0.588**	0.153^{NS}	1.00	0.368**	0.387**	-0.299*	-0.161^{NS}	-0.237^{NS}	-0.033^{NS}	0.061^{NS}	-0.110^{NS}	0.166^{NS}	0.628**	-0.113^{NS}
YPP	0.640**	0.307*	0.299*	0.078^{NS}	0.202^{NS}	0.421**	0.906**	-0.005^{NS}	0.803**	0.352**	1.00	0.991**	-0.001^{NS}	0.466**	0.356**	0.215^{NS}	0.449**	0.089^{NS}	-0.073^{NS}	0.142^{NS}	0.143^{NS}
YPH	0.614**	0.330**	0.345**	0.119^{NS}	0.253*	0.449**	0.893**	0.012^{NS}	0.809**	0.382**	0.994**	1.00	0.001^{NS}	0.433**	0.329**	0.193^{NS}	0.422**	0.113^{NS}	-0.043^{NS}	0.142^{NS}	0.135^{NS}
NL	-0.038^{NS}	0.022^{NS}	-0.269*	-0.254*	-0.404**	-0.121^{NS}	-0.154^{NS}	-0.574**	0.228^{NS}	-0.308*	0.005^{NS}	0.004^{NS}	1.00	-0.281*	-0.199^{NS}	0.305*	-0.415**	0.153^{NS}	0.165^{NS}	-0.278*	-0.226^{NS}
PT	0.122^{NS}	0.041^{NS}	0.368**	0.238^{NS}	0.268*	-0.157^{NS}	0.520**	-0.128^{NS}	0.287*	-0.178^{NS}	0.490**	0.457**	-0.280*	1.00	0.837**	0.291*	0.596**	0.153^{NS}	-0.230^{NS}	-0.101^{NS}	0.262*
PD	0.005^{NS}	0.168^{NS}	0.276*	0.019^{NS}	0.113^{NS}	-0.167^{NS}	0.366**	-0.310*	0.283*	-0.252*	0.384**	0.359**	-0.206^{NS}	0.915**	1.00	0.396**	0.632**	0.072^{NS}	-0.086^{NS}	-0.099^{NS}	0.088^{NS}
ED	-0.152^{NS}	0.059^{NS}	-0.284*	-0.293*	-0.357**	0.150^{NS}	0.214^{NS}	-0.579**	0.131^{NS}	-0.083^{NS}	0.208^{NS}	0.191^{NS}	0.328**	0.315*	0.467**	1.00	0.313*	-0.112^{NS}	0.137^{NS}	0.171^{NS}	0.047^{NS}
FF	0.111^{NS}	0.370**	0.264*	-0.071^{NS}	0.110^{NS}	0.140^{NS}	0.568**	-0.116^{NS}	0.200^{NS}	0.076^{NS}	0.481**	0.446**	-0.438**	0.635**	0.689**	0.348**	1.00	-0.169^{NS}	-0.183^{NS}	-0.033^{NS}	0.074^{NS}
SG	-0.115^{NS}	0.063^{NS}	0.345**	0.300*	0.187^{NS}	-0.154^{NS}	-0.065^{NS}	0.056^{NS}	0.315*	-0.109^{NS}	0.108^{NS}	0.129^{NS}	0.136^{NS}	0.250*	0.087^{NS}	-0.165^{NS}	-0.149^{NS}	1.00	0.050^{NS}	-0.285*	0.264*
TSS	-0.433**	0.487**	0.024^{NS}	-0.158^{NS}	-0.139^{NS}	0.169^{NS}	-0.165^{NS}	0.108^{NS}	-0.028^{NS}	0.181^{NS}	-0.125^{NS}	-0.084^{NS}	0.293*	-0.399**	-0.169^{NS}	0.120^{NS}	-0.296*	0.172^{NS}	1.00	-0.042^{NS}	0.176^{NS}
AA	0.267*	-0.221^{NS}	-0.081^{NS}	0.157^{NS}	0.109^{NS}	0.690**	0.222^{NS}	0.341**	-0.014^{NS}	0.703**	0.144^{NS}	0.149^{NS}	-0.291*	-0.092^{NS}	-0.142^{NS}	0.186^{NS}	-0.046^{NS}	-0.347**	-0.030^{NS}	1.00	-0.052^{NS}
Acidity	0.022^{NS}	0.079^{NS}	-0.193^{NS}	-0.032^{NS}	-0.105^{NS}	-0.208^{NS}	0.152^{NS}	0.191^{NS}	0.149^{NS}	-0.106^{NS}	0.175^{NS}	0.157^{NS}	-0.264*	0.266*	0.089^{NS}	0.071^{NS}	0.069^{NS}	0.323**	0.192^{NS}	-0.041^{NS}	1.00

*significant at 5% level of significance, **significant at 1% level of significance

NB: Number of branches per plant; **PH:** Plant height at maturity (cm); **DFF:** Days to 50% flowering; **DFP:** Days to first picking; **DLP:** Days to last picking; **NMF:** Number of marketable fruits per plant; **WMF:** Weight of marketable fruits per plant (g); **NUMF:** Number of unmarketable fruits per plant; **WUMF:** Weight of unmarketable fruits per plant (g);**TNF:** Total number of fruits per plant; **YPP:** Yield of fruits per plant (g); **YPH:** Yield of fruits per hectare (q); **NL:** Number of locules per fruits; **PT:** Pericarp thickness (mm); **PD:** Polar diameter (cm); **ED:** Equatorial diameter (cm); **FF:** Fruit firmness (kg/cm^2); **SG:** Specific gravity (g/cm^3); **TSS:** Total soluble solids (^{0} brix); **AA:** Ascorbic acid (mg/100g); **Acidity:** Titrable Acidity (%)

Table 3: Estimates of direct (diagonal values) and indirect effects of various characters over yield per hectare

	NB	PH	DFF	DFP	DLP	NMF	WMF	NUMF	WUMF	TNF	YPP	NL	PT	PD	ED	FF	SG	TSS	AA	Acidity
NB	0.051	-0.009	0.001	-0.008	-0.001	-0.107	0.290	-0.030	0.250	0.125	0.150	0.008	-0.021	0.000	-0.024	-0.018	-0.008	-0.009	-0.020	-0.002
PH	-0.010	0.046	-0.004	-0.004	0.001	-0.065	0.200	-0.019	0.066	0.076	0.072	-0.005	-0.007	0.010	0.009	-0.060	0.004	0.010	0.017	-0.007
DFF	-0.004	0.009	-0.019	0.060	0.010	-0.078	0.225	-0.037	0.038	0.105	0.070	0.058	-0.063	0.017	-0.045	-0.043	0.024	0.001	0.006	0.017
DFP	-0.006	-0.002	-0.015	0.074	0.010	-0.066	0.067	-0.060	0.003	0.113	0.018	0.054	-0.041	0.001	-0.046	0.012	0.021	-0.003	-0.012	0.003
DLP	-0.006	0.003	-0.017	0.070	0.011	-0.091	0.185	-0.056	-0.003	0.133	0.047	0.087	-0.046	0.007	-0.056	-0.018	0.013	-0.003	-0.008	0.009
NMF	0.015	0.008	-0.004	0.013	0.003	-0.371	0.281	-0.046	0.085	0.383	0.099	0.026	0.027	-0.010	0.024	-0.023	-0.011	0.004	-0.053	0.018
WMF	0.025	0.015	-0.007	0.008	0.003	-0.172	0.607	-0.010	0.180	0.168	0.213	0.033	-0.089	0.022	0.034	-0.092	-0.005	-0.004	-0.017	-0.013
NUMF	0.009	0.005	-0.004	0.026	0.004	-0.101	0.038	-0.168	-0.037	0.240	-0.01	0.123	0.022	-0.019	-0.091	0.019	0.004	0.002	-0.026	-0.017
WUMF	0.034	0.008	-0.002	0.001	0.000	-0.083	0.288	0.016	0.380	0.062	0.188	-0.049	-0.049	0.017	0.021	-0.032	0.022	-0.001	0.001	-0.013
TNF	0.016	0.008	-0.005	0.021	0.004	-0.348	0.250	-0.099	0.058	0.408	0.083	0.066	0.031	-0.015	-0.013	-0.012	-0.008	0.004	-0.054	0.009
YPP	0.033	0.014	-0.006	0.006	0.002	-0.156	0.550	0.001	0.305	0.144	0.235	-0.001	-0.084	0.023	0.033	-0.078	0.008	-0.003	-0.011	-0.015
NL	-0.002	0.001	0.005	-0.019	-0.004	0.045	-0.093	0.097	0.086	-0.126	0.001	-0.214	0.048	-0.013	0.052	0.071	0.010	0.006	0.022	0.023
PT	0.006	0.002	-0.007	0.018	0.003	0.058	0.315	0.022	0.109	-0.073	0.115	0.060	-0.172	0.056	0.050	-0.103	0.018	-0.008	0.007	-0.023
PD	0.000	0.008	-0.005	0.001	0.001	0.062	0.222	0.052	0.108	-0.103	0.090	0.044	-0.157	0.061	0.074	-0.112	0.006	-0.004	0.011	-0.008

ED	-0.008	0.003	0.005	-0.022	-0.004	-0.056	0.130	0.097	0.050	-0.034	0.049	-0.070	-0.054	0.028	0.158	-0.057	-0.012	0.003	-0.014	-0.006
FF	0.006	0.017	-0.005	-0.005	0.001	-0.052	0.345	0.020	0.076	0.031	0.113	0.094	-0.109	0.042	0.055	-0.162	-0.011	-0.006	0.003	-0.006
SG	-0.006	0.003	-0.006	0.022	0.002	0.057	-0.040	-0.010	0.120	-0.045	0.025	-0.029	-0.043	0.005	-0.026	0.024	0.070	0.004	0.026	-0.028
TSS	-0.022	0.022	0.000	-0.012	-0.002	-0.063	-0.100	-0.018	-0.011	0.074	-0.029	-0.063	0.069	-0.010	0.019	0.048	0.012	0.021	0.002	-0.017
AA	0.014	-0.010	0.002	0.012	0.001	-0.256	0.135	-0.057	-0.005	0.287	0.034	0.062	0.016	-0.009	0.029	0.007	-0.024	-0.001	-0.076	0.004
Acidity	0.001	0.004	0.004	-0.002	-0.001	0.077	0.092	-0.032	0.057	-0.043	0.041	0.057	-0.046	0.005	0.011	-0.011	0.023	0.004	0.003	-0.088

Residual are (-0.0084)

NB: Number of branches per plant; PH: Plant height (cm); DFF: Days to 50% flowering; DFP: Days to first picking; DLP: Days to last picking; NMF: Number of marketable fruits per plant; WMF: Weight of marketable fruits per plant (g); NUMF: Number of unmarketable fruits per plant; WUMF: Weight of unmarketable fruits per plant (g);TNF: Total number of fruits per plant; YPP: Yield of fruits per plant (g); YPH: Yield of fruits per hectare (q); NL: Number of locules per fruits; PT: Pericarp thickness (mm); PD: Polar diameter (cm); ED: Equatorial diameter (cm); FF: Fruit firmness (kg/cm^2); SG: Specific gravity (g/cm^3); TSS: Total soluble solids (^{0} brix); AA: Ascorbic acid (mg/100g); Acidity: Titrable Acidity (%)

4. Conclusion
The results obtained in this investigation revealed the occurrence of considerable positive as well as negative direct and indirect effects by various characters on the fruit yield of tomato through one or other characters. Thus, plant characters namely number of branches per plant, plant height, days to 50% flowering, number of fruits per plant, weight of fruits per plant and fruit diameter showing high degree of correlation and heritability deserves greater weightage for efficient selection in any tomato improvement programme. Likewise, for characters pertaining to fruit quality pericarp thickness of fruits, fruit firmness, acidity content and ascorbic acid content in fruits proved to be most dependable characters.

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