

Association, Direct and Indirect Effect of Productivity and Quality Traits in Tomato (*Solanum lycopersicum* L.)

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Abstract Twenty tomato advanced lines, with a check variety (Megha), were evaluated during *khariif*, 2014 to study the association and path analysis based on different growth, yield and quality traits. The analysis of variance indicated significantly higher amount of differences among the genotypes for all the 17 characters studied. Fruit yield had positive and highly significant association with number of fruits per plant, stem thickness, plant height and number of primary branches per plant. Strong association of these traits revealed that the selection based on these traits would ultimately improve the fruit yield. Path coefficient analysis revealed that number of fruits per cluster, number of fruits per plant, average fruit weight and

stem thickness had highest positive direct effect on fruit yield both at genotypic and phenotypic levels. Hence, it would be rewarding to lay stress on these characters in selection program for increasing the yield.

Keywords Association, Correlation, Path analysis, Advanced lines, Tomato.

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important, popular and extensively used vegetable as fresh fruit [1] which belongs to the family solanaceae. It is widely grown all over the world (mainly tropics and subtropics). Tomato is an important commercial and dietary crop. Due to its short duration and high yield, its area is increasing day by day. Yield is the resultant and combined effect of several component characters as well as environment. Understanding the interaction of characters among themselves and with environment has been of great use in plant breeding. Correlation studies provide information on the nature and extent of association between two pairs of metric characters. From this it would be possible to bring about genetic up gradation in one character by selection of the other. Obviously, knowledge about character associations will surely help to identify the characters to make selection for higher yield with a view to determine the extent and nature of relationship prevailing among

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Table 1. Continued.

	AFW	SI	DM	PT	FRM	TSS	SHLF	FYPP
PH	-0.2357	-0.1358	-0.3664*	0.3793*	0.1873	0.374*	0.1726	0.9421**
PB	-0.123	-0.1654	-0.2346	0.1216	0.3878*	0.0994	0.1141	0.9169**
ST	-0.2757	-0.3462*	-0.3163*	0.2861	0.2976	0.2078	0.0359	0.8217**
DFFL	0.1648	-0.2914	0.328*	-0.3632*	-0.0606	-0.1719	-0.1738	-0.6955**
D50FL	0.3045*	0.1821	0.1982	0.0106	0.1741	-0.2924	0.1079	-0.4677**
FPCL	-0.4072**	0.2064	0.1022	-0.1487	-0.3527*	-0.3904*	-0.051	0.252
FTPCL	-0.4367**	0.1779	-0.008	-0.094	-0.2196	-0.3626*	0.055	0.4135**
PFST	-0.2704	0.2288	-0.1737	0.0372	-0.0034	-0.1577	0.285	0.5305**
NOFT	-0.7092**	-0.34*	-0.0849	0.0976	-0.0174	0.0769	0.0012	0.8452**
AFW	1.000	0.4631**	0.0077	0.1747	0.5112**	-0.0924	0.3243*	-0.1057
SI		1.000	0.1562	0.4063**	0.2739	-0.2814	0.3544**	-0.2896
DM			1.000	0.1388	0.0196	-0.5132**	0.4699**	0.3327*
PT				1.000	0.6528**	0.0378	0.5546**	0.2014
FRM					1.000	-0.0363	0.4955**	0.4333**
TSS						1.000	-0.2801	0.0244
SHLF							1.000	0.2772
FYPP								1.000

*Significant at 5% probability level

PH - Plant height (cm),
 PB - Number of primary branches
 per plant
 ST - Stem girth (cm)
 DFFL - Days to first flowering
 D50FL - Days to 59% flowering

**Significant at 1% probability level

FPCL - Number of flowers per cluster
 FTPCL - Number of fruits per cluster
 PEST - Per cent fruit set
 NOFT - Number of fruits per plant
 AFW - Average fruit weight (g)
 SI - Shape index

Correlation r value=0.3043 (5%) and
0.3931 (1%),

DM - Dry matter content (%)
 PT - Pericarp thickness (mm)
 FRM - Fruit firmness (kg/cm²)
 TSS - Total Soluble Solids (°Brix)
 SHLF - Shelf life of fruits (days)
 FYPP - Fruit yield per plant

Results and Discussion

Character association

Fruit yield per plant Vs yield components

A highly significant and positive association of fruit yield per plant was observed with plant height (0.9421 and 0.5863), number of primary branches per plant (0.9169 and 0.5210), number of fruits (0.8452 and 0.7310), stem thickness (0.8217 and 0.6458) and per cent fruit set (0.5305 and 0.4736) at both the genotypic and phenotypic levels, respectively (Tables 1 and 2). Similar results also found by Mohanty [6]. Significant negative association with fruit yield per plant was found with days to first flowering (-0.6955 and -0.4375) and days to 50% flowering (-0.4677 and -0.2500) at both the levels. The results of Singh [7] support the findings, but the average fruit weight (-0.3670) and number of fruits per plant (-0.2737) had

significant negative association with fruit yield per plant only at phenotypic level.

Correlation among yield components

Plant height had highly significant and positive correlation with number of primary branches per plant (0.9671 and 0.5852) and number of fruits per plant (0.9366 and 0.6895) (The earlier findings [8] are in line with the present findings), similarly the number of primary branches with stem thickness (0.9884 and 0.5613) and number of fruits per plant (0.6591 and 0.4802). The results of earlier findings [7, 9] are in agreement with the obtained results, Stem thickness with number of fruits per plant (0.8187 and 0.6662), Days to first flowering with days to 50% flowering (0.8072 and 0.4174), days to 50% flowering with average fruit weight (0.3045 and 0.3324), number of flowers per cluster with number of fruits per cluster (0.9034 and 0.7367), number of fruits per cluster with number

Table 2. Continued.

	AFW	SI	DM	PT	FRM	TSS	SHLF	FYPP
PH	-0.2477	-0.0879	-0.2483	0.2650	0.1321	-0.2414	0.1025	0.5863**
PB	-0.0950	-0.0976	-0.2846	0.1131	0.1919	0.0514	0.1003	0.5210**
ST	-0.2680	-0.2404	-0.2072	0.2620	0.2195	0.1735	0.0486	0.6458**
DFFL	0.2203	-0.2005	0.1856	-0.2386	-0.0264	-0.9730	-0.1152	-0.4375*
D50FL	0.3324*	0.1588	0.1694	-0.0114	0.0967	-0.2311	0.0970	-0.2500*
FPCL	-0.2744	0.1296	0.1362	-0.1109	-0.2745	-0.2982	-0.0513	0.0966
FTPCL	-0.3100*	0.1599	-0.0219	-0.0948	-0.2367	-0.3119*	-0.0541	0.3727*
PFST	-0.2528	0.1962	-0.1220	0.0574	0.0920	-0.5670	0.1942	0.4736**
NOFT	-0.6325**	-0.3095*	-0.0805	0.0771	0.0087	0.0585	0.0039	0.7310**
AFW	1.000	0.4184**	0.0212	0.1298	0.3511*	-0.0814	0.2830	-0.2737**
SI		1.000	0.1304	0.3834*	0.2333	-0.2472	0.3294*	-0.3670**
DM			1.000	0.1232	0.0340	-0.4888**	0.4468**	0.3802*
PT				1.000	5623**	0.0421	0.5391**	0.2009
FRM					1.000	-0.0206	0.4420**	0.1841
TSS						1.000	-0.2763	0.0477
SHLF							1.000	0.2536
FYPP								1.000

*Significant at 5% probability level
 PH - Plant height (cm)
 PB - Number of primary branches per plant
 ST - Stem girth (cm)
 DFFL - Days to first flowering
 D50FL - Days to 59% flowering

**Significant at 1% probability level
 FPCL - Number of flowers per cluster
 FTPCL - Number of fruits per cluster
 PEST - Per cent fruit set
 NOFT - Number of fruits per plant
 AFW - Average fruit weight (g)
 SI - Shape index

Correlation r value=0.3043 (5%) and 0.3931 (1%)
 DM - Dry matter content (%)
 PT - Pericarp thickness (mm)
 FRM - Fruit firmness (kg/cm²)
 TSS - Total Soluble Solids (°Brix)
 SHLF - Shelf life of fruits (days)
 FYPP - Fruit yield per plant

tion at genotypic level and negative direct effect at phenotypic level. On the contrary, the direct effect were negative at genotypic level and positive at phenotypic level for number of fruits per cluster (-1.070 and 0.1106), number of primary branches (-0.7321 and 0.0037), dry matter content (-.3583 and 0.0813), fruit firmness (-0.3118 and 0.2803) and per cent fruit set (-0.3057 and 0.1076), respectively.

Indirect effects

The indirect and positive effect of different traits on fruit yield per plant was exhibited by plant height via TSS (0.0065 and 0.0508) and number of fruits per cluster (0.0065 and 0.0449), number of primary branches per plant influenced via plant height (0.7081 and 0.0022) and days to 50% flowering (0.627 and 0.0019), stem thickness via plant height (0.896 and 0.224) and number of primary branches (0.8347 and 0.1679), days to first flowering influenced through plant height

(0.4686 and 0.0778) and number of fruits per cluster (0.1603 and 0.0344), days to 50% flowering via days to first flowering (0.4634 and 0.0300) and plant height (0.3861 and 0.0363), number of flowers per cluster via number of fruits per cluster (0.4866 and 0.1150) and number of fruit per plant (0.1666 and 0.0346).

Number of fruits per cluster had positive indirect effect through number of primary branches (0.2919 and 0.0234) and number of flower per cluster (0.9667 and 0.0815), per cent first fruit set had through number of flowers per cluster (0.0055 and 0.0172) and number of fruits per cluster (0.241 and 0.0533). However average fruit weight (-0.0827 and -0.0272) had negative indirect effect on fruit yield per plant. Number of fruits per plant showed positive indirect effect through number of flowers per cluster (0.9936 and 0.1711), plant height (0.3378 and 0.5328) and stem thickness (0.2629 and 0.5138) Joshi et al. [11] and Singh [7] were also of same opinion, average fruit weight had positive effect through fruit firmness (0.7401 and

Table 3. Direct (diagonal) and indirect effects of yield components on fruit yield of different advanced tomato lines at genotypic level.

	PH	PB	ST	DFFL	D50FL	FPCL	FTPCL	PEST	NOFT
PH	0.0175	0.0169	0.0186	-0.0206	-0.0118	0.0011	0.0065	0.0128	0.0164
PB	0.7081	-0.7321	-0.7236	0.6270	0.1134	0.0037	-0.1997	-0.4300	0.4826
ST	0.8960	0.8347	0.8445	-0.6487	-0.4285	-0.2938	0.0740	0.4115	0.6914
DFFL	0.4686	-0.3403	-0.3052	0.3973	-0.3207	-0.0515	0.1603	-0.2653	-0.2640
D50FL	0.3861	-0.0889	-0.2931	0.4634	0.5741	0.0343	-0.0255	-0.0004	-0.2925
FPCL	0.0348	-0.0027	-0.1874	-0.0698	0.0322	0.5386	0.4866	-0.0097	0.1666
FTPCL	-0.3956	0.2919	-0.0937	-0.4317	-0.0476	0.9667	-1.0700	-0.8436	-0.6156
PFST	-0.2245	-0.1795	-0.1489	0.2041	0.0002	0.0055	0.2410	-0.3057	0.1874
NOFT	0.3378	0.2116	0.2629	-0.2133	-0.1635	0.9936	0.1847	0.1968	0.3211
AFW	-0.3413	-0.1781	-0.3991	0.2386	0.4408	-0.5896	0.6322	-0.3915	-1.0267
SI	0.1336	-0.1627	-0.3404	-0.2865	-0.1790	-0.2030	0.1749	0.2250	-0.3343
DM	0.1313	0.0841	0.1133	-0.1175	-0.0710	-0.0366	0.0029	0.0622	0.0304
PT	-0.3052	-0.0978	-0.2302	0.2922	-0.0086	-0.1196	0.0757	-0.0299	-0.0785
FRM	-0.0584	-0.1209	-0.0928	0.0189	-0.543	0.1100	0.0685	0.0011	0.0054
TSS	0.0211	0.0056	0.0117	-0.0097	-0.0165	0.0220	-0.0205	-0.0089	0.0043
SHLF	-0.0813	0.0538	-0.0169	-0.0818	-0.0508	-0.0240	0.0259	-0.1342	-0.0006

Table 3. Continued.

	AFW	SI	DM	PT	FRM	TSS	SHLF	FYPP
PH	-0.0041	0.0024	-0.0064	0.0066	0.0033	0.0065	0.0030	0.9421**
PB	0.0901	0.1211	0.1718	-0.0890	-0.2839	-0.0728	-0.0836	0.91069**
ST	-0.2328	-0.2924	-0.2671	0.2416	0.2513	0.1755	0.0303	0.8217**
DFFL	0.0655	-0.1158	0.1303	-0.1443	-0.0241	-0.0683	-0.0690	-0.6955**
D50FL	0.1748	0.1045	0.1138	0.0061	0.1000	-0.1679	0.0619	-0.4677**
FPCL	-0.2193	0.112	0.0550	-0.0801	-0.1900	-0.2104	-0.0274	0.0252
FTPCL	0.4672	-0.1904	0.0086	0.1006	0.2350	0.3880	-0.0589	0.4135**
PFST	-0.0827	-0.0699	0.0531	-0.0114	0.0010	0.0482	-0.0871	0.5305**
NOFT	-0.2277	-0.1092	-0.2728	0.3134	-0.0560	0.2468	0.0039	0.8452**
AFW	1.4477	0.6705	0.0111	0.2529	0.7401	-0.1338	0.4695	-0.1057
SI	0.4554	0.9833	0.1536	0.3995	0.2693	-0.2767	0.3485	-0.2896
DM	-0.0027	-0.0560	-0.3583	-0.0497	-0.0070	0.1839	-0.1683	-0.3327**
PT	-0.1406	-0.3270	-0.117	-0.8047	-0.5254	0.0304	-0.4463	0.2014
FRM	-0.1594	-0.0854	-0.0061	0.2035	-0.3118	0.0113	0.1545	0.4333**
TSS	-0.0052	-0.0159	-0.0289	0.0021	-0.0020	0.0564	-0.0158	0.0244
SHLF	0.1528	0.1669	-0.2213	0.2612	0.2334	-0.1319	0.4710	0.2772

Residual effect- 0.2627

*Significant at 5% probability level

**Significant at 1% probability level

Correlation r value = 0.3043 (5%) and 0.3931 (1%)

PH - Plant height (cm)

PB-Number of primary branches per plant

ST - Stem girth (cm)

DFFL - Days to first flowering

D50FL - Days to 50% flowering

FPCL - Number of flowers per cluster

FTPCL - Number of fruits per cluster

PEST - Per cent fruit set

NOFT - Number of fruits per plant

AFW - Average fruit weight (g)

SI - Shape index

DM - Dry matter content (%)

PT - Pericarp thickness (mm)

FRM - Fruit firmness (kg/cm²)

TSS - Total Soluble Solids (°Brix)

SHLF - Shelf life of fruits (days)

FYPP - Fruit yield per plant

0.1949) and shape index (0.6705 and 0.2323) Prashanth [12] is also of same opinion. Fruit shape index had positive and indirect influence on fruit yield per plant through plant height (0.1336 and 0.0079) at both lev-

els. Dry matter showed positive influence at genotypic level through plant height (0.1313) and number of primary branches (0.0841), pericarp thickness influenced through days to first flowering (0.2922 and

Table 4. Direct (diagonal) and indirect effects of yield components on fruit yield of different advanced tomato lines at phenotypic level.

	PH	PB	ST	DFFL	D50FL	FPCL	FTPCL	PEST	NOFT
PH	-0.2103	-0.1231	-0.1564	0.1094	0.1063	0.0217	0.0449	-0.0526	-0.1450
PB	0.0022	0.0037	0.0021	0.0019	-0.0008	0.0004	0.0008	0.0008	0.0018
ST	0.2224	0.1679	0.2991	-0.1323	-0.1161	-0.0875	0.0055	0.0762	0.1993
DFFL	0.0778	0.0752	0.0661	-0.1495	-0.0624	0.0016	0.0344	0.0437	0.0649
D50FL	0.0363	0.0151	0.0279	0.0300	-0.0718	-0.0036	-0.0067	0.0065	-0.0277
FPCL	-0.0161	-0.0179	-0.0457	-0.0017	0.0078	0.1561	0.1150	0.0250	0.0346
FTPCL	0.0236	0.0234	0.0020	-0.0255	0.0102	0.0815	0.1106	0.0548	0.0558
PFST	-0.0269	0.0221	0.0274	-0.0315	-0.0098	0.0172	0.0533	0.1076	0.0501
NOFT	0.5328	0.3703	0.5138	-0.3349	-0.2977	0.1711	0.3889	0.3591	0.7712
AFW	-0.1325	-0.0527	-0.1488	0.1223	-0.1845	-0.1523	0.1721	-0.1403	-0.3512
SI	0.0079	0.0087	0.0215	0.0179	-0.0142	-0.0116	-0.0143	-0.0176	0.0277
DM	-0.0202	-0.0231	-0.0168	0.0151	0.0138	0.0111	-0.0018	-0.0099	-0.0065
PT	-0.0365	-0.0156	-0.0361	0.0329	0.0016	-0.0153	0.0131	-0.0079	-0.0106
FRM	0.0370	0.0538	0.0615	-0.0074	0.0271	-0.0769	-0.0663	0.0258	0.0024
TSS	0.0354	0.0075	0.0255	-0.0143	-0.0339	0.0438	-0.0458	-0.0083	0.0086
SHLF	0.0057	-0.005	0.0027	0.006	0.0054	-0.002	-0.0030	0.0107	0.0002

Table 4. Continued.

	AFW	SI	DM	PT	FRM	TSS	SHLF	FYPP
PH	0.0521	0.0185	0.0522	-0.0557	-0.0278	0.0508	-0.0216	0.5863**
PB	-0.0004	-0.004	-0.0011	0.0004	0.0007	0.0002	0.0004	0.5210**
ST	-0.0802	-0.0719	-0.0619	0.0784	0.0657	0.0519	0.0145	0.6458**
DFFL	-0.0329	0.0300	-0.0277	0.0357	0.0039	0.0145	0.0172	-0.4375**
D50FL	-0.0239	-0.0114	-0.0122	0.0008	-0.0069	0.0166	-0.0070	-0.2500
FPCL	-0.0428	0.0202	0.0213	-0.0173	-0.0428	-0.0465	-0.0080	0.0966
FTPCL	-0.0343	0.0177	-0.0024	-0.0105	-0.0262	-0.0345	0.0060	0.3727*
PFST	-0.0272	0.0211	-0.0131	0.0062	0.0099	-0.0061	0.0209	0.4736**
NOFT	-0.4878	-0.2387	-0.0620	0.0595	0.0067	0.0451	0.0030	0.7310**
AFW	0.5552	0.2323	0.0118	0.0721	0.1949	-0.0452	0.1571	-0.2737
SI	-0.0374	-0.0895	-0.0117	-0.0343	-0.0209	0.0221	-0.0295	-0.3670*
DM	0.0017	0.0106	0.0813	0.0100	0.0028	-0.0397	0.0363	-0.3802*
PT	-0.0179	-0.0528	-0.0170	-0.1378	-0.0775	0.0058	-0.0743	0.2009
FRM	0.0984	0.0654	0.0095	0.1576	0.2803	-0.0058	0.1239	0.1841
TSS	-0.0120	-0.0363	-0.0718	0.0062	-0.0030	0.1468	-0.0406	0.0477
SHLF	0.0156	0.0182	0.0247	0.0298	0.0244	-0.015	0.0552	0.2536

Residual effect- 0.3382

PH - Plant height (cm)

PB-Number of primary branches per plant

ST - Stem girth (cm)

DFFL - Days to first flowering

D50FL - Days to 59% flowering

FPCL - Number of flowers per cluster

FTPCL - Number of fruits per cluster

PEST - Per cent fruit set

NOFT - Number of fruits per plant

AFW - Average fruit weight (g)

SI - Shape index

DM - Dry matter content (%)

PT - Pericarp thickness (mm)

FRM - Fruit firmness (kg/cm²)

TSS - Total Soluble Solids (°Brix)

SHLF - Shelf life of fruits (days)

FYPP - Fruit yield per plant

0.0329) and number of fruits per cluster (0.0757 and 0.0131). It influenced the fruit yield per plant in negative direction through fruit firmness (-0.5254 and -0.0775), fruit shelf life (-0.4463 and -0.0743) and shape index (-0.3270 and -0.0528) at both levels. Fruit firm-

ness had positive effect at both the levels for pericarp thickness (0.2035 and 0.1576) and fruit shelf life (0.1545 and 0.1239). Total soluble solids content had positive indirect influence on fruit yield per plant via number of flower per cluster (0.0220 and 0.0438) and

fruit shelf life had positive effect at both the levels for pericarp thickness (0.2612 and 0.0298) and fruit firmness (0.2334 and 0.0244) whereas, negative indirect effect on fruit yield per plant was noticed through number of flowers per cluster (-0.0240 and -0.0020) and total soluble solids (-0.1319 and -0.015).

Finally the investigation revealed that fruit yield had positive and highly significant association with number of fruits per plant, stem thickness, plant height and number of primary branches per plant. Strong association of these traits revealed that the selection based on these traits would ultimately improve the fruit yield. Path coefficient analysis revealed that number of fruits per cluster, number of fruits per plant, average fruit weight and stem thickness had highest positive direct effect on fruit yield both at genotypic and phenotypic levels. Hence, it would be rewarding to lay stress on these characters in selection program for increasing the yield.

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