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HERITABLE AND NON HERITABLE COMPONENTS OF PHENOTYPIC CORRELATION COEFFICIENT AND PATH ANALYSIS IN TOMATO (*SOLANUM LYCOPERSICUM* L.).

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ABSTRACT

An investigation was carried out to study character associations among 16 yield traits including yield on 30 genotype of tomato (15 exotic and 15 indigenous). Genotypic coefficient of variation played a major role for the expression of the traits and ranged from 9.35 (days to 50% flowering) to 42.02 (fruit yield per plant). Heritability in broad sense ranged from 66.00 (primary branches) to 90.10 (fruit per plant). High genetic advance was observed for Fruit yield per plant (81.95) coupled with high heritability (89.60). The contributions through heritable and non heritable components to the magnitude phenotypic correlation coefficient were examined and it was found that in most of the cases heritable components contributed maximum towards the magnitude of phenotypic correlation coefficient however, in few cases environment factors seem to play a major role to bring down the magnitude of phenotypic correlation coefficient compared to its genotypic contributions. Average fruit weight (0.74), fruits per plant (0.55), equatorial diameter (0.43) fruits per cluster (0.42), locule number (0.39) and cluster per plant (0.36), polar diameter (0.36) and flowers per cluster (0.18) were positively associated with fruit yield at phenotypic level, indicating improvement in these traits will increase the fruit yield. Path-coefficient analysis revealed that Average fruit weight (0.61) followed by fruits per plant (0.36), polar diameter (0.18), cluster per plant (0.15)and fruits per cluster (0.13) had highest positive direct effect on fruit yield .Locule number (0.376) , equatorial number(0.367) and polar diameter (0.243) had highest positive indirect effect through average fruit weight on fruit yield.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops in India. It is important source of Vitamin A, Vitamin C and minerals (Hari, 1997). The red pigment in tomato (lycopene) is now being considered as the "world's most powerful natural antioxidant" (Meena *et al.*, 2013 and 2014).Tomato is protective supplementary food and considered as important commercial and dietary vegetable crop (Pedapati *et al.*, 2013).Tomato stands unique among vegetables because of its high nutritive value, medicinal values and other myriad uses. The berry fruit type of tomato is the most intensively studied model species (Giovannoni, 2001). A well planned breeding program based on the prior knowledge of genetic association of yield with other component traits is the pre-requisite for improvement of yield in any crop. As we know that Yield is a polygenic trait, which is governed by numbers of genes. However, direct selection for yield alone is usually not very effective or may often be misleading. Hence, selection based on its contributing characters could be more efficient and reliable (Kumar *et al.*, 2013a and Kumar *et al.*, 2014), an adequate knowledge about the magnitude and degree of association of yield with its attributing characters is of great significance to the breeders through which they can clearly understand the strength of correlated traits, when they have to exercise selection for simultaneous improvement of more than one character.

Genetic associations have bearing on observed phenotypic correlation, therefore, contributions made by heritable factors to the observed association becomes imperative. The objective of the present investigation has been to examine direct and indirect contributions of causal variables to the yield and to find out the contributions of heritable factors to the magnitude of observed phenotypic correleation coefficient.

MATERIALS AND METHODS

The present investigation was carried out during post-rainyseason of 2012 at Vegetable Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (UP), India. The experimental material consist of 30 genotypes / cultivars, fifteen exotic lines and fifteen indigenous lines, of tomato received from various sources, including Indian Institute of Vegetable Research, Varanasi and National Bureau of Plant Genetic Resources, New Delhi, and maintained at Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University. The experiment was laid out in randomized block design with three replications. Nursery was planted in second week of August and about 4 week old seedlings were transplanted during second week of September with row-to-row x plant-to-plant spacing maintained at 60 cm x 45 cm. Each plot consists of 10 plants and represent a single entry in each replication. Standard agronomic practices were followed to raise a good crop. Observations on days to first flowering, day to 50% flowering and days to 50% fruiting was taken on plot basis. Five plants, excluding border plants, were randomly selected for recording of data on various yield and fruit quality traits such as number of primary branches (PB), number of secondary branches (SB), plant height (PH) (in cm), clusters per palnt (Cl/P), flowers per cluster (Fl/Cl), fruits per cluster (Fr/Cl), fruits per plant (Fr/P), equatorial diameter (ED) (in cm), polar diameter (PD) (in cm), pericarp thickness (PT) (mm), locule number per fruit (LN), average fruit weight (AFW) (in g) and fruit yield per plant (FY/P) (in kg). Analysis of data collected on all the traits was done using Windostat ® ver. 8.5 software for statistical data analysis.

Values of genotypic and environmental correlation obtained from the analysis of data were subjected to estimate the contributions of heritable and non-heritable factors to the magnitude of phenotypic correlation coefficient with the help of formula given by Falconer and Mackey (1996).

$r_p = h_x h_y r_g + e_x e_y r_e$ or, $r_p = r_G + r_E$

Where,

r_p = phenotypic correlation coefficient between trait x and y; $r_G = h_x h_y r_g$ = contribution due to heritable factors; $r_E = e_x e_y r_e$ = contribution due to non-heritable factors; h_x = square root of heritable variation of trait "x"; h_y = square root of heritable variation of trait "y"; e_x = square root of non-heritable variation of trait "x"; e_y = square root of non-heritable variation of trait "y"; r_g = genotypic correlation coefficient between trait x and y; r_e = environmental correlation coefficient between trait x and y.

RESULTS AND DISCUSSION

Correlation coefficient analysis

The phenotypic correlations along with the contributions due to genetic and environmental causes to the phenotypic correlation among the 16 traits under investigation have been presented in Table 1. average fruit weight (0.74**), fruits per plant (0.55*), equatorial diameter (0.43*), fruits per cluster (0.42*), Locule number (0.39*) and clusters per plant (0.36*) showed positive and significant association with fruit yield per plant. Polar diameter (0.36) and flowers per cluster (0.18) showed positive correlation with fruit yield.Days to 50% flowering (0.95**) and days to 50% fruiting (0.86**) was positively associated with each other whereas all of these traits showed a significantly negative association with locule number per fruit. A significant negative correlation was observed between number of primary branches and days to 50% fruiting(-0.38*). Among the traits associated with yield, number of clusters per plant showed highly significant and positive association with fruits per plant(0.62**),fruits per cluster was positively and significantly associated with fruits per plant(0.61**),locule number and average fruit weight; and locule number and average fruit weight (0.61**) were also found significantly and positively associated with each other. Number of secondary branches was positively and significantly associated with plant height(0.55**). Number of primary branches was positively and significantly associated with number of secondary branches (0.42*), equatorial diameter showed positive and significant correlation with polar diameter (0.42*) and plant height also showed a positive and significant association with fruits per cluster and fruits per plant(0.38*). Pericarp thickness was not found significantly associated with any of the traits under study.

Since, genetic correlation coefficient is the derived value which is based on derived genetic covariances and variances, its limit may not necessarily lie between +1 to -1 (as for phenotypic correlation coefficient). Therefore, the magnitude of genetic correlation coefficient as such may not be compared directly with the phenotypic correlation coefficient. In the present study an attempt was made to compare the contribution of genotypic factors and environmental factors of correlation towards the phenotypic correlation coefficient values obtained for several trait combinations. For most of the trait combination the contribution due to hereditary factors ($h_x h_y r_g = G$) was either close or very close to phenotypic correlation coefficient values suggesting the little role of non-heritable factors in the phenotypic correlations, whereas in few cases, such as correlation between locule number and days to first flowering, locule number and days to 50% flowering, locule number and days to 50% fruiting, plant height and fruits per cluster, and plant height and fruits per plant, the magnitude of contribution due to hereditary factors was higher than the magnitude of phenotypic correlation coefficients. It was observed that in such cases the contribution towards phenotypic correlation due to environmental factors was having opposite direction to that of genotypic factors which brought down the actual phenotypic correlation to a lower side than the magnitude of contribution due to hereditary factors. It indicated that the actual association for such trait pairs was more affected by the environmental factors and therefore, selection based on the association studies for such trait pairs should be given due precautions.

Similar to the observations in the present study Singh *et al.* (1997) also observed strong positive correlation for number of fruits per plant and number of fruits per cluster with fruit yield. Das *et al.* (1998) also observed significant positive correlation for fruit yield per plant and fruits per plant and fruit weight. They also found a significant positive correlation between fruit equatorial diameter and locule per fruit similar to the present results. Golani *et al.* (2007) reported a significant positive correlation between yield and locule number per fruit which supports the current finding.

Prasad and Rai (1999) and Ara *et al.* (2009) observed significant positive correlation for yield and fruit weight. Mohanty (2002a, 2002b) also reported significant positive correlation of yield with fruits per plant. A negative and significant association of yield with average fruit weight was reported by Mohanty (2002b) in contrast to the present findings where a strong positive correlation was observed between the two. Mohanty (2002b) also reported a negative correlation between yield and plant height which was also observed in present investigation but association was not significant in present study. Joshi *et al.* (2004) reported a significant positive correlation between yield and average fruit weight similar to the findings of present study. Ghosh *et al.* (2010) and Tasisa *et al.* (2012) reported a significant positive correlation between

Table 1: Phenotypiccorrelation (rp), genotypic (G = hxhyrG) and environmental (E = exeyrE) contribution tophenoty piccorrelation for yield and yieldtr aitsamong 30 genoty pesoftomato

Characters		D50Fl	D50Fr	PB	SB	PH	Cl/P	Fl/Cl	Fr/Cl	Fr/P	ED	PD	PT	LN	AFW	FY/P
DFF	rp	0.9537**	0.8767**	-0.2853	-0.0757	0.1896	0.0424	-0.0627	0.0796	0.0874	-0.0049	0.2356	0.0559	-0.3958*	-0.195	-0.0836
	G	0.7956	0.7692	-0.2660	-0.0694	0.1835	-0.0095	-0.0758	0.0990	0.0987	-0.0122	0.1969	0.0612	-0.4053	-0.1838	-0.0903
	E	0.1582	0.1074	-0.0194	-0.0063	0.0060	0.0520	0.0132	-0.0195	-0.0113	0.0073	0.0387	-0.0054	0.0096	-0.0112	0.0068
D50Fl	rp		0.8602**	-0.3391	-0.0434	0.1787	0.0124	-0.0814	0.127	0.1425	0.0625	0.3042	0.0196	-0.3625*	-0.1209	-0.0135
	G		0.7404	-0.3118	-0.0340	0.1826	-0.0268	-0.0960	0.1226	0.1480	0.0394	0.2602	0.0139	-0.3842	-0.1165	-0.0277
	E		0.1199	-0.0274	-0.0093	-0.0038	0.0391	0.0145	0.0044	-0.0054	0.0231	0.0440	0.0057	0.0216	-0.0044	0.0142
D50Fr	rp			-0.3879*	-0.088	0.2468	0.0548	0.0499	0.1708	0.1164	-0.1688	0.3139	0.0045	-0.5385**	-0.2342	-0.1091
	G			-0.3438	-0.0657	0.2577	0.0258	0.0498	0.1868	0.1229	-0.1730	0.2703	0.0135	-0.5489	-0.2205	-0.1151
	E			-0.0441	-0.0224	-0.0108	0.0290	0.0001	-0.0159	-0.0064	0.0041	0.0435	-0.0090	0.0101	-0.0137	0.0059
PB	rp				0.4216*	0.2288	-0.0017	0.0539	-0.1048	-0.048	0.0823	-0.4904**	0.0666	0.2057	-0.0915	-0.1918
	G				0.3226	0.1769	0.0146	0.0628	-0.1207	-0.0381	0.0734	-0.4601	0.0710	0.2126	-0.0914	-0.1710
	E				0.0990	0.0520	-0.0162	-0.0088	0.0158	-0.0099	0.0089	-0.0304	-0.0045	-0.0068	-0.0002	-0.0208
SB	rp					0.5143**	-0.1429	-0.216	-0.0267	0.0864	-0.1499	-0.2252	-0.1287	-0.1131	-0.2763	-0.2317
	G					0.4874	-0.1560	-0.2402	-0.0770	0.0713	-0.0952	-0.1878	-0.0954	-0.0795	-0.2570	-0.2336
	E					0.0268	0.0130	0.0242	0.0504	0.0151	-0.0548	-0.0374	-0.0333	-0.0336	-0.0193	0.0021
PH	rp						0.0637	0.2087	0.3892*	0.3822*	-0.2686	-0.1129	-0.1292	-0.1992	-0.2688	-0.0305
	G						0.0798	0.2381	0.4068	0.3970	-0.2198	-0.0901	-0.1139	-0.1759	-0.2737	-0.0238
	E						-0.0161	-0.0294	-0.0177	-0.0147	-0.0490	-0.0228	-0.0153	-0.0234	0.0049	-0.0067
Cl/P	rp							0.1215	0.0688	0.6296**	-0.1328	-0.2205	0.0277	0.0347	0.0166	0.3688*
	G							0.1684	0.1275	0.5624	-0.1133	-0.2337	0.0518	0.0234	0.0147	0.3400
	E							-0.0467	-0.0587	0.0674	-0.0195	0.0132	-0.0240	0.0112	0.0019	0.0288
Fl/Cl	rp								0.6419**	0.3463	0.044	-0.061	0.1369	-0.0019	0.0549	0.1856
	G								0.5500	0.3725	0.0361	-0.0266	0.1415	-0.0196	0.0143	0.1588
	E								0.0919	-0.0260	0.0078	-0.0345	-0.0046	0.0177	0.0406	0.0268
Fr/Cl	rp									0.6129**	0.1351	0.1965	-0.0188	-0.0442	0.1003	0.4290*
	G									0.5526	0.0962	0.2111	0.0122	-0.0676	0.0467	0.3701
	E									0.0604	0.0389	-0.0146	-0.0311	0.0234	0.0535	0.0590
Fr/P	rp										0.0229	-0.0212	-0.0847	-0.0679	0.0622	0.5531**
	G										0.0147	-0.0265	-0.0563	-0.0805	0.0584	0.5063
	E										0.0082	0.0054	-0.0284	0.0125	0.0038	0.0468
ED	rp											0.426*	0.1136	0.5464**	0.5999**	0.4333*
	G											0.2768	0.0394	0.3914	0.4344	0.3708
	E											0.1492	0.0743	0.1550	0.1655	0.0626
PD	rp												0.0252	-0.0711	0.3971*	0.3605
	G												-0.0126	-0.1482	0.3234	0.3244
	E												0.0379	0.0770	0.0737	0.0362
PT	rp													-0.0681	-0.0681	-0.0455
	G													-0.0841	-0.0829	-0.0219
	E													0.0160	0.0147	-0.0237
LN	rp														0.6149**	0.3991*
	G														0.4831	0.3412
	E														0.1318	0.0579
AFW	rp															0.7419**
	G															0.6160
	E															0.1259

Table 2: Direct and indirect effect of nine component traits on fruit yield per plant in tomato

Characters	D50Fr	PH	Cl/ P	Fr/ Cl	Fr/ P	ED	PD	LN	AFW	Correlation coefficient with FY/P
D50Fr	-0.071	-0.010	0.008	0.023	0.043	0.012	0.058	-0.030	-0.143	-0.1091
PH	-0.018	-0.039	0.010	0.052	0.141	0.019	-0.021	-0.011	-0.164	-0.0305
Cl/P	-0.004	-0.003	0.153	0.009	0.233	0.009	-0.041	0.002	0.010	0.3688*
Fr/Cl	-0.012	-0.015	0.011	0.134	0.226	-0.010	0.036	-0.002	0.061	0.429*
Fr/P	-0.008	-0.015	0.096	0.082	0.369	-0.002	-0.004	-0.004	0.038	0.5531**
ED	0.012	0.010	-0.020	0.018	0.009	-0.071	0.079	0.030	0.367	0.4333*
PD	-0.022	0.004	-0.034	0.026	-0.008	-0.030	0.185	-0.004	0.243	0.3605
LN	0.038	0.008	0.005	-0.006	-0.025	-0.039	-0.013	0.055	0.376	0.3991*
AFW	0.017	0.010	0.003	0.013	0.023	-0.042	0.074	0.034	0.611	0.7419**

Direct effects are on main diagonal in bold; *P=0.05, **P=0.01; Residual effect (R) = 0.4022

yield and cluster per plant, fruits per cluster and fruits per plant which is in accordance to the present study. The study of Al-Aysh *et al.* (2012) also supports the current findings as they also observed a significant positive correlation between average fruit weight and fruit yield per plant. Manna and Paul (2012) similar to most of the earlier findings reported a significant positive correlation between fruit yield per plant and fruit weight and number of fruits per plant.

Path-coefficient analysis

The simple correlation alone, however, is not a true reflection of the nature of association of the different traits with each other when other characters are held constant. Due to mutual relationship among different characters, which may be positive or negative, these associations become more complex and do not lead to any meaningful interpretations. The path coefficient analysis is a powerful method in analyzing the scheme of causal relationship in the development of various traits. The correlations are partitioned into direct and indirect effects to know the precise direct and indirect cause of associations. The concept of path coefficient analysis was originally developed by Wright in 1921, but its first use in plant breeding was demonstrated by Dewey and Lu in 1959.

Path-coefficient analysis is simply standardized partial regression coefficient, which splits the correlation coefficients into the measures of direct and indirect effects of a set of independent variables on the dependent variables. If the correlation between yield and a character is due to the direct effect of the character it reflects a true relationship between them and selection can be practiced for such a character in order to improve the yield. But if the correlation is mainly due to indirect effect of the character through another component trait, the breeder has to select for the latter trait through which the indirect effect is exerted.

The various component of yield do not contribute to increased yield in simple additive and straight fashion. The metabolic growth and developmental processes are intricately woven and each interacts *inter se* in a subtle manner. An understanding of the interdependence will be useful in evolving efficient selection and breeding strategies for minimizing the negative effects and for maximizing the synergistic effects. The interaction becomes complex with the increase of components. The use of this method probes into cause and effect relationships among the variables. In the present investigation, the phenotypic correlations of fruit yield per plant with selected nine yield traits, were partitioned into their corresponding direct and indirect effects through path coefficient analysis (Table-2). The independent traits were selected either on the basis of their significant correlation with yield or they must be significantly correlated with those traits which are having significant correlation with yield (Table-1).

Analysis revealed that magnitude of direct effect on yield per plant was found to be highest for average fruit weight(0.61) followed by fruits per plant(0.36), polar diameter(0.18), clusters per plant(0.15), fruits per cluster(0.13) and locule number (0.05). All the traits, except days to 50% fruiting, plant height and equatorial diameter, showed positive direct effect on fruit yield per plant. Days to 50% flowering exhibited indirect positive effect through most of the traits except plant height, locule number and average fruit weight. Plant height a showed positive indirect effect on Days to 50% flowering, polar diameter, locule number and average fruit yield.. Cluster per plant was having positive indirect effect through most of the traits except Days to 50% flowering plant height and polar diameter. Fruits per cluster was also having positive indirect effect on fruit per plant, average fruit weight polar diameter and cluster per plant but remaining traits having negative indirect effect on fruit yield. Equatorial diameter was having indirect positive effect through most of the traits except cluster per plant. Polar diameter exhibited indirect negative effect through most of the traits except average fruit fruit weight and fruit per cluster and plant height. Indirect effect of locule number was positive through average fruit weight, Days to 50%, flowering,plant height and cluster per plant. Average fruit weight showed positive indirect effect on fruit yield per plant through most of the traits except equatorial diameter.

In present investigation, average fruit weight and fruits per plant showed high positive and direct effect had highly significant positive correlation with fruit yield per plant. Therefore, the fruits with higher mean weight and cultivars with higher number of fruits per plant should be considered as selection criteria for increasing yield per plant. Out of the nine independent traits selected for path analysis, clusters per plant, fruits per cluster, fruits per plant and average fruit weight exerted positive direct effect and positive indirect effects via most of the traits and was significantly associated with yield also. It also signifies the importance of these indirect effects for selection based improvement in tomato. A plant breeder should therefore, emphasize on these traits while practicing selection.

Phenotypic path-coefficient analysis indicated the importance of fruits per plant and average fruit weight in the improvement of fruit yield per plant owing to the information of direct positive effect and highly significant positive correlation for these two traits with fruit yield. This observation of the present study finds support by the reports of Vikram and Kohli (1998), Mohanty (2002a, 2002b), Joshi *et al.* (2004), Asati *et al.* (2008), Ara *et al.* (2009), Ghosh *et al.* (2010), Al-Aysh *et al.* (2012) and Manna and Paul (2012).

In contrast to the present observation Prasad and Rai (1999), Joshi *et al.* (2004), Asati *et al.* (2008), Mehta and Asati (2008), Ara *et al.* (2009) observed a direct positive effect of plant height on yield per plant. Tasisa *et al.* (2012) reported a positive direct effect of clusters per plant on yield per plant similar to the observations in present investigation, whereas, a positive direct effect of plant height is not in agreement with the findings of present study. The value of residual effect (R=0.4022) in the present study indicated that nearly 60% of the causal traits for fruit yield was considered for the analysis and about 40% of the causal variables are left untouched due to one or other reasons.

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