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Correlation and Path Coefficient Analysis in Superior Recombinant Inbred Lines of Tomato (*Solanum lycopersicum* L.)

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Sixteen superior recombinant inbred lines (RILs) and two commercial varieties *viz.*, Anagha and ArkaVikas were evaluated for growth, yield and quality parameters in tomato during *rabi* 2019-2020 in randomized block design with three replications. Correlation analysis revealed that equatorial fruit diameter (cm), polar fruit diameter (cm), average fruit weight (g), number of locules per fruit and pericarp thickness (mm) exhibited significant and positive association with fruit yield per plant (kg) at both genotypic and phenotypic level. Path coefficient analysis revealed that average fruit weight had very high direct positive effect on fruit yield per plant followed by equatorial fruit diameter. Hence, direct selection for these traits would be rewarding for improving fruit yield per plant.

Introduction

Tomato (*Solanum lycopersicum* L.) is the most economically important and widely grown vegetable crop in the world. It belongs to the Solanaceae family with its diploid chromosome number 2n =24 and believed to have its origin in the mountainous regions of the Andes comprising Peru, Ecuador and Chile. It is universally treated as a protective food because of its rich lycopene content- a powerful antioxidant, valued for anti-cancerous property worldwide (Bose *et al.*, 2002) and generally eulogised as poor man's orange because of its nutritive value and attractive appearance. It is also a treasure of vitamin A, C and minerals. Tomatoes are used directly as raw vegetable in sandwiches and salad. It is regarded as No. 1 processing vegetable in the world. Various processed products *viz.*, paste, puree, syrup, juice, ketchup, sauce, whole peeled tomato, *etc*. are prepared from tomato. Tomato puree and tomato paste have great export demand.

World-over, tomato cultivation spans over an area of 5.02 million hectare, with a production of 170.75 million tonnes. India is the second largest producer (11.5 %) after China (30.7 %) followed by U.S.A. (8.1 %). In India, an area of 0.81 million hectare is under tomato cultivation with an annual production of 19.67 million tonnes. Average productivity of tomato in India remains low at 24.36 t/ha as against 33.99 t/ha, the world average. Madhya Pradesh, Karnataka, Andhra Pradesh, Telangana, Gujarat, Odisha, West Bengal, Bihar and Maharashtra are the leading states in the production of tomato in India (Anon., 2018).

Correlation coefficient is a statistical measure to determine the extent of association, whether positive or negative association between various plant characters and thus helps to identify the character on which selection can be imposed for improvement in associated characters. Hence, understanding of the inter-relationship between yield and yield influencing characters is vital importance because this would facilitates effective selection for simultaneous improvement in one or more yield contributing characters.

The nature and direction of association among the characters was measured by simple correlation. Path coefficient analysis is an important biometrical tool which is effective for determining the various yield components of a crop. It is simply a standardized partial regression coefficient, which splits the correlation into direct and indirect effects. In other words, it measures the direct and indirect contribution of various independent characters on a dependent character and thus enables the breeders to judge best about the important component characters during selection. The concept of path analysis was developed by Wright (1921) and the technique was first used by Dewey and Lu (1959) that help in determining yield contributing characters hence, it is useful in indirect selection as yield is a complex and polygenic character. The direct selection for yield may not be reliable approach because, it is highly influenced by environmental factors.

Therefore, it becomes essential to identify the component characters through which yield improvement could be achieved. Correlations in combination with path analysis would give a better insight into cause and effect relationship between different pairs of characters.

Materials and Methods

The experiment has been carried out at Regional Horticultural Research and Extension Centre (RHREC), Kumbapur, Dharwad, UHS, Bagalkote during *rabi* 2019-2020 with eighteen tomato genotypes consisting of sixteen superior recombinant inbred lines and two commercial varieties *viz.*, Anagha and ArkaVikas. The experiment was laid out in Randomized Block Design. Thirty days old healthy, uniform seedlings were transplanted with spacing of 60 x 45 cm. The recommended dose of fertilizers at the rate of 120:80:50 kg NPK per hectare with half dose of nitrogen and full dose of phosphorous and potassium was applied as basal dose. Remaining half dose of nitrogen at the rate of 60 kg per hectare was given as top dress.

Depending on the weather condition irrigation was provided as and when required. Plants were provided with staking at 45 days after transplanting. Regular cultural practices and plant protection measures were followed throughout the cropping period. Data was recorded for characters *viz.*, plant height (cm) at 60 and 90 DAT, number of branches per plant at 60 and 90 DAT, days for first flowering, days for 50 per cent flowering, number of flower clusters per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, average fruit weight (g), equatorial fruit diameter (cm), polar fruit diameter (cm), fruit yield per plant (kg), fruit yield per plot (kg), fruit yield per hectare (t), number of locules per fruit, pericarp thickness (mm), TSS (^{o} Brix) and pH.

The genotypic and phenotypic correlation coefficient of growth, yield and quality contributing traits were estimated as per described by Al-Jibouri *et al.*, (1958). The direct and indirect effect was estimated as per the method of Wright (1921) and Dewey and Lu (1959).

Results and Discussion

Correlation studies

In the present investigation both genotypic and phenotypic correlations were worked out for fruit yield per plant and its contributing characters (Table 1 and table 2, respectively) where, a narrow difference was noticed between the genotypic and phenotypic correlation coefficient for various characters. This reveals that there was less influence of environment in the expression of the traits and also indicates the presence of strong inherent association among the traits.

Fruit yield per plant had significant positive association with traits like equatorial fruit diameter, polar fruit diameter, average fruit weight, number of locules per fruit and pericarp thickness at both genotypic and phenotypic level. Since, these association characters are in the desirable direction, it indicates that simultaneous selection for these characters would be rewarding for improving the fruit yield per plant.

These results were found to be in accordance with Joshi *et al.*, (2004) for average fruit weight, equatorial fruit diameter, polar fruit diameter and pericarp thickness, Anitha *et al.*, (2007) for number of locules per fruit, Prashanth *et al.,* (2008) for equatorial fruit diameter, polar fruit diameter, average fruit weight, number of locules per fruit and pericarp thickness.

Plant height at 90 DAT exhibited significant positive correlation with number of branches per plant at 90 DAT at genotypic level only. The finding was in agreement with Mahapatra *et al.*, (2013) for number of branches per plant.

Number of branches per plant at 90 DAT showed significant positive correlation with number of fruits per plant at phenotypic level only. The result was in agreement with Anjum *et al.,* (2009) for number of fruits per plant.

Equatorial fruit diameter had significant positive correlation with polar fruit diameter, average fruit weight, number of locules per fruit at phenotypic level only, pericarp thickness at both phenotypic and genotypic level and TSS at genotypic level only.

These results were found to be in accordance with Khapte and Jansirani (2014) for average fruit weight, number of locules per fruit and pericarp thickness.

Polar fruit diameter had significant positive correlation with average fruit weight, number of locules per fruit, pericarp thickness and pH both at phenotypic and genotypic level. The results are in conformity with Mahapatra *et al.,* (2013) for fruit weight and pericarp thickness.

Table.1 Estimates of genotypic correlation coefficients for growth, yield and quality parameters in superior RILs of tomato

@	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
X_1	**1.000**	0.445**	-0.283	-0.174	-0.267	-0.177	-0.255	-0.228	-0.193	-0.199	0.037	-0.254	-0.516**
X_2		**1.000**	-0.292	-0.088	0.318	-0.572	-0.438	-0.560	-0.233	-0.633**	0.162	0.083	-0.578**
X_3			**1.000**	0.875	0.108	-0.284	0.021	-0.124	-0.281	0.112	0.395**	0.061	-0.043
X_4				**1.000**	0.220	-0.368	-0.049	-0.230	-0.201	-0.002	0.158	-0.061	-0.102
X_5					**1.000**	-0.695	-0.384	-0.722	-0.641	-0.207	0.213	-0.376**	-0.167
X_6						**1.000**	0.658	0.920	0.783	0.500**	-0.334*	0.275*	0.660**
X_7							**1.000**	0.645**	0.315*	0.530**	-0.280*	0.400**	0.590**
X_8								**1.000**	0.826**	0.453**	-0.226	0.316*	0.759**
X_9									**1.000**	0.038	-0.193	0.363**	0.480**
X_{10}										**1.000**	-0.560**	-0.134	0.710**
X_{11}											**1.000**	0.033	-0.425**
X_{12}												**1.000**	0.064
X_{13}													**1.000**

** Significant at 1% level of Significance * Significant at 5% level of Significance

X_1 - Plant height at 90 DAT (cm) X_5 - No. of fruits/plant X_9 - No. of locules/fruit

X_2 - No. of branches/plant at 90 DAT X_6 - Equatorial fruit diameter (cm) X_{10} - Pericarp thickness (mm)

X_3 - Days for first flowering X_7 - Polar fruit diameter (cm) X_{11} - TSS

X_4 - Days for 50 per cent flowering X_8 - Average fruit weight (g) X_{12} - pH

X_{13}- Fruit yield/plant (kg)

Table.2 Estimates of phenotypic correlation coefficients for growth, yield and quality parameters in superior RILs of tomato

@	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
X_1	**1.000**	0.381**	-0.216	-0.093	-0.219	-0.178	-0.228	-0.195	-0.141	-0.184	-0.084	-0.240	-0.431**
X_2		**1.000**	-0.165	-0.032	0.288*	-0.504**	-0.367**	-0.517**	-0.219	-0.536**	0.054	0.016	-0.477**
X_3			**1.000**	0.783**	0.065	-0.237	0.045	-0.122	-0.240	0.074	0.255	0.040	-0.063
X_4				**1.000**	0.105	-0.290*	-0.019	-0.189	-0.184	-0.034	0.041	-0.017	-0.135
X_5					**1.000**	-0.604**	-0.338*	-0.665**	-0.571**	-0.150	0.132	-0.354**	-0.036
X_6						**1.000**	0.633**	0.856**	0.746**	0.479**	-0.246	0.261	0.606**
X_7							**1.000**	0.608**	0.301*	0.519**	-0.210	0.358**	0.534**
X_8								**1.000**	0.781**	0.429**	-0.168	0.289*	0.704**
X_9									**1.000**	0.047	-0.146	0.335*	0.433**
X_{10}										**1.000**	-0.430**	-0.131	0.660**
X_{11}											**1.000**	0.041	-0.316*
X_{12}												**1.000**	0.036
X_{13}													**1.000**

** Significant at 1% level of Significance * Significant at 5% level of Significance
X_1 - Plant height at 90 DAT (cm) X_5 - No. of fruits/plant X_9 - No. of locules/fruit
X_2 - No. of branches/plant at 90 DAT X_6 - Equatorial fruit diameter (cm) X_{10} - Pericarp thickness (mm)
X_3 - Days for first flower flowering X_7 - Polar fruit diameter (cm) X_{11} - TSS
X_4 - Days for 50 per cent flowering X_8 - Average fruit weight (g) X_{12} - pH
X_{13}- Fruit yield/plant (kg)

Table.3 Genotypic path coefficient analysis of the component characters on fruit yield per plant in superior RILs of tomato

@	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	rG
X_1	**-0.174**	-0.077	0.049	0.030	0.046	0.031	0.044	0.040	0.034	0.035	-0.006	0.044	-0.516**
X_2	0.136	**0.306**	-0.089	-0.027	0.097	-0.175	-0.134	-0.171	-0.071	-0.194	0.049	0.025	-0.578**
X_3	0.090	0.093	**-0.317**	-0.278	-0.034	0.090	-0.007	0.039	0.089	-0.036	-0.125	-0.019	-0.043
X_4	-0.105	-0.053	0.529	**0.604**	0.133	-0.222	-0.030	-0.139	-0.122	-0.001	0.096	-0.037	-0.102
X_5	-0.222	0.265	0.090	0.183	**0.834**	-0.579	-0.320	-0.602	-0.534	-0.172	0.177	-0.313	-0.167
X_6	-0.125	-0.406	-0.202	-0.261	-0.493	**0.710**	0.467	0.653	0.556	0.355	-0.237	0.195	0.660**
X_7	0.183	0.315	-0.015	0.035	0.276	-0.473	**-0.719**	-0.464	-0.226	-0.381	0.201	-0.287	0.590**
X_8	-0.641	-1.576	-0.348	-0.648	-2.034	2.590	1.818	**2.816**	2.326	1.276	-0.636	0.890	0.759**
X_9	0.329	0.397	0.480	0.343	1.093	-1.336	-0.537	-1.409	**-1.706**	-0.064	0.330	-0.618	0.480**
X_{10}	0.070	0.224	-0.040	0.001	0.073	-0.177	-0.187	-0.160	-0.013	**-0.353**	0.198	0.047	0.710**
X_{11}	-0.017	-0.077	-0.188	-0.075	-0.101	0.159	0.133	0.108	0.092	0.267	**-0.476**	-0.016	-0.425**
X_{12}	-0.039	0.013	0.009	-0.009	-0.057	0.042	0.061	0.048	0.055	-0.020	0.005	**0.153**	0.064

RESIDUAL EFFECT = 0.295 rG- Genotypic correlation value of fruit yield per plant (kg)
** Significant at 1% level of Significance
X_1 - Plant height at 90 DAT (cm) X_5 - No. of fruits/plant X_9 - No. of locules/fruit
X_2 - No. of branches/plant at 90 DAT X_6 - Equatorial fruit diameter (cm) X_{10} - Pericarp thickness (mm)
X_3 - Days for first flowering X_7 - Polar fruit diameter (cm) X_{11} - TSS
X_4 - Days for 50 per cent flowering X_8 - Average fruit weight (g) X_{12} - pH

Average fruit weight exhibited significant positive association with number of locules per fruit, pericarp thickness and pH both at genotypic and phenotypic level. The results are in conformity with Joshi *et al.,* (2004) and Buckseth *et al.,* (2012) for pericarp thickness, Mahapatra *et al.,* (2013) for number of locules per fruit and pericarp thickness.

From the above results, it is convincible that a great deal of success can be achieved in improvement of fruit yield per plant of superior RILs of tomato by applying selection pressure on traits like average fruit weight, equatorial fruit diameter and polar fruit diameter as these traits had significant and positive correlation with fruit yield per plant.

Path coefficient analysis

Correlation in combination with path analysis would give a better insight into cause and effect relationship between different pairs of characters. In the present study, path coefficient analysis between the components of tomato genotypes was worked out. As the genotypic coefficient is inherent and the path analysis was discussed only at genotypic level (Table 3).

Out of twelve independent traits selected for path analysis, the traits like equatorial fruit diameter, polar fruit diameter, average fruit weight, number of locules per fruit and pericarp thickness had significant correlation with fruit yield per plant. From among the above mentioned traits, average fruit weight exhibited a high direct positive effect on fruit yield per plant, this indicates true relationship between them and direct selection for the trait will be rewarding for yield improvement.

Similar findings were reported by Indurani *et al.,* (2010), Kumar and Dudi (2011), Manna and Paul (2012), Buckseth *et al.,* (2012), Kumar *et al.,* (2013), Chernet *et al.,* (2013), Mahapatra *et al.,* (2013) and Sherpa *et al.,* (2014) in tomato. Along with average fruit weight, equatorial fruit diameter should also be considered for yield improvement in tomato as it had significant positive correlation and direct positive effect on fruit yield per plant.

Average fruit weight was significantly and positively correlated with fruit yield per plant, and had direct positive effect (2.816) on fruit yield per plant. However it also had indirect positive effect via equatorial fruit diameter, number of locules per fruit, polar fruit diameter, pericarp thickness and pH.

Therefore, average fruit weight when considered, simultaneously the traits like equatorial fruit diameter, number of locules per fruit, polar fruit diameter, pericarp thickness and pH will be rewarding for improvement in yield. Similar type of observations were also made by Singh *et al.,* (2004) for fruit yield per plant and Golani*et al.,* (2007) for number of locules per fruit in tomato.

Equatorial fruit diameter also had significant and positive association with fruit yield per plant. It also had direct positive effect (0.710) on fruit yield per plant and indirect positive effect through average fruit weight, number of locules per fruit, polar fruit diameter, pericarp thickness and pH. Hence selection for these traits will be rewarding for yield improvement. Similar results were reported by Mahapatra *et al.,* (2013) and Kumar *et al.,* (2013) for fruit yield per plant.

From the above findings it can be concluded that while conducting selection for yield improvement in superior RILs of tomato, emphasize must be given to the genotypes having more average fruit weight and equatorial fruit diameter.

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