GENETIC ASSOCIATION ANALYSIS FOR YIELD AND QUALITY TRAITS IN TOMATO (*SOLANUM LYCOPERSICUM* L.)

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Abstract: The present investigation was conducted during *Rabi* and *Kharif* 2010-11 at Vegetable Research Station, Dr. Y.S.R. Horticultural University, Hyderabad (A.P.), India. 37 tomato (*Solanum lycopersicum* L.) genotypes were evaluated to estimate the nature and magnitude of associations of different characters with yield per plant and among themselves. The experiment was conducted using a randomized block design with three replications. Yield per plant showed highest positive and significant genotypic and phenotypic correlation with pericarp thickness (r_g= 0.655, r_p= 0.611) followed by average fruit weight (r_g=0.522, r_p= 0.512), fruit length (r_g= 0.350, r_p= 0.309), no. of flowers per plant (r_g= 0.371, r_p= 0.231) as well as negatively significant correlation with days to 50% flowering (r_g= -0.308, r_p= -0.286), which indicated that these traits play important role in yield improvement. Genotypic and phenotypic path coefficient analysis revealed that positive direct effects were exerted by pericarp thickness, no. of flowers per cluster, shelf life and days to 50% flowering showed negative direct effect. This implies that direct selection for these characters might be effective and there is a possibility of improvement in yield per plant.

Keywords: Correlation, Path analysis, Quality, Tomato, Yield

Introduction: Tomato (*Solanum lycopersicum* L.) is an important vegetable crop belongs to the family Solanaceae and it is native of west coast of South America (Mexico and Peru) and was cultivated by Indians about 500 B.C. long before arrival of Spaniards [1]. The fruit can be eaten as raw, cooked and processed. Large quantities of tomatoes are used to produce ketchup, paste, puree, powder, juice and soup. Tomato is an important source of vitamin A, B, C and other nutrient elements. During ripening, there is a 500 fold increase in the level of lycopene in tomato fruit [2]. Increased lycopene has proven nutritional value as an antioxidant that is associated with a low incidence of certain forms of human cancer [2]. Tomato is widely disseminated vegetable crop all over the world [3], ranking second in importance to potato but tops the list of processed vegetables and grown on 4.98 million hectares of land area [4]. India is the second largest tomato producer in the world after China, accounting for about 11% of the world tomato production [5]. During 2010-1 1, the area and production of tomato in India was about 0.865 million hectare and 16.82 million tonnes. However, the average national productivity is very low (19.5 tonnes/ha) as compared to other countries like USA (81 t/ha), Spain (74 t/ha) and Brazil (60.7 t/ha) [5]. This indicates that there is a need of increase the productivity of this crop by developing superior yielding varieties through appropriate breeding work to meet the demand of domestic and export markets. The degree of association between characters as indicated by the correlation coefficients has always been a helpful instrument for the selection of desirable characters under a breeding program. Like other crops, yield of tomato is the final product attributed by a complex chain of interrelating effects of different characters [6]. So, it is essential to make a comparative study among important characters to select desirable ones. Knowledge in respect of the nature and magnitude of association of yield with various component characters is a pre-requisite to bring improvement in the desired direction. Correlation studies between fruit yield and its components; and knowledge of relative contribution of such characters towards yield would be of great value in planning and execution of breeding programmes. However, it does not give an exact picture of relative importance of direct and indirect effects of various yield attributes. Under such circumstances, path coefficient analysis is an effective tool [6], [7] and this facilitates the partitioning of correlation coefficients in to direct and indirect effects on yield and other attributes. Keeping in view above facts, the present investigation was conducted to determine the nature and magnitude of association among various characters and their direct and indirect effects on fruit yield of tomato.

Materials and method: The present investigation was conducted during Rabi (Oct-Jan) and Kharif (June-Sept.) 2010- 2011 at Vegetable Research Station, Dr. Y.S.R. Horticultural University, Hyderabad (A.P.), India, which is situated at 17^o 19^1 North latitude, 78^o 23^1 East longitude at mean altitude of 542.3m above the Mean Sea Level. The climate of Hyderabad was classified as dry tropical and semi arid. The rain fall mainly received from South West Monsoon approximately 555.1 mm and maximum mean temperature ranged from 27.7^{o}C to 41.8 ^{o}C, while mean minimum temperature varied from 9.7 ^{o}C to 28.2 ^{o}C recorded during crop growth period. Soil is clay loam with pH 7.80 and electrical conductivity 0.24 dS m^{-1}. The experimental material comprised of

37 genotypes (24 F_1 hybrids, 11 parents and 2 commercial checks) of tomato. The experiment was laid out in randomized block design with three replications at the spacing of 60cm between rows and 45cm between plants. A plot size of 4.5m × 2.4m was kept for each genotype. All the recommended cultural practices and plant protection measures were followed as Dr. Y.S.R.HU recommendations. Data were recorded for 16 characters *viz*., plant height (cm), no. of primary branches per plant, days to 50% flowering, no. of flowers per cluster, no. of fruits per cluster, fruit length (cm), fruit width (cm), average fruit weight (g.), yield/plant (kg/plant), no. of locules per fruits, pericarp thickness(mm), TSS(^{o}Brix), titrable acidity (%), ascorbic acid (mg/100g), lycopene (mg/100g) and shelf life (days). TSS content of fruit juice was estimated with help of a Hand Refractometer (ERMA) calibrated at 20^{o}C. The data obtained were corrected for temperature correlation from standard correlation table and represented in ^{o}Brix [8]. Total acidity was determined by titrating the diluted fruit juice against 0.1N NaOH solution using phenolphthalein as indicator [8]. The data was represented in terms of percentage of citric acid. The 2,6- dichlorophenol indophenols dye titration method was used to estimate the ascorbic acid content of fruit juice [9]. Lycopene content was determined by pigment extracted into petroleum ether and optical density was measured at 503nm in sprectophotometric metre using petroleum ether as blank [9].Data collected during the two growing seasons (*Rabi* & *Kharif,* 2010-11) for above characters were pooled and analysis of variance was done as suggested by [10]. Phenotypic and genotypic correlation coefficients were estimated following [11]. The significance of phenotypic and genotypic correlation coefficient was tested by referring the standard table [12] at n-2 degrees of freedom. Where, n is no. of genotypes. Correlation effects were further partitioned into components of direct and indirect effects by path coefficient analysis as per [13].

Results and Discussions: Analysis of variance for yield, yield contributing and quality characters under study are summarized and presented in table1. The mean sum of squares for genotypes was found to be highly significant for all the characters studied indicating the wealth of genetic variability among parents and crosses created by hybridization.

Correlation analysis: The major causes underlying association are either due to pleiotropic gene action or linkage or both. The phenotypic correlations were normally of genetic and environmental interaction which provided information about the association between the two characters. Genotypic correlation provided a measure of genetic association between the characters, normally used in selection. While environment as well as genetic architecture of a genotype plays a great role in achieving higher yield combined with better quality. The genotypic and phenotypic correlation for fruit yield and its component in tomato are presented in Table 2 and only significant correlations are discussed here. For most of the characters studied, phenotypic correlation coefficient (r_p) was lower in magnitude than that of corresponding genotypic correlation coefficients (table 2). This clearly indicated inherent association among various characters independent of environmental factors influence [14]. According to [15], greater yield response is obtained when the character for which indirect selection is practiced has high heritability and high correlation with yield per plant. The practical utility of selecting for a given character as a means of improving another depends on the extent to which improvement in the major character is facilitated by selection for the indicators [11]. Such improvement depends on genotypic and phenotypic correlations of the characters. Positive and significant genotypic and phenotypic correlation of yield/plant with pericarp thickness (r_g=0.655, r_p= 0.611), average fruit weight (r_g=0.522, r_p=0.512), fruit length (r_g=0.352, r_p= 0.309), no. of flowers per cluster (r_g=0.371, r_p=0.275), fruit width (r_g=0.271, r_p=0.268) and shelf life (r_g=0.276, r_p=0.231) were recorded (table 2). Similar results were found by [16], [17] and [18] in tomato. This implied that any increase in either of above characters would results in significant increase in fruit yield per plant. Negative and significant genotypic and phenotypic correlation of yield per plant with days to 50%flowering was recorded (Table 2). This implied that keeping components constant any decrease in the above factor would lead to increase in yield/plant. This results are in agreement with findings of [16]. Pericarp thickness showed positive and significant association with fruit length (r_g= 0.489, r_p= 0.443), fruit width (r_g= 0.410, r_p=0.398), average fruit weight (r_g= 0.734, r_p= 0.693) and no. of flowers per cluster (r_g= 0.322, r_p= 0.262) at genotypic and phenotypic level. Similar results were reported by [16] for fruit width, fruit length and average fruit weight. This indicated that strong positive relationship of pericarp thickness with fruit characters. Average fruit weight showed positive and significant correlation with fruit length (r_g= 0.709, r_p= 0.639), fruit width (r_g= 0.667, r_p= 0.646), no. of locules per fruit (r_g= 0.317, r_p= 0.275) and no. of flowers per cluster (r_g= 0.270, r_p= 0.212) at genotypic and phenotypic level. These findings were accordance with [19] for fruit length, fruit width and average fruit weight. This implied that average fruit weight is closely related to fruit volume. Fruit width (r_g= 0.503, r_p= 0.460), no. of flowers per clusters (rg= 0.440, rp= 0.278) and days to 50% flowering were positively and significantly correlated with fruit length. Similar findings were also reported by [19] for fruit width in tomato. This implies that increase in above factors contributes increase in fruit length. No. of fruits per cluster (r_g= 0.226, r_p= 0.196) and TSS (r_g= 0.326, r_p= 0.215) were positively and significantly correlated with no. of flowers per cluster at both levels. These findings were in agreement with those of [20] for no. of fruits/cluster and [21] for TSS in tomato. Positive and significant genotypic and phenotypic association of fruit width with no. of locules/fruit (r_g= 0.746, r_p=0.659) and days to 50% flowering (r_g= 0.251, r_p= 0.221) indicating the strong positive relationship between the characters. Similar results were reported by [20] for no. of locules/fruit. This indicated that traits *viz*., no. of locules per fruit, no. of fruits/cluster, TSS, Days to 50% flowering also play important role in crop improvement programme and simultaneous selection for these traits can also improve fruit yield per plant. Positive and significant association of plant height with no. of primary branches per plant [22], shelf life [18] and no. of primary branches/plant with no. of fruits/cluster [22] were observed at both levels (Table2). This indicates that strong association between growth parameters in tomato.

In case of quality traits, ascorbic acid content was positively significantly associated with no. of primary branches and no. of fruits per cluster at both levels (Table 2). TSS showed positive significant correlation with no. of fruits per cluster and plant height at both levels (Table 2). This elucidated that need of focus at above fruit bearing traits to improve fruit quality traits. Ascorbic acid negatively significantly correlated with fruit length, fruit width [21], average fruit weight and pericarp thickness at both level (Table2). Negative and significant genotypic and phenotypic association of TSS with average fruit weight, fruit width and titrable acidity were recorded (Table 2). This indicates the inverse relationship between fruit growth parameters and fruit quality parameters.

Path coefficient analysis: It is useful in partitioning the correlation coefficients into direct and indirect effects to measure the relative importance of causal factors and permits critical determination of the specific forces acting to produce a given correlation [23], [24]. As yield is influenced by many components or contributing traits both in positive and negative directions, it was considered as resultant (dependent) variable and rest of the characters considered as causal (independent) variable.

At phenotypic level characters like average fruit weight (0.415), pericarp thickness (0.303), plant height (0.206), lycopene (0.168), no. of fruits per cluster (0.160), shelf life (0.125) and no. of flowers/cluster (0.049) exerted relatively higher magnitude positive direct effect on yield per plant (Table 3). These observations were in agreement with the findings of [22] for average fruit weight, [21] for pericarp thickness, [14] for plant height, [18] for shelf life and [20] for no. fruits/cluster and no. of flowers/cluster in tomato. Among above characters, only pericarp thickness (r_p= 0.611), average fruit weight (r_p= 0.513), no. of flowers/cluster (0.275) and shelf life (0.231) showed positive and significant phenotypic correlation with fruit yield/plant (Table 3). This revealed that the existence of true relationship between fruit yield/plant and pericarp thickness, average fruit weight, shelf life and no. of flowers per plant, indicating selection for such characters would be most likely effective for yield improvement. Even though the traits like days to 50% flowering followed by no. of primary branches/plant [25], fruit width [26] and titrable acidity exerted relatively strong negative direct effects on yield/plant, but only days to 50% flowering showed significant negative phenotypic correlation with yield/plant (Table 3). This indicated that days to 50% flowering could have inverse relationship with yield/plant. The phenotypic positive indirect effects of fruit width and no. of primary branches/plant were counteracted by their own respective phenotypic negative direct effects leading to positive phenotypic correlation with yield/plant (Table 3). This indicated that the role of positive indirect effects of these traits should be given appropriate focus in selection for higher yield/plant. Genotypic path coefficient analysis indicated that positive direct effects were exerted by pericarp thickness (0.786) followed by no. of locules/fruit (0.667), shelf life (0.272), no. of fruits/cluster (0.244) and lycopene (0.125) respectively (Table 4). These findings are in consonance with those of [21] for pericarp thickness and no. of locules per fruit, [18] for self life and no. of fruits per plant in tomato. This suggested that the above characters play important role in improvement of yield/plant. However, pericarp thickness, shelf life and no. of fruits/cluster, no. of flowers/cluster had positive significant genotypic correlation on yield/plant (table 4). Hence, it reflects a true relationship between them and selection can be practiced for such traits in order to improve yield [15].Negative genotypic direct effects were exerted on yield/plant characters like fruit width (-0.386), TSS (-0.299), plant height (-0.196), fruit length (-0.194), ascorbic acid (-0.143), titrable acidity (-0.137), average fruit weight (-0.111) and days to 50% flowering (-0.094) respectively (table 4). Negative and significant correlation with yield/plant found with days 50% to flowering only (Table 4). Hence, it indicated that the negative association of days to 50% flowering that any decrease in magnitude of this character would result in increase in yield/plant. The genotypic positive indirect effects of fruit width, fruit length and average fruit weight were counteracted by their own respective genotypic negative direct effects leading to positive genotypic correlation with yield per plant. These results were accordance with the findings of [26] for fruit length and [16] for average fruit weight in tomato. This indicated that the role of positive indirect effects of these characters should be given appropriate focus in selection for higher yield/plant.Overall path analysis revealed that direct effects of pericarp thickness, no. of fruits per cluster, no. of flowers per cluster, shelf life and days to 50% flowering where as indirect effects of fruit width, fruit length and average fruit weight on yield per plant should be considered simultaneously as selection traits for yield per plant improvement. The residual effects of phenotypic and genotypic were 0.661 and 0.562 recorded respectively had been indicated that some more traits contributed to fruit yield/plant. Hence, there is need to consider some traits in this study.

Conclusion: The yield contributing traits like pericarp thickness, average fruit weight, fruit length, no. of flowers per cluster, fruit width and shelf life were found to have positive and significant correlation whereas days to 50% flowering showed negative and significant association with yield per plant at both genotypic and phenotypic level.The character viz., pericarp thickness, no. of flowers/cluster, shelf life and no. of fruits/cluster exhibited highest positive direct effects on yield/plant. Hence, these characters could be reliably looked for, while selecting high yielding genotypes.

References:

1. Rehman, F., S. Khan, F. Aridullah and Shafiullah, 2000. Performance of different tomato cultivars under the climatic conditions of Northern areas (GILGIT). *Pak. J. Biol. Sci.,* 3: 833-835.
2. Bai, Y. and P . Lindhout, 2007. Domestication and breeding of tomatoes : What have we gained and what can we gain in the future. *Annals of Botany*, 100(5): 1085-1094.
3. Adebooye, O.C., G.O. Adeoye and H. Tijani-Eniola, 2006. Quality of fruits of three varieties of tomato (*Lycopersicon esculentum* (L.) Mill) as affected by phosphorus rates. *J. Agron.,* 5: 396-400.
4. FAOSTAT, 2011. Statistical data base of food and agriculture of united nations. FAO, Rome, Italy.
5. 5.Indian Horticulture Database, 2011. National Horticulture Board, Department of Agriculture and cooperation, Government of India. www.nhb.gov .in.
6. Islam, B.M.R., N.A. Ivy, M.G. Rasul and M. Zakaria, 2010. Character association and path analysis of exotic tomato (*Solanum lycopersicum* L.) genotypes. *Bangladesh J. Pt. Breeding Gen.,* 23(1):13-18.
7. McGiffen, M.E., D.J. Pantone and J.B. Masiunas, 1994. Path analysis of tomato yield components in relation to competition with black and eastern black nightshade. *J. of American Soci. Hort. Sci.,* 1 19: 6-1 1.
8. A.O.A.C.1984. *Official Methods of Analysis*. Association of Official Analytical Chemist. Washington D.C.
9. Ranganna, S. 1997. *Mannual of Analysis of Fruits and Vegetables Products.* Tata Mc. Graw Hill Publ. Co. Ltd., New Delhi.
10. Panse, V.G. and Sukhatme, P.V. 1978. *Statistical Methods for Agricultural Workers*. ICAR, New Delhi, pp. 68-75.
11. Johnson, H.W., H.F. Robinson, R.E. Comstock, 1955. Genetic and phenotypic correlation in soyabeans and their implications in selection. *Agron. J.*, 47: 477-483.
12. Snedecor, G.W. and W.G. Cochran, 1967. Statistical Methods Applied to Experiments in Agriculture and Biology. 6th Edn., Iowa State University Press, Iowa.
13. Dewey, D.R. and K.H. Lu, 1959. Correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.*, 51: 515-18.
14. Tasisa, J., D. Belew and K. Bantte, 2012. Genetic associations analysis among some traits of tomato (*Lycopersicon esculentum* Mill.) genotypes in West Showa, Ethiopia. *Int. Jr. of Plant breed. Genet.,* 6(3): 129-139, 2012.
15. Singh, B.D., 1993. Plant Breeding Principles and Methods. Kalayani Publishers, New Delhi, pages: 677.
16. Prashanth, S.J., R.P. Jaiprakashan, R. Mulge and M.B. Madalageri. 2008. Correlation and path analysis in tomato (*Lycopersicon esculentumMill.*). *Asian J. Hort.*, 3: 403-408.
17. Singh, A.K., 2007. Correlation and path coefficient studies in tomato under cold arid conditions of ladakh. *Haryana J. Hortc. Sci.*, 36(3&4): 346-347.
18. Buckseth, T., M.K. Sharma and K.S. Thakur, 2012. Genetic diversity and path analysis in tomato (*Solanum lycopersicum* L.). *Veg. Sci.* 39(2): 221-223.
19. Prasad, V.S.R.K. and M. Rai, 1999. Genetic variation, component association and direct and indirect selections in some exotic tomato germplasm. *Indian J. of Hort.*, 56 (3): 262-266.
20. Prashanth, S. J., 2003, Genetic variability and

divergence studies in tomato (*Lycopersicon esculentum* Mill). M.Sc.(Agri.) Thesis, Uni. Agric. Sci., Dharwad (India).
21. Manna, M. and A. Paul, 2012. Studies of genetic variability and character association of fruit quality parameters in tomato. *Hort Flora Res. Spectrum,* 1: 110-16.
22. Srivastava, K., K. Kumari, S.P. Singh and R. Kumar, 2013. Association studies for yield and its component traits in tomato (*Solanum lycopersicum* L.). *Plant Archives*, 13(1), 105-112.
23. Bhatt, G.M., 1973. Significance of path coefficient analysis in determining the nature of character association. *Euphytica*, 22: 338-343.
24. Khan, M.R. and A.S. Qureshi, 2001. Path coefficient and correlation analysis studies on the variation induced by gamma irradiation in M1 generation of chickpea (*Cicer arientinum* L.). *J. Biological Sci.*, 1: 108-110.
25. Asati, B.S., N. Rai and A.K. Singh, 2008.Genetic parameters study for yield and quality traits in tomato. *The Asian J. Horti,*. 3(2): 222-225.
26. .Tiwari, J.K. and D. Upadhyay, 2011. Correlation and Path-coefficient Studies in Tomato (Lycopersicon esculentum Mill.). *Res. J. of Agri. Sci.,* 2(1): 63-68.

Table 1. Analysis of variance for yield, yield contributing and quality characters in tomato

S.No.	Characters	Replications df=2	Treatment df= 36	Error df=72
1	PH	263.489	1694.068**	88.104
2	NPB	2.380	4.756**	0.250
3	DFF	0.250	12.207**	0.627
4	NFC	0.135	0.701**	0.123
5	NFrC	0.138	0.878**	0.074
6	FL	0.253	1.183**	0.083
7	FW	0.016	1.566**	0.029
8	AFW	9.585	832.182**	2.796
9	YPP	0.926	1.758**	0.014
10	NLP	0.276	1.885**	0.179
11	PT	0.003	1.755**	0.065
12	TSS	0.003	0.4797**	0.048
13	TA	0.029	0.053**	0.005
14	AA	417.923	135.245**	0.040
15	LY	0.062	16.351**	0.165
16	SL	1.124	8.167**	0.661

ISSN 2347 – 8691

Table 2: Correlation coefficients at genotypic (G) and phenotypic (P) level of various characters in tomato genotypes.

Character		PH	NPB	DFF	NFC	NFrC	FL	FW	AFW	NLF	PT	TSS	TA	AA	LY	SL	YPP
PH	G	**1.000**	0.352**	-0.042	0.162	0.042	-0.332**	-0.141	-0.338**	0.057	-0.018	0.345**	-0.263**	0.017	-0.206*	0.322**	0.068
	P	**1.000**	0.323**	-0.035	0.124	0.069	-0.288**	-0.116	-0.312**	0.056	0.010	0.311**	-0.203*	0.016	-0.194*	0.263**	0.067
NPB	G		**1.000**	-0.605**	0.036	0.274**	-0.399**	-0.223*	-0.167	-0.118	0.042	0.179	0.136	0.225*	0.098	0.199*	0.171
	P		**1.000**	-0.555**	-0.012	0.239*	-0.335**	-0.188*	-0.152	-0.073	0.052	0.095	0.097	0.208*	0.087	0.154	0.141
DFF	G			**1.000**	0.082	-0.178	0.333**	0.251**	0.124	0.251**	-0.227*	-0.157	-0.100	-0.197*	-0.128	-0.386**	-0.308**
	P			**1.000**	0.045	-0.156	0.306**	0.221*	0.111	0.167	-0.191*	-0.101	-0.079	-0.181	-0.100	-0.291**	-0.286**
NFC	G				**1.000**	0.226*	0.440**	-0.032	0.270**	-0.271**	0.322**	0.326**	-0.163	0.204*	-0.054	0.067	0.371**
	P				**1.000**	0.196*	0.278*	-0.038	0.212**	-0.172	0.262**	0.245**	-0.120	0.162	-0.055	0.041	0.275**
NFrC	G					**1.000**	0.034	-0.362**	-0.038	-0.248**	-0.120	0.029	0.004	0.286**	-0.191*	0.134	0.200*
	P					**1.000**	0.006	-0.308**	-0.026	-0.183	-0.093	0.074	0.030	0.250**	-0.151	0.158	0.182
FL	G						**1.000**	0.503**	0.709**	0.197*	0.489**	-0.101	-0.050	-0.246**	-0.165	-0.006	0.352**
	P						**1.000**	0.460**	0.639**	0.152	0.443**	-0.133	-0.057	-0.223*	-0.156	-0.076	0.309**
FW	G							**1.000**	0.667**	0.746**	0.410**	-0.355**	0.155	-0.317**	-0.032	-0.069	0.271**
	P							**1.000**	0.646**	0.659**	0.398**	-0.308**	0.124	-0.308**	-0.031	-0.089	0.268**
AFW	G								**1.000**	0.317**	0.734**	-0.218*	0.020	-0.367**	-0.150	-0.116	0.522**
	P								**1.000**	0.275**	0.693**	-0.188*	0.020	-0.365**	-0.148	-0.101	0.512**
NLF	G									**1.000**	0.050	-0.171	0.189*	-0.097	-0.054	-0.147	0.113
	P									**1.000**	0.057	-0.142	0.110	-0.085	-0.046	-0.125	0.107
PT	G										**1.000**	0.136	-0.135	-0.234*	-0.100	0.081	0.655**
	P										**1.000**	0.108	-0.127	-0.221*	-0.096	0.049	0.611**
TSS	G											**1.000**	-0.218*	0.155	0.042	0.163	0.042
	P											**1.000**	-0.206*	0.134	0.051	0.163	0.057
TA	G												**1.000**	-0.103	0.056	-0.035	-0.108
	P												**1.000**	-0.093	0.070	0.005	-0.101
AA	G													**1.000**	0.101	0.018	-0.013
	P													**1.000**	0.099	0.019	-0.013
LY	G														**1.000**	0.052	0.031
	P														**1.000**	0.059	0.028
SL	G															**1.000**	0.276*
	P															**1.000**	0.231*
YPP	G																**1.000**
	P																**1.000**

If correlation coefficient (r) ≥ 0.187 and 0.243, significant at 5% (*) and 1% (**) level respectively.

PH=Plant height (cm), NPB = No. of primary branches/ plant, DFF = Days to 50% flowering, NFC = No. of flowers/ cluster, NFrC = No. of fruits/ cluster, FL = fruit lenth (cm), FW = fruit width (cm), AFW = Average Fruit Weight (gm), NLF = No. of locules/ fruit, PT= Pericarp thickness (mm), TSS = Total Soluble Solids, TA = Titrable Acidity (%), AA = Ascorbic Acid (mg/100g), LY = Lycopene (mg/100g), SL = Shelf life (days) and YPP = yield/ plant (kg).

Table 3: Phenotypic direct effect (bold) and indirect effects of various characters on fruit yield per plant of tomato genotypes.

Character	PH	NPB	DFF	NFC	NFrC	FL	FW	AFW	NLF	PT	TSS	TA	AA	LY	SL	r_p
PH	**0.206**	0.066	-0.007	0.026	0.014	-0.059	-0.024	-0.064	0.011	0.002	0.064	-0.042	0.003	-0.040	0.054	0.067
NPB	-0.028	**-0.085**	0.047	0.001	-0.020	0.029	0.016	0.013	0.006	-0.004	-0.008	-0.008	-0.018	-0.007	-0.013	0.140
DFF	0.009	0.139	**-0.251**	-0.011	0.039	-0.077	-0.055	-0.028	-0.042	0.048	0.025	0.020	0.045	0.025	0.073	-0.286**
NFC	0.006	-0.001	0.002	**0.049**	0.010	0.014	-0.002	0.010	-0.008	0.013	0.012	-0.006	0.008	-0.003	0.002	0.275**
NFrC	0.011	0.038	-0.025	0.031	**0.160**	0.001	-0.049	-0.004	-0.029	-0.015	0.012	0.005	0.040	-0.024	0.025	0.182
FL	-0.019	-0.022	0.020	0.018	0.000	**0.066**	0.030	0.042	0.010	0.029	-0.009	-0.004	-0.015	-0.010	-0.005	0.309**
FW	0.007	0.011	-0.013	0.002	0.018	-0.027	**-0.059**	-0.038	-0.039	-0.024	0.018	-0.007	0.018	0.002	0.005	0.268**
AFW	-0.130	-0.063	0.046	0.088	-0.011	0.265	0.268	**0.415**	0.114	0.288	-0.078	0.008	-0.152	-0.061	-0.042	0.513**
NLF	0.005	-0.007	0.016	-0.017	-0.018	0.015	0.064	0.027	**0.098**	0.006	-0.014	0.011	-0.008	-0.004	-0.012	0.107
PT	0.003	0.016	-0.058	0.079	-0.028	0.134	0.121	0.210	0.017	**0.303**	0.033	-0.038	-0.067	-0.029	0.015	0.611**
TSS	-0.017	-0.005	0.005	-0.013	-0.004	0.007	0.016	0.010	0.008	-0.006	**-0.053**	0.011	-0.007	-0.003	-0.009	0.057
TA	0.011	-0.005	0.004	0.006	-0.002	0.003	-0.006	-0.001	-0.006	0.007	0.011	**-0.052**	0.005	-0.004	0.000	-0.101
AA	0.002	0.024	-0.021	0.019	0.029	-0.026	-0.036	-0.042	-0.010	-0.026	0.015	-0.011	**0.115**	0.011	0.002	-0.013
LY	-0.033	0.015	-0.017	-0.009	-0.025	-0.026	-0.005	-0.025	-0.008	-0.016	0.009	0.012	0.017	**0.168**	0.010	0.028
SL	0.033	0.019	-0.036	0.005	0.020	-0.009	-0.011	-0.013	-0.016	0.006	0.020	0.001	0.002	0.007	**0.125**	0.231*

If $r_p \geq 0.187$ and 0.243 ,* and ** indicate significant at 5% and 1% probability level respectively; $R^2 = 0.563$, Residual effect = 0.6608; r_p = Phenotypic correlation, PH=Plant height (cm), NPB = No. of primary branches/ plant, DFF = Days to 50% flowering, NFC = No. of flowers/ cluster, NFrC = No. of fruits/ cluster, FL = fruit lenth (cm), FW = fruit width (cm), AFW = Average Fruit Weight (gm), NLF = No. of locules/ fruit, PT= Pericarp thickness (mm), TSS = Total Soluble Solids, TA = Titrable Acidity (%), AA = Ascorbic Acid (mg/100g), LY = Lycopene (mg/100g), SL = Shelf life (days) and YPP = yield/ plant (kg).

Table 4:Genotypic direct effect (bold) and indirect effects of various characters on fruit yield per plant of tomato genotypes.

Character	PH	NPB	DFF	NFC	NFrC	FL	FW	AFW	NLF	PT	TSS	TA	AA	LY	SL	r_g
PH	**-0.196**	-0.069	0.008	-0.032	-0.008	0.065	0.028	0.066	-0.011	0.004	-0.068	0.052	-0.003	0.040	-0.063	0.068
NPB	0.000	**0.001**	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.171
DFF	0.004	0.057	**-0.094**	-0.008	0.017	-0.031	-0.023	-0.012	-0.024	0.021	0.015	0.009	0.018	0.012	0.036	-0.308**
NFC	0.078	0.017	0.039	**0.479**	0.108	0.211	-0.015	0.129	-0.130	0.154	0.156	-0.078	0.098	-0.026	0.032	0.371**
NFrC	0.010	0.067	-0.043	0.055	**0.244**	0.008	-0.088	-0.009	-0.060	-0.029	0.007	0.001	0.070	-0.046	0.033	0.200*
FL	0.064	0.077	-0.065	-0.085	-0.007	**-0.194**	-0.097	-0.137	-0.038	-0.095	0.019	0.010	0.048	0.032	0.001	0.352**
FW	0.054	0.086	-0.097	0.012	0.140	-0.194	**-0.386**	-0.257	-0.288	-0.158	0.137	-0.060	0.122	0.012	0.027	0.271**
AFW	0.038	0.019	-0.014	-0.030	0.004	-0.079	-0.074	**-0.111**	-0.035	-0.082	0.024	-0.002	0.041	0.017	0.013	0.522**
NLF	0.038	-0.079	0.168	-0.181	-0.166	0.131	0.498	0.212	**0.667**	0.033	-0.114	0.126	-0.065	-0.036	-0.098	0.113
PT	-0.014	0.033	-0.178	0.253	-0.094	0.385	0.322	0.576	0.039	**0.786**	0.107	-0.106	-0.184	-0.079	0.064	0.655**
TSS	-0.103	-0.054	0.047	-0.098	-0.009	0.030	0.106	0.065	0.051	-0.041	**-0.299**	0.065	-0.046	-0.013	-0.049	0.042
TA	0.036	-0.019	0.014	0.022	-0.001	0.007	-0.021	-0.003	-0.026	0.018	0.030	**-0.137**	0.014	-0.008	0.005	-0.108
A	-0.002	-0.032	0.028	-0.029	-0.041	0.035	0.045	0.053	0.014	0.033	-0.022	0.015	**-0.143**	-0.014	-0.003	-0.013
LY	-0.026	0.012	-0.016	-0.007	-0.024	-0.021	-0.004	-0.019	-0.007	-0.012	0.005	0.007	0.013	**0.125**	0.006	0.031
SL	0.088	0.054	-0.105	0.018	0.037	-0.002	-0.019	-0.032	-0.040	0.022	0.045	-0.009	0.005	0.014	**0.272**	0.276**

If $r_g \geq 0.187$ and 0.243 ,* and ** indicate significant at 5% and 1% probability level respectively; $R^2 = 0.684$, Residual effect = 0.562; r_g = Phenotypic correlation, PH=Plant height (cm), NPB = No. of primary branches/ plant, DFF = Days to 50% flowering, NFC = No. of flowers/ cluster, NFrC = No. of fruits/ cluster, FL = fruit lenth (cm), FW = fruit width (cm), AFW = Average Fruit Weight (gm), NLF = No. of locules/ fruit, PT= Pericarp thickness (mm), TSS = Total Soluble Solids, TA = Titrable Acidity (%), AA = Ascorbic Acid (mg/100g), LY = Lycopene (mg/100g), SL = Shelf life (days) and YPP = yield/ plant (kg).

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