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Character association and path study in tomato (*Solanum lycopersicon*)

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Abstract
The present investigation, correlation and path in tomato was undertaken in randomized Block design with three replications on twenty genotypes at the Nana Ji Deshmukh Krishi Farm. The objective of the study was to evaluate correlation and path of traits among tomato accession based on quantitative traits. Thirty tomato acessession were planted in 2014-15 in randomized block design with three replications. Data on 15 quantitative traits were collected and subjected to various statistical analyses. As the study revealed, In general, genotypic correlations were higher than phenotypic ones in magnitude for all the characters. The character which showed negative association at genotypic level also showed negative association at phenotypic level. The fruit yield per plant exhibited significant and positive correlation with fruit diameter and fruit per plant at genotypic level while fruit yield per plant exhibited significant and positive correlation with fruit diameter and fruit per plant at phenotypic level. Path coefficient analysis revealed that the positive direct effect on fruit yield per plant was exhibited by fruit diameter and fruit per plant at genotypic level Path coefficient analysis revealed that the positive direct effect on fruit yield per plant exhibited by fruit diameter, fruit per plant, plant height, days to 50% flowering and fruits per cluster at phenotypic level.

Keywords: correlation, path, tomato, genotypic, phenotypic

Introduction
Tomato (*Solanum lycpersicon* L.) is one of the most important vegetable grown all over the world. It is native of Peru Ecuador Bolivia Region of Andes, South America Rick (1969). Its production in 2020 the cultivation area available for the production of tomato across India during the fiscal year 2020 was approximately 813 thousand hectares estimated to be around 19328 metric tons, Anonymous (2020) [2]. Tomato is mainly consumed as salad, cooked or processed into several products like ketchup, juice, puree, sauce and whole canned fruit Yadav *et al*., (2013) [14]. It is a good source of an antioxidant (lycopene), ascorbic acid and Vitamin B; recent epidemiological studies have shown that consumption of tomato and its products reduce risk of developing digestive tract and prostate cancers Khapte and Jansirani (2014). The degree and direction of relationship between two or more variables could be found out through statistical measure of Correlation coefficient. It helps to measures the mutual relationship between various plant characters and determines the component characters on which selection could be made for genetic improvement of yield and quality contributing traits while the path analysis partitioning the correlation coefficient into the direct and indirect effect of a set of independent variables on dependent variables Nagariya *et al*., (2015) [9]. Hence, there is pre-requisite for preliminary investigations of characters in the genotypes. Thus, keeping above considerations in view, the present research work has been conducted to study the correlation and path coefficient analysis in 30 genotypes on 13 characters of tomato.

Method and Materials
The Experiment was conducted to evaluate the thirty genotypes/varieties under normal soil and rainfed condition at Agriculture Farm, Nana Ji Deshmukh New Agriculture Campus, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna (M.P.). The place of experiment in Chitrakoot is situated at $25^0$10' North latitude and $80^0$85' East longitude. The altitude is about 200m above mean sea level. The experiment was laid out fallowing Randomized Block Design (RBD) with three replications during *Kharif* 2015. Five competitive plants from each replication were randomly selected from recording observation for all the 13 quantitative traits except days to 50% flowering and days to maturity which was recorded on whole plot basis. Average data from the sampled plant of each replication in various statistical analyses The morphological characters were recorded as per the DUS guidelines.

The genotypic and phenotypic correlation coefficient of yield and quality contributing traits were estimated as per described method AlJibouri *et al*., (1958). The direct and indirect effect was estimated as per the method of Wright (1921) [13] and elaborated by Dewey and Lu (1959) [3] respectively.

Result and Discussion

The knowledge of association of various characters related to yield is important for future improvement in a complex polygenic character through selection. The genetic improvement in fruit yield is not possible without bringing an improvement in the yield component characters. The inclusion of various component characters in a selection scheme is obviously not practicable and under these situations, knowledge with respect to relationship of various traits with fruit yield and quality parameters would be of great help in formulating an effective and efficient selection. All the possible genotypic and phenotypic correlation coefficient between fruit yield and quality components is given in (Table 1 and 2). The present study discloses that in general, genotypic correlation coefficient were higher than their phenotypic ones. Similar finding were observed by Nagariya *et al*., (2015) [9] and Sudesh and Anita (2016) [11]. In present study, fruit yield per plant exhibited significant and positive correlation with fruit diameter and fruit per plant, while significant and negative correlation with number of flower per cluster and number of flower per inflorescence at genotypic level. Days to maturity exhibited highly significant and positive correlation with fruit per plant branches per plant, fruit weight and plant height whereas days to first flowering and locules per fruit showed significant and negative correlation at genotypic level. Plant height showed significant and positive correlation with branches per plant while showed highly significant and negative correlation with locules per fruit at genotypic level. Fruit diameter exhibited highly significant and positive correlation with pericarp thickness, average fruit weight, branches per plant and locules per fruit; Pericarp thickness with average fruit weight, branches per plant; Locules per fruit with average fruit weight; fruit weight per plant with fruits per plant, branches per plant and days to 50% flowering; Average fruit weight with branches per plant; Fruits per plant with branches per plant and flowers per inflorescence; Fruits per cluster with flowers per cluster; Flowers per cluster with flowers per inflorescence and Flowers per inflorescence with days o 50% flowering while Fruit diameter with number of fruit per cluster and number of flower per cluster; pericarp thickness with flower per cluster, days to 50% flowering; Fruit weight with days to first flowering; Average fruit weight with fruit per cluster and flower per cluster; fruit per plant with days to first flowering; fruit per cluster with branches per plant; Flower per cluster with days to 50% flowering and branches per plant; flower per inflorescence with days to first flowering and days to 50% flowering with days to first flowering exhibited highly significant and negative correlation at genotypic level. Fruit yield per plant exhibited significant and positive correlation with fruit diameter (0.254)and fruit per plant (0.230), while significant and negative correlation with number of flower per cluster (-0.337) and number of flower per inflorescence (-0.228)) at genotypic level. Days to Maturity exhibited highly significant and positive correlation with fruit per plant (0.646), branches per plant (0.633), fruit weight (0.406) and plant height (0.364) whereas days to first flowering (-0.529) and locules per fruit (-0.311) showed significant and negative correlation at genotypic level. Plant height showed significant and positive correlation with branches per plant (0.287) while showed highly significant and negative correlation with locules per fruit (-0.428) at genotypic level. Fruit diameter exhibited highly significant and positive correlation with pericarp thickness (0.719), average fruit weight (0.674), branches per plant (0.463) and locules per fruit (0.397); Pericarp thickness with average fruit weight (0.505), branches per plant (0.499); Locules per fruit with average fruit weight (0.514); fruit weight per plant with fruits per plant (0.420), branches per plant (0.414) and days to 50% flowering; Average fruit weight with branches per plant (0.320); Fruits per plant with branches per plant (0.683) and flowers per inflorescence (0.308); Fruits per cluster with flowers per cluster (0.987); Flowers per cluster with flowers per inflorescence (0.476) and Flowers per inflorescence with days to 50% flowering (0.300) while Fruit diameter with number of fruit per cluster(-0.479) and number of flower per cluster (-0.458); pericarp thickness with flower per cluster (-0.628), days to 50% flowering (-0.391); Fruit weight with days to first flowering (-0.511); Average fruit weight with fruit per cluster (-0.5480 and flower per cluster (-0.515); fruit per plant with days to first flowering (-0.665); fruit per cluster with branches per plant (-0.560); Flower per cluster with days to 50% flowering (-0.419) and branches per plant (-0.398); flower per inflorescence with days to first flowering (-0.487) and days to 50% flowering with days to first flowering (-0.307) exhibited highly significant and negative correlation at genotypic level. At phenotypic level, Fruit yield per plant exhibited significant and positive correlation with fruit diameter (0.216) and fruit per plant (0.166),while significant and negative correlation with number of locules per fruit (-0.131). Days to Maturity exhibited highly significant and positive correlation with fruit per plant (0.528), branches per plant (0.390), fruit weight (0.399) and plant height (0.327) whereas days to first flowering (-0.225) and locules per fruit (-0.287) showed significant and negative correlation at phenotypic level. Plant height showed significant and positive correlation with branches per plant (0.227) while showed highly significant and negative correlation with locules per fruit (-0.378) at phenotypic level. Fruit diameter exhibited highly significant and positive correlation with, average fruit weight (0.587), pericarp thickness (0.533), Locules per fruit(0.363)and branches per plant (0.292); Pericarp thickness with average fruit weight (0.391), branches per plant (0.296); Locules per fruit with average fruit weight (0.481); Fruit weight per plant with fruits per plant (0.326),Average fruit wt.(0.263) and branches per plant (0.228); Average fruit weight with branches per plant (0.210); Fruits per plant with branches per plant (0.623) and flowers per inflorescence (0.221); Fruits per cluster with flowers per cluster (0.631); Flowers per cluster with flowers per inflorescence (0.226) and days o 50% flowering with days to Ist flowering(0.598) while Pericarp thickness with flower per cluster (-0.213) and fruit per cluster (-0.229); Fruit weight with days to first flowering (-0.231); Average fruit weight with fruit per cluster (-0.347) and flower per cluster (-0.228); Fruit per plant with days to first flowering (-0.275); flower per inflorescence with days to first flowering (-0.219) exhibited significant and negative correlation at phenotypic level. The other rest of the characters were too low to be considered of any consequence or association at phenotypic level with the characters under study. The other rest of the characters were too low to be considered of any consequence or association at phenotypic level with the characters. Similar finding were also reported by Nair and Thamburai (1995) [10], Vikram and Kohali (1998)

[12], Yadav and Singh (1998) [14], Mohanty *et al.* (2003) [7] Hindayatulah *et al.* (2008) [4], Maurya *et al.* (2011) [5] for number of fruits per plant and average fruit weight, and Monamodi, *et al.* (2013) [8].

Path coefficient analysis is a tool to partition the observed correlation into direct and indirect effects of yield components on yield which provide clearer picture of character association for formulating efficient selection strategy. Path coefficient analysis differs from simple correlation in that in point out the course and their relative importance whereas; the later measures simply the mutual association ignoring the causation.

In the present study the path coefficient analysis was estimated at phenotypic and genotypic level (Table 3 and 4.) Path coefficient analysis revealed that the positive direct effect on fruit yield per plant was exerted by fruit diameter and fruit per plant, while negative direct effect was exerted by the characters pericarp thickness, flowers per inflorescence, locules per fruit, plant height, days to Ist flowering, days to maturity, days to 50% flowering, fruit per cluster, branches per plant, fruit weight per plant and average fruit weight had exerted maximum substantial negative direct effect on fruit yield at genotypic level.

At phenotypic level, path coefficient analysis revealed that the positive direct effect on fruit yield per plant exhibited by fruit diameter, fruit per plant, plant height, days to 50% flowering and fruits per cluster while negative direct effect was exerted on fruit yield per plant by the characters locules per fruit, days to maturity, branches per plant, flowers per inflorescence, average fruit weight, pericarp thickness, days to Ist flowering and fruit weight per plant had exerted negative direct effect on fruit yield per plant.

Number of fruits per plant, locules per fruit and days to Ist flowering *via* days to maturity, Locules per fruit and pericarp thickness *via* plant height; Fruit diameter and flowers per inflorescence *via* pericarp thickness; Fruit diameter and plant height *via* Locules per fruit; Fruits per plant *via* fruit weight per plant; Fruit diameter *via* Average fruit weight; days to first flowering *via* Fruits per plant; Pericarp thickness *via* fruits per cluster; Pericarp thickness and fruits per plant *via* number of flowers per inflorescence; Fruit diameter and fruit per plant *via* Branches per plant; Pericarp thickness *via* days to 50% flowering; and Flowers per inflorescence and plant height *via* days to first flowering exerted positive indirect effect whereas fruit per plant *via* days to first flowering; pericarp thickness *via* branches per plant; Fruit diameter *via* Fruits per cluster; Pericarp thickness *via* Fruits per plant; pericarp thickness *via* Average fruit weight; pericarp thickness *via* Fruit weight per plant; pericarp thickness *via* fruit diameter and pericarp thickness *via* days to maturity express substantial indirect negative contribution on fruit yield per plant at genotypic level.

At phenotypic level, the perusal of table revealed that the positive indirect effect on fruit yield per plant was expressed by characters fruits per plant *via* branches per plant; fruit diameter *via* Average fruit weight; Fruit diameter *via* Locules per fruit; Fruits diameter *via* Pericarp thickness and Fruits per plant *via* Days to maturity exerted substantial positive effect while other characters showed very low values as indirect effects at phenotypic level. Similar results were also reported by earlier workers Mohanty *et al*. (2003) [7] reported that number of fruit per plant and average fruit weight had direct effect on yield per plant. Hindayatulah *et al.* (2008) [4], Maurya *et al.* (2011) [5] for number of fruits per plant Monamodi, *et al*.(2013) [8] also observed that fruit weight per plant had greatest direct effect on yield per plant and Meena and Bahadur (2015) [6] for fruit weight had a very high positive direct genotypic and phenotypic effect on fruit yield per plant. The estimate of residual factors was found at phenotypic level (0.883) and genotypic level (0.469) which showed moderate effect for the characters includes which indicated that characters included in this study explained almost all variability towards yield for future study.

Table 1: Estimates of Genotypic Correlations for different 15 characters in Tomato

Characters	First Flow.	50 % Flow.	Branches/ Pla	Flowers/ Inflorescence	Flowers/ Cluster	Fruit/ Cluster	Fruits/ Plant	Average Fruit Weight	Fruit Weight / Plant (g)	Locules / Fruit	Pericarp Thickness	Fruit Diameter	Plant Height	Days to Maturity	Fruit Yield/ Plant (g)
Days to Ist Flow.	1.000	-0.307	-0.188	-0.487	-0.014	0.183	-0.665	0.017	-0.511	-0.038	-0.052	-0.062	-0.402	-0.529	-0.107
Days to 50 % Flow.		1.000	0.185	0.300	-0.419	0.206	0.034	0.048	0.369	-0.093	-0.391	-0.040	0.111	-0.157	0.098
Branches/ Plant			1.000	-0.017	-0.398	-0.560	0.683	0.320	0.414	0.007	0.499	0.463	0.287	0.633	0.122
Flowers/ Inflor.				1.000	0.476	0.098	0.308	-0.054	0.000	0.170	-0.271	-0.032	0.006	0.020	-0.228
Flowers/ Cluster					1.000	0.987	0.125	-0.515	-0.147	-0.040	-0.628	-0.458	-0.047	0.134	-0.337
Fruit/ Cluster						1.000	0.127	-0.548	-0.094	-0.260	-0.370	-0.479	-0.242	0.128	-0.043
Fruits/ Plant							1.000	0.129	0.420	-0.024	0.232	0.067	0.184	0.646	0.230
Av. Fruit Weight								1.000	0.279	0.514	0.505	0.674	0.041	-0.071	-0.028
Fruit Weight(g)									1.000	-0.077	0.286	0.167	0.127	0.406	0.015
Locules/ Fruit										1.000	0.138	0.397	-0.428	-0.311	-0.107
Pericarp Thickness											1.000	0.719	-0.215	0.239	0.067
Fruit Diameter												1.000	-0.037	0.018	0.254
Plant height													1.000	0.364	0.121
Days to Maturity														1.000	0.021
FruitYield/Plant															1.000

Table 2: Estimates of Phenotypic Correlations for different 15 characters in Tomato.

Characters	Ist Flow	50 % Flow.	Branches/ Plant	Flowers/ Inflor.	Flowers/ Cluster	Fruit/ Cluster	Fruits/ Pl.	Av. Fruit Wt.	Fruit Weight/ Pl.	Locules/ Fruit	Pericarp Thickness	Fruit Diameter	Plant Height	Days to Maturity	Fruit Yield/ p
Days to First Flowering	1.000	0.598**	-0.069	-0.219*	-0.048	-0.195	-0.275**	0.004	-0.231*	0.046	-0.025	0.055	-0.047	-0.225*	-0.019
Days to 50 % Flowering		1.000	0.009	0.067	-0.176	-0.193	-0.009	0.021	0.177	0.044	-0.104	0.069	0.104	-0.049	0.061
Branches/ Plant			1.000	0.053	-0.206	-0.225*	0.623**	0.210*	0.228*	0.011	0.296**	0.292**	0.227*	0.390**	0.060
Flowers/ Inflor				1.000	0.226*	0.151	0.221*	-0.026	0.001	0.077	-0.025	-0.012	0.023	0.003	-0.070
Flowers/ Cluster					1.000	0.631**	0.028	-0.228*	-0.061	-0.044	-0.213*	-0.238*	-0.136	0.040	-0.051
Fruit/ Cluster						1.000	0.128	-0.347**	-0.045	-0.215*	-0.229*	-0.341**	-0.220*	0.037	0.024
Fruits/ Plant							1.000	0.086	0.326**	-0.007	0.250*	0.074	0.126	0.528**	0.166
Av. Fruit Weight (g)								1.000	0.263*	0.481**	0.391**	0.587**	0.051	-0.064	-0.015
Fruit Wt.Plant (g)									1.000	-0.076	0.232*	0.156	0.108	0.399**	0.014
Locules/ Fruit										1.000	0.117	0.363**	-0.378**	-0.287**	-0.131
Pericarp Thickness											1.000	0.533**	-0.152	0.186	0.044
Fruit Diameter												1.000	-0.063	0.017	0.216*
Plant Height													1.000	0.327**	0.104
Days to Maturity														1.000	0.015
Fruit Yield/ Plant (g)															1.000

Table 3: Direct and indirect effects for different characters on Fruit yield per plant at genotypic level in Tomato.

No	Character	Days to First Flowering	Days to 50 % Flowering	Branches/ Plant	Flowers/ Inflorescence	Fruit/ Cluster	Fruits/ Plant	Average Fruit Weight (g)	Fruit Weight/ Plant (g)	Locules/ Fruit	Pericarp Thickness (mm)	Fruit Diameter (cm)	Plant Height (cm)	Days to Maturity
1	Days to First Flowering	-0.530	0.163	0.100	0.258	-0.097	0.352	-0.009	0.271	0.020	0.027	0.033	0.213	0.280
2	Days to 50 % Flowering	0.097	-0.315	-0.058	-0.094	-0.065	-0.011	-0.015	-0.116	0.029	0.123	0.013	-0.035	0.049
3	Branches/ Plant	0.044	-0.043	-0.233	0.004	0.130	-0.159	-0.075	-0.096	-0.002	-0.116	-0.108	-0.067	-0.147
4	Flowers/ Inflorescence	0.455	-0.280	0.016	-0.934	-0.091	-0.288	0.050	0.000	-0.158	0.254	0.030	-0.006	-0.019
5	Fruit/ Cluster	-0.053	-0.060	0.163	-0.029	-0.292	-0.037	0.160	0.027	0.076	0.108	0.140	0.071	-0.037
6	Fruits/ Plant	-0.719	0.037	0.738	0.333	0.138	1.080	0.140	0.454	-0.026	0.251	0.072	0.198	0.698
7	Average Fruit Weight (g)	-0.001	-0.003	-0.017	0.003	0.030	-0.007	-0.054	-0.015	-0.028	-0.027	-0.037	-0.002	0.004
8	Fruit Weight/ Plant (g)	0.063	-0.046	-0.051	0.000	0.012	-0.052	-0.035	-0.124	0.010	-0.035	-0.021	-0.016	-0.050
9	Locules/ Fruit	0.034	0.086	-0.007	-0.156	0.239	0.022	-0.472	0.071	-0.918	-0.127	-0.365	0.393	0.285
10	Pericarp Thickness	0.086	0.653	-0.834	0.453	0.618	-0.388	-0.843	-0.478	-0.231	-1.670	-1.201	0.359	-0.399
11	Fruit Diameter (cm)	-0.104	-0.067	0.775	-0.053	-0.803	0.112	1.129	0.279	0.666	1.205	1.676	-0.062	0.030
12	Plant Height (cm)	0.315	-0.087	-0.225	-0.005	0.189	-0.144	-0.032	-0.099	0.335	0.168	0.029	-0.784	-0.285
13	Days to Maturity	0.205	0.061	-0.246	-0.008	-0.050	-0.251	0.028	-0.158	0.121	-0.093	-0.007	-0.141	-0.388
	Fruit Yield/ Plant (g)	-0.107	0.098	0.122	-0.228	-0.043	0.230	-0.028	0.015	-0.107	0.067	0.254	0.121	0.021
	Partial R^2	0.057	-0.031	-0.028	0.213	0.012	0.249	0.002	-0.002	0.098	-0.112	0.425	-0.095	-0.008
Residual Effect = 0.4696; Direct Effect on Main Diagonal (Bold Figure)														

Table 4: Direct and indirect effects for different characters on Fruit yield per plant at phenotypic level in Tomato.

Characters	Days to First Flowering	Days to 50 % Flowering	Branches/ Plant	Flowers/ Inflorescence	Fruit/ Cluster	Fruits/ Plant	Ave Fruit Weight (g)	Fruit Weight/ Plant	Locules/ Fruit	Pericarp Thickness (mm)	Fruit Diameter (cm)	Plant Height (cm)	Days to Maturity
Days to First Flowering	-0.080	-0.048	0.006	0.018	0.016	0.022	0.000	0.019	-0.004	0.002	-0.004	0.004	0.018
Days to 50 % Flowering	0.054	0.091	0.001	0.006	-0.018	-0.001	0.002	0.016	0.004	-0.009	0.006	0.009	-0.004
Branches/ Plant	0.014	-0.002	-0.203	-0.011	0.046	-0.127	-0.043	-0.046	-0.002	-0.060	-0.059	-0.046	-0.079
Flowers/ Inflorescence	0.036	-0.011	-0.009	-0.165	-0.025	-0.037	0.004	0.000	-0.013	0.004	0.002	-0.004	-0.001
Fruit/ Cluster	-0.004	-0.004	-0.005	0.003	0.022	0.003	-0.008	-0.001	-0.005	-0.005	-0.008	-0.005	0.001
Fruits/ Plant	-0.118	-0.004	0.268	0.095	0.055	0.430	0.037	0.140	-0.003	0.107	0.032	0.054	0.227
Average Fruit Weight	-0.001	-0.003	-0.031	0.004	0.051	-0.013	-0.147	-0.039	-0.071	-0.058	-0.086	-0.007	0.009
Fruit Wt. Plant (g)	0.016	-0.012	-0.016	0.000	0.003	-0.023	-0.018	-0.070	0.005	-0.016	-0.011	-0.008	-0.028
Locules/ Fruit	-0.011	-0.010	-0.003	-0.018	0.050	0.002	-0.112	0.018	-0.234	-0.027	-0.085	0.088	0.067
Pericarp Thickness	0.002	0.010	-0.029	0.003	0.023	-0.025	-0.039	-0.023	-0.012	-0.099	-0.053	0.015	-0.018
Fruit Diameter	0.027	0.034	0.144	-0.006	-0.168	0.036	0.289	0.077	0.179	0.262	0.492	-0.031	0.008
Plant Height (cm)	-0.005	0.011	0.024	0.002	-0.023	0.013	0.005	0.011	-0.040	-0.016	-0.007	0.106	0.035
Days to Maturity	0.049	0.011	-0.086	-0.001	-0.008	-0.116	0.014	-0.088	0.063	-0.041	-0.004	-0.072	-0.220
Fruit Yield/ Plant (g)	-0.019	0.061	0.060	-0.070	0.024	0.166	-0.015	0.014	-0.131	0.044	0.216	0.104	0.015
Partial R^2	0.002	0.006	-0.012	0.012	0.001	0.071	0.002	-0.001	0.031	-0.004	0.106	0.011	-0.003
R SQUARE = 0.2199 RESIDUAL EFFECT = 0.8832 ; Direct Effect on Main diagonal(Bold Figures)													

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