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Studies on correlation and path coefficient analysis for yield and quality traits in tomato

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Abstract
A study was conducted at Vegetable Research Farm, DRPCAU, Pusa, Samastipur, Bihar during *rabi* 2015-16 to evaluate the genotypes of tomato (*Solanum lycopersicum* L.) for yield and quality. Investigation was carried out on variability for different morpho-physiological characters of 24 genotypes which were grown in Randomized Block Design with three replications. In the present investigation, character association among the yield and yield attributing traits and identify better combinations as selection criteria for developing high yielding tomato genotypes. Fruit yield per plant was positively correlated with number of primary branches per plant, equatorial diameter, polar diameter, number of fruits per plant, average fruit weight, total soluble solid, days to first flowering and titrable acidity suggesting that selection based on these characters would result better genotypes with higher yield. Among them number of primary branches per plant, equatorial diameter, polar diameter, number of fruits per plant were highly significantly correlated with yield per plant and average fruit weight and total soluble solid significantly correlated with yield per plant. Path coefficient analysis study revealed positive direct effect for plant height at maturity, number of primary branches per plant, days to first flowering, days to fruit maturity at physiological stage, polar diameter, number of locules per fruit, number of fruits per plant, average fruit weight, total soluble solid, titrable acidity and ascorbic acid on fruit yield per plant and selection based on these 18 characters would be more reliable for yield improvement.

Keywords: Correlation coefficient and Path analysis

Introduction
Tomato (*Solanum lycopersicum* L.) is an important crop of solanaceous family which have chromosome number 2n = 2X = 24. It originated in wild form in the Peru- Ecuador – Bolvia region of Andes (South America) and is grown in almost every corner of the world (Roberston and Labate, 2007) [18]. It is typical day neutral plant and is mainly self-pollinated, but a certain percentage of cross-pollination also occurs (Depra *et al*., 2014) [2]. Tomato is universally known as "Protective Food" (Thamburaj and Singh, 2013) [23]. India is a source of diversity genotypes of tomato. Identification of superior genotypes among the existing germplasm becomes extremely important for future breeding programme and also for promoting production per unit area. The development of an effective improvement programme depends upon the existence of genetic variability and knowledge of genotypic and phenotypic correlation of yield and yield attributing components. Genetic variability is the measure of the tendency of individual genotypes in a population to vary from each other. Variability depends on genetic factors, environmental factors, (edaphic & climatic factor), bioactive compounds (caused by physiological factors) *etc*. Galton (1889) [5] observed that a part of the continuous variation is due to heritability. The degree to which the variability of a quantitative character is transmitted to the progeny is referred as heritability. It provides useful biometrical concept and has been considered to be an index of effectiveness of selection because it helps in proportioning the total variation into heritable and environmental effects.

The correlation coefficient measures the mutual relationship between two or more variables and gives an idea about the various associations existing between the yield and yield components. Correlation coefficient between a pair of characters is either positive or negative and it may be high or low. Estimation of correlation coefficient among the yield and quality contributing variables is necessary to understand the direction of selection and to maximize yield in the shortest period of time. Genetic correlation indicates the relative importance of character (s) on which greater emphasis should be given towards selection for yield and quality improvement.

The study of path co-efficient elucidates the intrinsic nature of observed association between yield and its attributes. 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) [14].

Materials and Methods

The present investigation was carried out at Vegetable Research Farm, DRPCAU, Pusa, Samastipur, Bihar during *rabi* 2015-16. The experimental materials comprised of twenty-four genotypes of tomato collected from two different sources. The experiment was laid out in a randomized block design with three replications accommodating 10 plant in each. Seeds were transplanted at a spacing of 60 × 45 cm. The genotypes studied are sweet 72, PT-2009-08, EC-519823, EC-519778, CN-2237 A, Arka Alok, Cherry Tomato, PT-41, CLN-2123E, Utkal Pallavi, Arka Abha, EC-519770, EC-519758, CLN-1154R, CLN-2870A, Big Oval 2009, S-108, Sherozi, Nandhi, CO-3, Azad T-5, Avinash-221, Arka Meghali and Masina. All the recommended cultural practices were adopted for raising the crop successfully. The experimental details and observations to be recorded as follows: The observations were recorded on five randomly selected plants per replication for each genotype on eighteen characters: i) plant height at maturity (cm), ii) number of primary branches per plant, iii) number of days to first flowering, iv) number of days to fruit setting, v) number of days to fruit maturity at physiological stage, vi) equatorial diameter (cm), vii) polar diameter (cm), viii) number of locules per fruit, ix) number of fruits per plant, x) average fruit weight (g), xi) yield per plant (kg), xii) yield per hectare (q/ha) xiii) total soluble solids (^{0}Brix), xiv) titrable acidity (%), xv) zinc content (mg/100g), xvi) iron content (mg/100g), xvii) lycopene content (mg/100g) and xviii) ascorbic acid content (mg/100g). Mean across the replications were calculated for each traits and the analysis of variation was carried out. Phenotypic and genotypic correlation coefficients were calculated from the variance and covariance component as suggested by Aljibouri *et al.* (1958) [1] as well as Panse and Sukhatme (1967) [16]. The correlation coefficients of yield with various quantitative characters were partitioned into direct and indirect effect with the help of path coefficient analysis as suggested by Dewy and Lu (1959) [3].

Result and Discussion

In order to find out the degree and direction of relationship of the yield contributing characters with yield and inter relationship between themselves, correlation (phenotypic and genotypic) coefficient analysis was carried out for all traits under investigation. Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield. Correlation analysis showed phenotypic and genotypic correlation for most of the character pairs were in same direction and genotypic estimates were higher than the phenotypic one, indicating inherent association between the characters. The test of significance was carried out for phenotypic correlation but the appropriate test of significance for genotypic correlation is not available. The correlation coefficient analysis were presented in table 1 and 2, respectively.

Phenotypic Correlation Analysis

The phenotypic correlation coefficients among the sixteen characters studied in twenty four genotypes in tomato have been presented in Table 1. The data revealed that fruit yield per plant expressed highly significant and positive correlation with number of primary branches per plant (0.9148), equatorial diameter (0.8320), polar diameter (0.7949) and number of fruits per plant (0.3363) whereas average fruit weight (0.2566) and total soluble solids (0.2445) showed significant and positive correlation, as well as plant height at maturity (-0.4391) showed highly significantly and negatively correlated with yield per plant.

Plant height at maturity has significant and positive correlation with days to first fruit setting (0.2696) and number of fruits per plant (0.2566). Plant height at maturity showed negative and highly significant correlation with average fruit weight (-0.5340), number of primary branches per plant (-0.4813), fruit length (-0.4093) and fruit diameter (-0.3729), whereas negative and significant correlation with total soluble solids (-0.2353). Number of primary branches per plant showed highly significant and positive correlation with fruit diameter (0.9089), polar diameter (0.8024) and number of fruits per plant (0.3616), whereas significant positive correlation with ascorbic acid (0.2592). Days to first flowering exhibited highly significant and positive correlation with days to fruit initiation (0.6335) and days to fruit maturity at physiological stage (0.5376). Days to fruit initiation showed highly significant and positive correlation with days to fruit maturity at physiological stage (0.4338), but negative significant correlation with number of locules per fruit (-0.2651) and lycopene content (-0.2508). Days to fruit maturity at physiological stage exhibited highly significant and positive correlation with average fruit weight (0.4102), whereas significant negative correlation with lycopene content (-0.2558) and number of fruits per plant (-0.2493). Equatorial diameter showed highly significant and positive correlation with polar diameter (0.8098) and number of fruit per plant (0.3496). Polar diameter exhibited highly significant positive correlation with total soluble solid (0.3616) and significant positive correlation with number of fruits per plant (0.2993). Number of locules per fruit showed highly significant positive correlation with lycopene content (0.4183), while highly significant negative correlation with ascorbic acid (-0.3100). Number of fruits per plant showed highly significant negative correlation with average fruit weight (-0.6095) and significant negative correlation with total soluble solid (-0.2384). Average fruit weight exhibited positive and highly significant correlation with total soluble solids (0.3220) and significant positive correlation with titrable acidity (0.2520). Total soluble solids showed highly significant positive correlation with zinc content (0.3126). Titrable acidity exhibited highly significant negative correlation with ascorbic acid (-0.4091) at one per cent level of significance. Fruit yield per plant had positive and highly significant correlation with number of primary branches per plant, equatorial diameter and polar diameter nevertheless positive significant correlation with number of fruits per plant, average fruit weight, and total soluble solids. Similar findings in tomato were also reported by Haydar *et al.*, (2007) [7], Singh *et al.* (2002) [31], Tiwari (2002), Singh *et al.* (2006) [22], Prashanth *et al.* (2008) [17], Meitei *et al.* (2014) [12] and Nwosu *et al.* (2014) [15]. Plant height was found negative and highly significant correlation with fruit yield per plant which was consonance with the findings of Dudi and Kalloo (1982) [4] in tomato.

Path Coefficient Analysis

Path coefficient analyses among the sixteen characters studied in twenty four genotypes in tomato have been presented in Table 2. Path analysis reveals whether the association of these characters with yield is due to their direct effect on yield or is a consequence of their indirect effects via other component characters. In other words, it measures the cause of association between two traits. Path analysis was carried out at phenotypic and genotypic level considering fruit yield per plant and fruit yield per hectare as dependent characters and its attributes as independent characters *viz*. plant height at maturity, number of primary branches per plant, days to first flowering, days to first fruit setting, days to fruit maturity at physiological stage, equatorial diameter, polar diameter, number of locules per fruit, number of fruits per plant, average fruit weight, total soluble solids, titrable acidity, zinc content, iron content, lycopene content and ascorbic acid. Each component has two path actions *viz*. direct effect on yield and indirect effect through components which are not revealed by correlation studies.

Plant height at maturity showed high positive direct effect (0.7120) on fruit yield per plant. It also exhibited very high negative indirect effect via. number of primary branches per plant (-2.4818). Number of primary branches showed very high positive direct effect (4.4248) on fruit yield per plant where as also very high negative indirect effect via equatorial diameter (-1.5849) followed by polar diameter (-1.1216) and high negative indirect effect via. plant height at maturity (-0.3993) on fruit yield per plant. Days to first flowering showed high positive direct effect (0.4050) on fruit yield per plant and high negative indirect effect via days to first fruit setting (-0.6459) on fruit yield per plant. Days to first fruit setting showed high negative direct effect (-0.6455) on fruit yield per plant where as high positive indirect effect via days to fruit maturity at physiological stage (0.4200) followed by days to first flowering (0.4053) and high negative indirect effect via. number of primary branches per plant (-0.5150). Days to fruit maturity at physiological stage showed high positive direct effect (0.7452) on fruit yield per plant. Whereas high negative indirect effect via number of primary branches per plant (-0.8798) on fruit yield per plant followed by days to first fruit setting (-0.3638). Equatorial diameter showed very high negative direct effect (-1.5836) on fruit yield per plant. It also exhibited very high negative indirect effect via polar diameter (-1.1834) and high negative indirect effect via plant height at maturity (-0.3382) whereas very high positive indirect effect via number of primary branches per plant (4.4285) on fruit yield per plant. Polar diameter showed very high negative direct effect (-1.1416) on fruit yield per plant and also very high negative indirect effect via equatorial diameter (-1.6416) and high negative indirect effect via plant height at maturity (-0.3647) on fruit yield per plant whereas very high positive indirect effect via number of primary branches per plant (4.3474) on fruit yield per plant. Number of locules per fruit showed high negative direct effect (-0.4647) on fruit yield per plant and moderate positive indirect effect via days to first fruit setting (0.2858) on fruit yield per plant. Number of fruits per plant showed high negative direct effect (-0.3202) on fruit yield per plant. It also exhibited high negative indirect effect via equatorial diameter (-0.6283) followed by polar diameter (-0.3703) and very high positive indirect effect via number of primary branches per plant (1.7540) on fruit yield per plant. Average fruit weight showed high negative direct effect (-0.3034) on fruit yield per plant and high positive indirect effect via number of primary branches per plant (0.9701) followed by days to fruit maturity at physiological stage (0.3852) on fruit yield per plant. It also exhibited high negative indirect effect via plant height at maturity (-0.4171) on fruit yield per plant. Total soluble solid showed high positive direct effect (0.3173) on fruit yield per plant and also high positive indirect effect via number of primary branches per plant (0.9991) on fruit yield per plant whereas high negative indirect effect via polar diameter (-0.4625) followed by equatorial diameter (-0.4625) on fruit yield per plant. Titrable acidity showed low negative direct effect (-0.1155) on fruit yield per plant whereas high positive indirect effect via number of primary branches per plant (0.3314) on fruit yield per plant. Zinc content showed low negative direct effect (-0.1896) on fruit yield per plant. It also exhibited high negative indirect effect via number of primary branches per plant (-0.3898) on fruit yield per plant and moderate positive indirect effect via equatorial diameter (0.2870) on fruit yield per plant. Iron content showed negligible positive direct effect (0.0492) on fruit yield per plant and very high negative indirect effect via number of primary branches per plant (-1.2886) whereas high positive indirect effect via plant height at maturity (0.3617) followed by equatorial diameter (0.3359) on fruit yield per plant. Lycopene content showed high positive direct effect (0.3662) on fruit yield per plant where as high negative indirect effect via number of primary branches per plant (-0.6180) on fruit yield per plant. Ascorbic acid showed moderate negative direct effect (-0.2694) on fruit yield per plant and also high negative indirect effect via equatorial diameter (-0.3682) whereas very high positive indirect effect via number of primary branches per plant (1.1949). Plant height had shown negative and significant correlation with yield per plant due to the negative and high indirect effect via primary branches per plant. This is in close conformity with the result of Singh *et al*. (2004) [20] and Golani *et al*. (2007) [6] in tomato. Primary branches per plant exhibited positive and significant correlation with yield per plant comprising there positive and high direct effect. This result in close conformity with the findings of Singh and Mittal (1976) [19] and Mehta and Asati (2008) [11] in tomato. Fruit diameter had shown positive and highly significant correlation with yield per plant due to the positive and high indirect via number of primary branches per plant. This corroborates with the findings of Joshi *et al*. (2004) and Meitei *et al*. (2014) [8, 12] in tomato. Fruit length had shown positive and highly significant correlation with yield per plant comprising its high and positive direct effect. This is in agreement with the findings of Joshi *et al.* (2004) [8] in tomato. Number of fruits per plant exhibited the positive and significant correlation with yield per plant via positive and high indirect effect via positive and high indirect effect of number of primary branches per plant. Similar findings in tomato were also reported by Kumar *et al*. (2003) [9], Mohanty (2003) [13], Meena and Bahadur (2015) [10] in tomato. Average fruit weight exhibited positive and significant correlation with yield due to its positive and moderate direct effect as well as positive and moderate indirect effect via number of primary branches per plant. This corroborates with the findings of Singh and Mittal (1976) [19], Kalda *et al*. (1996), Kumar *et al*. (2003) [9], Mohanty (2003) [13], Meena and Bahadur (2015) [10] in tomato. Total soluble solid given positive and significant correlation with yield per plant having the positive and moderate effect. This is in agreement with the findings of Meena and Bahadur (2015) [10] in tomato**.**

Table 1: Phenotypic correlation coefficient for eighteen characters in tomato

Ch.	PH	PB/P	DFF	DFr.S	DFr.M	ED	PD	Lo/ Fr.	Fr./ P	AFr.W	TSS	TA	Zn	Ir	Ly	AA
PH	1.0000															
PB/P	-0.4813**	1.0000														
DFF	0.0261	-0.0081	1.0000													
DFr.S	0.2696*	-0.0651	0.6335**	1.0000												
DFr.M	-0.0610	-0.1808	0.5376**	0.4338**	1.0000											
ED	-0.3729**	0.9089**	-0.0230	-0.0365	-0.1955	1.0000										
PD	-0.4093**	0.8024**	0.0224	-0.0793	-0.1774	0.8098**	1.0000									
Lo/ Fr.	-0.0770	-0.0395	-0.2057	-0.2651*	0.1585	-0.1061	-0.0918	1.0000								
Fr./ P	0.2566*	0.3616**	0.0310	0.1756	-0.2493*	0.3496**	0.2993*	0.0219	1.0000							
AFr.W.	-0.5340**	0.2181	-0.1021	-0.1845	0.4102**	0.1902	0.2046	0.1539	-0.6095**	1.0000						
TSS	-0.2353*	0.2095	0.0275	-0.2280	-0.0751	0.1747	0.3616**	-0.0055	-0.2384*	0.3220**	1.0000					
TA	-0.1446	0.0819	0.0368	-0.0943	0.1578	0.0971	0.0604	0.0441	-0.1073	0.2520*	0.1179	1.0000				
Zn	-0.0424	-0.1023	0.1304	0.0402	-0.0306	-0.1184	-0.0230	-0.0479	-0.0445	-0.0468	0.3126**	-0.2308	1.0000			
Ir	0.1871	-0.0705	-0.0882	0.0640	-0.0103	0.0094	-0.1114	0.1223	-0.1736	0.0583	0.1181	0.1820	0.0960	1.0000		
Ly	-0.1199	-0.1338	-0.2012	-0.2508*	-0.2558*	-0.1432	-0.0838	0.4183**	-0.0094	-0.2070	-0.1302	-0.1897	0.0079	-0.1959	1.0000	
AA	-0.1596	0.2592*	-0.0352	0.0411	-0.0618	0.2064	0.2038	-0.3100**	-0.0696	0.1356	0.1504	-0.4091**	-0.0530	0.0252	-0.2171	1.0000
Y/P	-0.4391	0.9148	0.0973	-0.0281	-0.0586	0.8320	0.7949	-0.0155	0.3363	0.2566	0.2445	0.1393	-0.1017	-0.1062	-0.1857	0.2134

** Significant at 1% level = 0.2373 *Significant at 5% level = 0.1816

Table 2: Genotypic path coefficient analysis of sixteen characters on fruit yield of tomato

Ch.	PH	PB/P	DFF	DFr.S	DFr.M	ED	PD	Lo/ Fr.	Fr./ P	AFr.W	TSS	TA	Zn	Ir	Ly	AA
PH	0.7120	-0.3993	0.0393	0.1925	-0.0398	-0.3382	-0.3647	-0.0668	0.2040	-0.4171	-0.1925	-0.1317	-0.0093	0.3617	-0.0934	-0.1258
PB/P	-2.4818	4.4248	0.0325	-0.5150	-0.8798	4.4285	4.3474	-0.1852	1.7540	0.9701	0.9991	0.3314	-0.3898	-1.2886	-0.6180	1.1949
DFI	0.0224	0.0030	0.4050	0.4053	0.1470	0.0280	0.0146	-0.1724	0.0263	-0.0351	-0.0369	0.0040	0.1104	0.0382	-0.1059	-0.0018
Fr.I	-0.1745	0.0751	-0.6459	-0.6455	-0.3638	0.0033	0.0592	0.2858	-0.1660	0.1700	0.2397	0.1164	-0.0684	0.2384	0.2228	-0.0620
DFr.M	-0.0417	-0.1482	0.2704	0.4200	0.7452	-0.1328	-0.1611	0.0755	-0.2108	0.3852	-0.1231	0.1199	-0.0028	0.0647	-0.2148	-0.0312
Fr.D	0.7523	-1.5849	-0.1096	0.0081	0.2822	-1.5836	-1.6416	0.1664	-0.6283	-0.2907	-0.3379	-0.1919	0.2870	0.3359	0.2655	-0.3682
Fr.L	0.5848	-1.1216	-0.0412	0.1048	0.2468	-1.1834	-1.1416	0.1336	-0.3703	-0.2929	-0.4625	-0.0600	0.0025	0.2379	0.1087	-0.2560
Lo/ Fr.	0.0436	0.0195	0.1978	0.2057	-0.0471	0.0488	0.0544	-0.4647	-0.0104	-0.0822	0.0177	-0.0113	0.0150	-0.1806	-0.2055	0.1484
Fr./ P	-0.0918	-0.1269	-0.0208	-0.0823	0.0906	-0.1271	-0.1039	-0.0072	-0.3202	0.2005	0.0803	0.0357	0.0204	0.2536	0.0037	0.0221
A Fr.W	0.1777	-0.0665	0.0263	0.0799	-0.1568	-0.0557	-0.0778	-0.0536	0.1899	-0.3034	-0.1077	-0.0832	0.0158	-0.0668	0.0644	-0.0442
TSS	-0.0858	0.0716	-0.0289	-0.1178	-0.0524	0.0677	0.1286	-0.0121	-0.0795	0.1126	0.3173	0.0305	0.1152	0.1942	-0.0454	0.0538
TA	0.0214	-0.0086	-0.0011	0.0208	-0.0186	-0.0140	-0.0061	-0.0028	0.0129	-0.0317	-0.0111	-0.1155	0.0323	-0.0637	0.0226	0.0497
Zn	0.0025	0.0167	-0.0517	-0.0201	0.0007	0.0343	0.0004	0.0061	0.0121	0.0099	-0.0688	0.0531	-0.1896	0.0389	-0.0005	0.0103
Ir	0.0250	-0.0143	0.0046	-0.0182	0.0043	-0.0104	-0.0103	0.0191	-0.0390	0.0108	0.0301	0.0271	-0.0101	0.0492	-0.0401	0.0055
Lycopene	-0.0480	-0.0511	-0.0958	-0.1264	-0.1055	-0.0614	-0.0349	0.1619	-0.0042	-0.0777	-0.0524	-0.0718	0.0010	-0.2984	0.3662	-0.0818
AA	0.0476	-0.0727	0.0012	-0.0259	0.0113	-0.0626	-0.0604	0.0860	0.0186	-0.0392	-0.0457	0.1159	0.0146	-0.0303	0.0602	-0.2694
Y/P	-0.5344	1.0164	-0.0178	-0.1142	-0.1358	1.0415	1.0023	-0.0304	0.3890	0.2892	0.2456	0.1685	-0.0558	-0.1157	-0.2096	0.2443

Residual effects = 0.1048

Characters (Ch.), Plant height at maturity (PH), Number of primary branches/plant (PB/P), Days to first flowering (DFF), Days to fist fruit setting (DFr.S), Days to fruit maturity at physiological stage (DFr.M), Equatorial diameter (ED), Polar diameter (PD), Number of locules/fruit (Lo/Fr.), Number of fruits/plant (Fr./P), Average fruit weight (AFr.W), Total soluble solids (TSS), Titrable acidity (TA), Zinc (Zn), Iron (Ir), Lycopene (Ly) and Ascorbic Acid (AA).

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