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Correlation and path analysis in tomato(*Lycopersicon esculentum* Mill.)

S.J. PRASHANTH, R.P. JAIPRAKASHNARAYAN, RAVINDRA MULGE AND M.B. MADALAGERI

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See end of the article for authors' affiliations

Correspondence to:

S.J. PRASHANTH
Department of Olericulture, K.R.C. College of Horticulture, UAS (D) Arabhavi, BELGAUM (KARNATAKA) INDIA

ABSTRACT

Correlation and path analysis were carried out in 67 tomato genotypes using growth, earliness, quality and yield characters. The results indicated the inverse relationship between growth and earliness characters but strong association between growth and yield characters. Total yield per plant was positively and significantly associated with early yield per plant, equatorial diameter of the fruit, fruit volume, average fruit weight, polar diameter of the fruit, number of fruits per plant, per cent fruit set, stem girth at 90 DAT, number of locules per fruit, plant height at 60 DAT, pericarp thickness and number of seeds per fruit. Total yield per plant was negatively and significantly associated with number of flowers per cluster and number of fruits per cluster. Path analysis revealed that early yield and average fruit weight had high direct positive effects on total yield. Hence, direct selection for early yield and average fruit weight is suggested for yield improvement.

Key words : Correlation and path analysis, Growth, Earliness, Quality and yield traits, Tomato

Tomato is one of the most popular, widely grown and versatile vegetable used for culinary purposes. Riped tomato fruit is consumed fresh as salads, after cooking and utilized in the preparation of range of processed products such as puree, paste, powder, ketchup, sauce, soup and canned whole fruits. Unripe green fruits are used for preparation of pickles and chutney. Information regarding association of characters like growth, earliness, quality yield and its component characters is very useful for plant breeder in developing commercial variety or hybrid. Many of these characters are inter related in desirable and undesirable direction. Correlation study measures the mutual relationship between various characters and helps in determining the component characters on which selection can be based for improvement in yield. The implications of correlation studies become more evident when correlations are partitioned into its components in path analysis in order to determine the relative magnitude of various attributes contributing to correlation. Hence, an attempt has been made in the present investigation to study the association of different traits, direct and indirect effects of characters based on *per se* performance.

MATERIALS AND METHODS

Total of 67 genotypes collected form different sources were evaluated in randomized block design with three replications at spacing of 75 x 60 cm. Observations on growth, earliness, quality and yield characters were recorded. Genotypic correlation coefficients were worked out among different traits using *per se* values (n = 201). Correlations and path analysis was carried out according to procedure given by Al-jibouri *et al*. (1958), and Goulden (1959), respectively.

RESULTS AND DISCUSSION

As the genotypic associations are inherent, the correlation and path analysis is discussed at genotypic level only (Table 1 and 2). Number of primary branches at 90 days after transplanting (DAT) was positively and significantly correlated with plant height at 60 DAT (Mohanty, 2003). Stem girth at 90 DAT was positively and significantly correlated with plant height at 60 DAT and number of primary branches at 90 DAT. This indicates that there was strong association between vegetative traits. Days to first flowering, days to fifty per cent flowering, days to first fruit set and days to first fruit maturity were significantly and negatively associated with plant height (at 60 DAT), number of primary branches (at 90 DAT) and stem girth (at 90 DAT) . These results elucidated the inverse relationship between earliness and growth parameters. Days to first flowering, days to fifty per cent flowering, days to first fruit set and days to first fruit maturity were significantly (at p=0.01) and positively associated among themselves with greater than 0.760 correlation coefficients indicated the presence of very strong association among the earliness parameters.

Per cent fruit set was positively and significantly correlated with plant height at 60 DAT, stem girth at 90 DAT, number of locules per fruit and number of seeds per fruit, but it had negative and significant association with number of flowers per cluster (Raijadhav *et al*., 1996) and equatorial diameter of the fruit . This indicates

Table 1 : Genotypic correlation coefficients among growth, earliness, quality and yield parameters in tomato

♦	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1.000	0.614**	0.463**	-0.181**	-0.284**	-0.288**	-0.252**	-0.237**	-0.487**	-0.107	-0.189**	0.145*	-0.186**	-0.197**	0.383**	0.305**	-0.100	0.655**	0.288**	0.246**
2		1.000	0.313**	-0.267**	-0.294**	-0.329**	-0.262**	-0.244**	-0.246**	-0.051	-0.368**	0.155*	-0.250**	-0.239**	0.259**	-0.025	-0.249**	0.555**	0.398**	0.342**
3			1.000	-0.224**	-0.240**	-0.249**	-0.338**	-0.116	-0.127	0.037	-0.096	0.150*	0.022	0.048	0.193**	0.300**	0.013	0.484**	0.444**	0.434**
4				1.000	0.993**	0.990**	1.054**	0.094	0.208**	0.021	0.136	0.002	0.102	0.117	0.045	0.246**	0.203**	-0.401**	-0.187**	-0.119
5					1.000	0.986**	1.044**	0.152*	0.256**	0.039	0.173*	-0.025	0.112	0.125	0.024	0.223**	0.243**	-0.417**	-0.169*	-0.102
6						1.000	1.057**	0.125	0.215**	0.014	0.129	0.027	0.114	0.137	0.067	0.310**	0.252**	-0.406**	-0.200**	-0.129
7							1.000	0.059	0.252**	0.055	0.192**	0.012	0.162*	0.200**	0.014	0.390**	0.223**	-0.423**	-0.210**	-0.126
8								1.000	-0.202**	-0.315**	-0.300**	-0.078	-0.235**	-0.206**	-0.112	-0.274**	0.922**	0.155*	-0.409**	-0.415**
9									1.000	0.578**	0.698**	0.018	0.616**	0.595**	-0.287**	-0.004	-0.219**	-0.540**	0.244**	0.287**
10										1.000	0.430**	0.311**	0.899**	0.866**	0.130	-0.159*	-0.409**	-0.416**	0.476**	0.496**
11											1.000	-0.036	0.427**	0.394**	-0.119	0.100	-0.290**	-0.410**	0.310**	0.349**
12												1.000	0.289**	0.290**	0.533**	0.242**	0.007	-0.007	0.144*	0.193**
13													1.000	1.002**	0.034	-0.074	-0.294**	-0.439**	0.372**	0.408**
14														1.000	0.054	-0.046	-0.257**	-0.425**	0.319**	0.354**
15															1.000	0.197**	-0.039	0.135	0.182**	0.208**
16																1.000	0.120	0.177*	0.082	0.149*
17																	1.000	0.253**	-0.372**	-0.355**
18																		1.000	0.213**	0.147*
19																			1.000	0.994**
20																				1.000

* and ** indicates significance values at P = 0.05 and P = 0.01, respectively

Critical 'rG' value at 5 per cent = 0.1382 Critical 'rG' value at 1 per cent = 0.1812

♦Characters: 1. Plant height at 60 DAT (cm), 2. Number of primary branches at 90 DAT, 3. Stem girth at 90 DAT (cm), 4. Number of flowers per cluster, 5. Polar diameter of the fruit (cm), 6. Equatorial diameter of the fruit (cm), 7. Pericarp thickness (cm), 8. Number of locules per fruit, 9. Fruit volume (cc). 10. Average fruit weight (g), 11. Number of seeds per fruit, 12. Per cent fruit set, 13. Number of fruits per cluster, 14. Number of fruits per plant, 15. Early yield per plant (kg)

DAT = Days after transplanting

Table 2 : Genotypic path coefficient analysis for total yield per plant in tomato

♦	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	rG
1.	-0.023	-0.005	-0.002	0.052	0.010	0.001	-0.003	0.005	0.037	-0.039	0.002	-0.006	-0.024	-0.056	0.298	0.246**
2.	-0.014	-0.009	-0.001	0.053	0.005	0.000	-0.007	0.005	0.050	-0.048	0.002	0.000	-0.060	-0.048	0.412	0.342**
3.	-0.011	-0.003	-0.004	0.025	0.003	0.000	-0.002	0.005	-0.004	0.010	0.001	-0.006	0.003	-0.042	0.459	0.434**
4.	0.005	0.002	0.001	-0.218	0.004	0.003	-0.005	-0.003	0.047	-0.041	-0.001	0.005	0.222	-0.013	-0.423	-0.415**
5.	0.011	0.002	0.001	0.044	-0.020	-0.005	0.013	0.001	-0.123	0.119	-0.002	0.000	-0.053	0.046	0.253	0.287**
6.	0.002	0.000	0.000	0.069	-0.012	-0.008	0.008	0.011	-0.179	0.173	0.001	0.003	-0.099	0.036	0.492	0.496**
7.	0.004	0.003	0.000	0.066	-0.014	-0.004	0.018	-0.001	-0.085	0.079	-0.001	-0.002	-0.070	0.035	0.320	0.349**
8.	-0.003	-0.001	-0.001	0.017	0.000	-0.003	-0.001	0.035	-0.058	0.058	0.003	-0.005	0.002	0.001	0.149	0.193**
9.	0.004	0.002	0.000	0.051	-0.012	-0.008	0.008	0.010	-0.200	0.200	0.000	0.001	-0.071	0.038	0.384	0.408**
10.	0.005	0.002	0.000	0.045	-0.012	-0.007	0.007	0.010	-0.200	0.199	0.000	0.001	-0.062	0.036	0.330	0.354**
11.	-0.009	-0.002	-0.001	0.024	0.006	-0.001	-0.002	0.019	-0.007	0.011	0.006	-0.004	-0.009	-0.012	0.188	0.208**
12.	-0.007	0.000	-0.001	0.060	0.000	0.001	0.002	0.008	0.015	-0.009	0.001	-0.019	0.029	-0.015	0.085	0.149*
13.	0.002	0.002	0.000	-0.201	0.004	0.003	-0.005	0.000	0.059	-0.051	0.000	-0.002	0.241	-0.022	-0.385	-0.355**
14.	-0.015	-0.005	-0.002	-0.034	0.011	0.003	-0.008	0.000	0.088	-0.085	0.001	-0.003	0.061	-0.086	0.220	0.147*
15.	-0.007	-0.003	-0.002	0.089	-0.005	-0.004	0.006	0.005	-0.074	0.064	0.001	-0.002	-0.090	-0.018	1.034	0.994**

Residual (R) = -0.0006. * and ** indicates significance of values at P=0.05 and P=0.01, respectively

rG = Genotypic correlation coefficients of total yield per plant. Diagonal values indicate direct effects.

♦ Characters: 1. Plant height at 60 DAT (cm), 2. Number of primary branches at 90 DAT, 3. Stem girth at 90 DAT (cm), 4. Number of flowers per cluster, 5. Polar diameter of the fruit (cm), 6. Equatorial diameter of the fruit (cm), 7. Pericarp thickness (cm), 8. Number of locules per fruit, 9. Fruit volume (cc), 10. Average fruit weight (g), 11. Number of seeds per fruit, 12. Per cent fruit set, 13. Number of fruits per cluster, 14. Number of fruits per plant, 15. Early yield per plant (kg)

DAT = Days after transplanting

the inverse relationship between per cent fruit set and number of flowers per cluster. Better growth results into more photosynthetic area and production of more photosynthates resulting into better fruit set. When there is more competition for photosynthates through increased number of flowers per cluster, fruit set has reduced. Number of fruits per cluster was positively and significantly associated with number of flowers per cluster. Similar results were reported by Sharma and Krishanswaroop (2000) in brinjal. Number of fruits per cluster was positively and significantly associated with per cent fruit set (Dhankar *et al*., 2001). These results indicated that, per cent fruit set has greatly contributed for increased number of fruits per cluster. Number of fruits per cluster had negative and significant association with equatorial diameter of the fruit (Srivastava and Sachan, 1973), fruit volume, pericarp thickness and average fruit weight (Fageria and Kohli, 1996), number of primary branches at 90 DAT and polar diameter of the fruit. This implies that increase in number of fruits per cluster consequently decreases polar and equatorial diameter of the fruit, average fruit weight and fruit volume and it is attributed to competition between sinks (fruits) for source (photosynthates). These negative associations need to be broken by *inter se* mating, since number of fruits per cluster is a strong contributor for total number of fruits, which is an ultimate yield-contributing trait.

Polar diameter of the fruit was negatively and significantly associated with plant height at 60 DAT (Krishnaprasad and Mathurarai, 1999), number of primary branches at 90 DAT (Mala and Vadivel, 1999) and number of flowers per cluster. Hence, plants with indeterminate growth habit had decreased polar diameter of the fruit. Equatorial diameter of the fruit was positively and significantly associated with polar diameter of the fruit (Singh *et al*., 1988). Therefore, for improvement of fruit size, both polar and equatorial diameter of the fruit should be considered simultaneously for selection. Pericarp thickness was positively and significantly associated with polar and equatorial diameter of the fruit. Pericarp thickness was negatively and significantly associated with number of primary branches at 90 DAT, number of flowers per cluster and plant height at 60 DAT (Fageria and Kohli, 1996), indicating inverse relationship between pericarp thickness and vegetative parameters. This is attributed to increased fruit number with indeterminate growth habit, as the fruit number is positively associated with growth parameters and negatively associated with pericarp thickness. Number of locules per fruit was positively and significantly associated with equatorial diameter of the fruit (Singh *et al*., 1974), number of primary branches (at 90 DAT), stem girth (at 90 DAT) and plant height (at 60 DAT). This is attributed to better growth resulting into better fruit size and more number of locules as revealed by correlation studies.

Number of seeds per fruit was positively and significantly associated with number of locules per fruit, plant height (at 60 DAT), number of primary branches (at 90 DAT) and stem girth (at 90 DAT). Number of seeds per fruit was negatively and significantly associated with polar diameter of the fruit at genotypic and phenotypic level. Better growth resulted into better fruit size and more number of locules and more seeds. High seed number is a desirable trait for getting higher seed yield, but for processing purpose, less number of seeds per fruit is preferred. Hence, selection can be exercised to reduce or increase the number of locules to alter number of seeds per fruit.

Average fruit weight was positively and significantly associated with fruit volume, polar and equatorial diameter of the fruit, number of locules per fruit (Krishnaprasad and Mathurarai, 1999), pericarp thickness (Dudi and Kalloo, 1982). Thus, average fruit weight is greatly contributed by these traits. Average fruit weight was inversely associated with number of primary branches at 90 DAT (Mala and Vadivel, 1999), number of flowers per cluster (Reddy and Gulshanlal, 1987) and plant height at 60 DAT (Fageria and Kohli, 1996). This is attributed to its (average fruit weight) inverse relation with number of fruits, where more competition for photosynthates resulted into reduced fruit size. Correlation studies also revealed that, average fruit weight is inversely associated with earliness parameters. Number of fruits per plant was positively and significantly associated with plant height at 60 DAT, (Raijadhav *et al*., 1996), number of primary branches at 90 DAT (Mala and Vadivel, 1999), stem girth at 90 DAT, number of fruits per cluster (Narendrakumar and Arya, 1995) per cent fruit set and number of flowers per cluster (Reddy and Gulshanlal, 1987). Number of fruits per plant was negatively and significantly associated with polar diameter of the fruit (Singh *et al*., 1974), fruit volume, average fruit weight (Mohanty, 2003), equatorial diameter of the fruit (Singh *et al*., 1974), pericarp thickness (Dudi and Kalloo, 1982), days to first fruit maturity, days to 50 per cent flowering, days to first fruit set and days to first flowering, indicates the inverse relationship. Correlation studies indicated that increased fruit number is the result of better growth, early flowering, good fruit set and higher number of flowers and fruits per cluster. Increased fruit number has resulted into reduced fruit size in terms of polar and equatorial diameter, weight of fruits and fruit volume. These negative associations need to be broken by *inter se* mating and selection, since number of fruits as well as fruit size greatly contributed for total yield.

Early yield per plant was positively and significantly associated with stem girth (at 90 DAT), number of primary branches (at 90 DAT) and plant height (at 60 DAT), equatorial diameter of the fruit, fruit volume, average fruit weight, pericarp thickness, polar diameter of the fruit and number of fruits per plant (Dudi and Kalloo, 1982). Thus, number of fruits, fruit size and growth traits have greatly contributed for early yield. Early yield per plant was negatively and significantly associated with days to first fruit maturity, days to first fruit set, days to first flowering, days to 50 per cent flowering at genotypic level and it (early yield) was negatively and significantly associated with number of flowers per cluster and number of fruits per cluster. The strong association between earliness traits is thus evident. For getting higher early and total yield negative selection needs to exercise on number of flowers and fruits per cluster. Total yield per plant was positively and significantly associated with early yield per plant (Dudi and Kalloo, 1982), equatorial diameter of the fruit (Mala and Vadivel, 1999), fruit volume, average fruit weight, polar diameter of the fruit, number of fruits per plant, per cent fruit set, stem girth (at 90 DAT), number of locules per fruit (Raijadhav *et al*., 1996), plant height (at 60 DAT), pericarp thickness and number of seeds per fruit. Total yield per plant was negatively and significantly associated with number of flowers per cluster and number of fruits per cluster (Fageria and Kohli, 1996). Correlation studies revealed that yield can be improved by selecting genotypes for better growth, high fruit set, big fruit size, thick pericarp, more number of fruits per plant and less number of flowers and fruits per cluster.

Average fruit weight was positively and significantly correlated (rG=0.354) with total yield and it had positive and high direct effects (0.199) on total yield (Mohanty, 2003), but it had high indirect and positive effects through early yield per plant (0.330) and negative effects through fruit volume (-0.200) on total yield. Therefore, for improvement of yield, average fruit weight needs to be considered along with early yield and fruit volume. Fruit volume was positively and significantly correlated (rG=0.408) with total yield and it had negative and high direct effects (-0.200) on total yield, but it had high indirect and positive effects through early yield per plant (0.384) and average fruit weight (0.200) on total yield. Under these circumstances, the indirect causal factors like early yield and fruit weight also need to be given due consideration along with fruit volume simultaneously for selection.

Number of flowers per cluster was negatively and significantly correlated (rG=-0.415) with total yield and it had negative and high direct effects (-0.218) on total yield, but it had high indirect and negative effects through early yield per plant (-0.423) and high indirect and positive effects through number of fruits per cluster (0.222) on total yield. Similar results were reported by Sharma and Krishanswaroop (2000) in brinjal. Under these circumstances, the indirect causal factors also need to be considered simultaneously for selection. Number of fruits per cluster was negatively and significantly correlated (rG=-0.355) with total yield and it had positive and high direct effects (0.241) on total yield (Dhankar *et al*., 2001) and it had high indirect and negative effects through early yield per plant (-0.385) and number of flowers per cluster (-0.201) on total yield. Under these circumstances, a restricted simultaneous selection model (Singh and Kolkar, 1977) can be followed, *i.e.*, restrictions are to be imposed to nullify the undesirable indirect effects through early yield per plant and number of flowers per cluster in order to make use of direct effects of number of fruits per cluster on total yield.

The correlation coefficient between total yield and early yield (rG=0.994) is almost equal to the direct effects (1.034) of early yield per plant on total yield (Dudi and Kalloo, 1982), Hence, direct selection for early yield per plant will be more reliable for yield (total) improvement. Polar (rG=0.287) and equatorial (rG=0.496) diameter of the fruit were positively and significantly correlated with total yield, and these characters had no direct effects on total yield, but both of these traits had high indirect and positive effects through early yield per plant and average fruit weight. Similar results were reported in brinjal by Ingale and Patil (1995). Therefore, the indirect causal factors also need to be considered for simultaneous selection.

Plant height at 60 DAT, number of primary branches at 90 DAT, stem girth at 90 DAT, pericarp thickness, number of locules per fruit, number of seeds per fruit and number of fruits per plant were positively and significantly correlated with total yield and these traits had no direct effects on total yield. These characters had high indirect and positive effects through early yield per plant on total yield. Similar results were reported by Dudi and Kalloo (1982). Hence, the indirect causal factors also need to be considered for selection.

Authors' affiliations:

R.P. JAIPRAKASHNARAYAN, RAVINDRA MULGE AND M.B. MADALAGERI, Department of Olericulture, K.R.C. College of Horticulture, U.A.S.(D), Arabhavi, BELGAUM (KARNATAKA) INDIA

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