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GENETIC VARIABILITY AND CHARACTER ASSOCIATION ANALYSIS FOR QUANTITATIVE AND QUALITATIVE TRAITS IN TOMATO (*SOLANUM LYCOPERSICUM* L.) HYBRIDS UNDER PROTECTED ENVIRONMENT

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ABSTRACT

The present study was carried out with ten tomato hybrids in polyhouse at experimental farm Department of Agriculture Guru Nanak college, Budhlada (Mansa) Punjab during Rabi 2020-21 to assess the genetic variability and character association analysis for Quantitative and qualitative traits in tomato (*Solanum lycopersicum* L.) hybrids for protected environment. The experiment was laid out in randomized block design with three replications. Data were recorded for fourteen Quantitative and qualitative characters. The experimental results revealed considerable differences among the genotypes for all the characters. Higher phenotypic and genotypic coefficients of variation (GCV, PCV) were observed for total number of fruits per plant, plant height, and total soluble solid. Moderate level of GCV and PCV was recorded for flowering days, number of locules per fruit, fruit yield per plant, number of fruit per cluster, number of flower per cluster, fruit diameter, number of cluster per plant, fruit length. High heritability together with high genetic advance as % of mean was observed in all the characters. Plant height, number of cluster per plant, pericarp thickness, total soluble solids, total number of fruit per plant, number of flower per cluster and number of fruits per cluster showed positive and significant connection with fruit yield /plant. Path coefficient analysis highest positive direct effects on fruit yield /plant was shown by total number of fruits per plant, plant height and number of locule per fruit, pericarp thickness, total soluble solid, fruit length could be reliable selection parameters for evolving high yielding genotypes
Keywords **:** Tomato, Genetic variability, Character association, Fruit yield

Introduction

Tomato (*Solanum lycopersicum* L.) is a self-pollinated crop that belongs to the family Solanaceae with chromosome number (2n=2x=24) and native to Central and South America (Vavilov, 1951). Popularly tomato is called as ***'Love Apple'***. Tomato is being cultivated in most of the countries of the world with global production of 183.9 million mt from an area of 7.6 million ha (Anonymous, 2018). China is the major producer of tomatoes in the world followed by India, the USA, Turkey, and Egypt. In India, tomato is cultivated in all agro-climatic regions under an area of about 8.09 lakh hectares with a production of 19.70 million mt (Anonymous, 2018), and the productivity is 25 mt per hectare (Anonymous, 2018). Tomatoes fruit has high demand in local and national markets Throughout the year production is not possible in open field conditions due to the susceptibility of crops to several biotic and abiotic stresses; to overcome these stresses, protected cultivation is the best substitute (Sinha *et al*., 2020).

In greenhouses, tomatoes are grown because it utilizes vertical space inside greenhouse; give slow and regular picking of fruit and producing higher fruit yield.

It offers many benefits to the producers like; earliness, higher quality, and productivity, pesticide residue free produce with higher returns to growers. As per the crop species, the microclimate surrounding the crop is partially/ fully controlled, so protected cultivation is a specialized and unique form of agriculture. Despite its economic importance, growers are not in a position to produce a good quality tomato with high productivity due to various biotic (pest and disease), abiotic (rainfall, temperature, relative humidity, and light intensity), and crop factors (flower and fruit drop). Identification of suitable hybrids is the most important factor for raising crops in a protected environment. Generally, under-protected environmental conditions indeterminate hybrids of tomatoes having the character of creeping nature are considered best for higher yield and high return due to their longer period growth and utilize vertical space (Singh and Kumar, 2017). Knowledge about the nature and level of inter-relationship of yield and other components is very valuable because selection based on one trait may directly or indirectly affect the performance of another trait. Therefore, assessment of inter-relationships among a number of component characters is an important requisite to bring improvement in desired direction. Path coefficient analysis partitions correlation coefficient into direct and indirect effect and gives information about the direct and indirect contribution made by different traits towards yield. Keeping all these facts in consideration, the present investigation was carried out.

Material and Method

The present study was conducted in poly house at experimental farm Department of Agriculture Guru Nanak College Budhlada during Rabi 2020-21 to identify superior tomato hybrids for polyhouse cultivation. Ten tomato hybrids were obtained from public and private sectors for this study (Annexure-1). Seedlings were raised in portrays filled with potting mixture. The tomato hybrids used for this experiment were laid out in RBD with three replications. The poly house is provided micro irrigation system with fogger unit to control temperature and humidity. Seedlings were raised in portrays filled with potting mixture. Transplanting was done at a spacing of 60 x 60 cm in raised beds. The observation were recorded for morphological traits such as Days to flowering, Days to first fruiting, no. of cluster per plant and no. of flower per cluster, no. of fruit per cluster, Total no. of fruit per plant and plant height(cm), fruit length, fruit diameter, no. of locule per fruit and Pericarp thickness, Total soluble solids (brix), average fruit weight(gm), fruit yield per plant (kg), for qualitative traits like fruit shape, Immature fruit skin colour and Mature fruit skin colour, leaf /foliage coverage, Stem pigmentation, pulpiness and plant habits and final fruit firmness. All mean values of the data taken randomly for each trait from five different plants from each treatment from all replication was used for further statistical study. Analysis of variance was analyzed as suggested by (Panse and Sukhatme, 1985).

Results and Discussion

Data from analysis of variance shown that mean sum of squares of all the genotypes were significant (Table-1) for Days to flowering, Days to first fruiting, no. of cluster per plant and no. of flower per cluster, no. of fruit per cluster, Total no. of fruit per plant and plant height (cm), fruit length, fruit diameter, no. of locule per fruit and Pericarp thickness (mm), Total soluble solids (brix), average fruit weight(gm), fruit yield per plant (kg),fruit shape, Immature fruit skin colour and Mature fruit skin colour, leaf /foliage coverage, Stem pigmentation, pulpiness and plant habits and final fruit firmness which indicate the ample of genetic variability exists in the genotypes. Thus there is abundant scope for selection of promising genotypes. Analogous finding were also reported by Hasan *et al*. (2016), Kumar *et al*. (2017) and panchbhaiya *et al*. (2018).

The estimates of variability showed that PCV were higher in magnitude than their corresponding GCV for all the characters (table 2), indicating variation is due to environmental factors present during the growing season of crop which influences their expression. Thus, selection for these traits might be unpredictable in nature. (Panchbhaiya *et al*., 2018) and (Ritonga *et al*., 2018) also observed high PCV values than the corresponding GCV values. High level of GCV and PCV were observed in total no. of fruits per plant (35.38%, 35.72%) after that plant height (29.78%, 29.86%), total soluble solids (27.06%, 27.29%) These high estimates indicate ample scope for enhancement of these traits through simple selection. High degree for PCV and GCV was reported by (Lekshmi and Celine 2017) and (Panchbhaiya *et al*., 2018).Moderate level of GCV and PCV was recorded for flowering days (22.20%, 22.41%), number of locules per fruit (19.38%, 20.13%),fruit yield per plant (17.51%, 18.88%), number of fruit per cluster (19.13%, 20.49%), number of flower per cluster (17.52%, 18.52%), Fruit diameter (11.17%, 13.51%), number of cluster per plant (16.55%, 17.37), fruit length (13.89%, 14.93%)The moderate estimates suggest that direct selection for these traits should be considered cautiously. Moderate estimates for GCV and PCV were reported by (Lekshmi and Celine 2017) and (Panchbhaiya *et al*., 2018). Low level of GCV and PCV was seen in Pericarp thickness (10.79%, 11.41%), average fruit weight (8.00%, 8.29%) and days to first fruiting (5.42%, 6.06%) Similar finding was also noted by (Rai *et al*., 2016)

By GCV and PCV alone, it is not possible to determine the amount of variation which is heritable. The heritability along with genetic advance is more meaningful and helps in predicating the resultant effect of selection on phenotypic expression (Johnson, 1955). High heritability estimates (>60%) were recorded for all the characters. High heritability together with high genetic advance as % of mean was observed in plant height (99.49 %, 61.19%), total soluble solids (98.35%, 55.29%), total number of fruits per plant (98.08%, 72.18%), flowering days (98.11%, 45.29%), days to first fruiting (80.14%,10.00%) and number of cluster per plant (90.77%, 32.49%), number of flower per cluster (89.51%, 34.14%), number of fruits per cluster (87.16%, 36.78%), fruit length (86.60%, 26.63%), fruit diameter (68.31%, 19.02%), number of locule per fruit (92.76%, 38.46%), pericarp thickness of fruit (89.49%, 21.03%), average fruit weight (92.95%, 15.88%), fruit yield per plant (86.01%, 33.45%) indicating strong influence of additive gene action and phenotypic selection is effective for these traits. Analogous observations were found by (Lekshmi and Celine 2017); (Ritonga *et al*., 2018); (Tasis *et al*., 2012) and (Meitei *et al.,* 2014).

The knowledge about the nature and level of inter-relationship of yield and other components is very valuable because selection based on one trait may directly or indirectly affect the performance of another trait. Assessment of interrelationships among a number of component characters is, therefore, an important requisite to bring improvement. In the present study, in general, the genotypic correlation coefficients were higher in magnitude than the corresponding phenotypic correlation (Table 3a &3b). High genotypic correlation coefficients revealed that there was heritable correlation among the characters. (Sehgal *et al*., 2018) and (Sharma *et al*., 2019), also observed similar result in their study (Anuradha Sinha *et al.,* 2020), (Md. Mehedi Hasan *et al.,* 2016).

At both genotypic and phenotypic level, plant height (0.728, 0.663), number of cluster per plant (0.726, 0.670), pericarp thickness (0.654, 0.553), total soluble solids (0.586, 0.544), total number of fruit per plant (0.715, 0.643), number of flower per cluster (0.445, 0.384) and number of fruits per cluster (0.515, 0.411) showed positive and significant

connection with fruit yield /plant. Selection on the basis of these traits might lead to higher yield Present study confirms the result of (Ritonga *et al*., 2018) and (Sharma *et al*., 2019)

Whereas, number of locule per fruit (0.376, 0.325) and average fruit weight (0.367, 0.313) showed positive correlation with fruit yield at genotypic level but on phenotypic level it was positive insignificant relationship (Anuradha Sinha *et al*., 2020).

Fruit Yield per plant also showed positive but insignificant relationship with fruit length (0.126, 0.117), fruit diameter (0.302, 0.245), similar results were recorded by (Sharma and Singh 2012) and (Kumar *et al.,* 2020), (Anvita Sharma *et al.,* 2021).

Path coefficient analysis is yield is the sum total of the many component characters which directly or indirectly contributed to it. Correlation studies give an idea about the positive and negative associations of different characters with yield and also among themselves. But the nature and extent of contribution of these characters towards yield is not obtained. Path coefficient analysis was used to make partition of the correlation coefficient of the different characters studied to know direct and indirect effects on yield. The information obtained helps in giving proper weightage to the various characters during selection or other breeding program so that the improvement of desirable traits can be achieved effectively (Md. Mehedi Hasan, 2016).

The path coefficient analysis allows partitions of correlation coefficients into direct and indirect effects of various traits towards dependent variable and thus, helps in forming proficient selection approach. The direct effects obtained at genotypic level were markedly different from those at phenotypic level (Table 4a & 4b). These differences might be due to varying degree of influence of environment on various traits studied. Highest positive direct effects on fruit yield /plant was shown by total number of fruits per plant (1.0104), plant height (0.7460) and number of locule per fruit (0.8537), pericarp thickness (0.0906), total soluble solid (0.2318), fruit length (0.3485) which suggests that it may considered as a prime trait for enhancing yield. (Ritonga *et al*., 2018), (Sehgal *et al*., 2018) and (Sharma *et al*., 2019) also reported direct and positive effects of these traits. (Kumar *et al.,* 2020) and (Anvita Sharma *et al.,* 2021). Negative and direct effect on fruit yield /plant were shown by number of cluster per plant (-0.1892), number of flower per cluster (-0.0606), fruit diameter (-0.3549) and average fruit weight (-0.1570) at genotypic and phenotypic level.

Maximum positive indirect effect on fruit yield per plant was exerted by number of cluster per plant via total number of fruit per plant (0.9825), plant height (0.4128), fruit length (0.1748), pericarp thickness (0.0581), total soluble solid (0.2119). However, indirect effect was negative via number of fruit per cluster (-0.3965) and number of flower per cluster (-0.0550). Number of flower per cluster was recorded to have positive indirect effect on fruit yield per plant through total number of fruit per plant (0.9415), fruit length (0.2605) and number of locule per fruit (0.3723), total soluble solid (0.2119). However the negative indirect effect was expressed via flowering days (-0.5596),number of cluster per plant (-0.1719) and number of fruits per cluster (-0.4350), fruit diameter (-0.2804), average fruit weight(-0.0711). Number of Fruit per cluster revealed high values of positive indirect effect on fruit yield per plant through total number of fruits per plant (0.9575), plant height(0.3733), fruit length(0.2100) number of locule per fruit(0.2366), pericarp thickness (0.0545) and total soluble solid (0.2162). However, negative indirect effect was exhibited in the characters i.e. average fruit weight (-0.0780), number of cluster plant (-0.1635). Total number of fruits per plant expressed a positive indirect effect on fruit yield per plant through plant height (0.4419), fruit length (0.1814), number of locule per fruit (0.2755) and pericarp thickness(0.0626), total soluble solid (0.2260). However, rest of the characters showed negative indirect effect viz., average fruit weight (-0.0771), fruit diameter (-0.2239), number of fruits per cluster (-0.4349). Highest positive indirect effect of plant height on fruit yield per plant was recorded through total soluble solid (0.1199). However, negative indirect effect was exhibited via, average fruit weight (-0.0887). Number of locule per fruits expressed a positive indirect effect on fruit yield per plant through fruit length (0.2057). However high negative indirect effect exhibited via, average fruit weight (-0.0653). Pericarp thickness revealed high values of positive indirect effect on fruit yield per plant through plant height (0.3807), total soluble solid (0.1723) and total number of fruits per plant (0.6982). However, negative indirect effect was shown through average fruit weight (-0.0542). Total soluble solid manifested highest positive indirect effect on fruit yield per plant through total number of fruits per plant (0.9851), plant height (0.3859), pericarp thickness (0.0673) However, rest of the characters showed negative indirect effect viz., average fruit weight (-0.0771), fruit diameter (-0.2373), number of fruits per cluster (-0.4281). Similar results were observed by (Joshi *et al*. 2019), (Hossain *et al*., 2016), (Rahman *et al*., 2015) and (Nagariya *et al*., 2015), Prajapati *et al*. (2015).

Conclusion

On the basis findings, it can be concluded that wide range of genetic variability are exists in present set of genetic material except few traits. Thus, there is abundant scope for selection of promising genotypes. Furthermore, high GCV, heritability and genetic advance as % of mean found in total number of fruits per plant, plant height, and total soluble solid show preponderance of additive gene action thus there is abundant scope for the enhancement of these traits through selection. Total number of fruits per plant, plant height and number of locule per fruit, pericarp thickness, total soluble solid and fruit length had high positive direct effects on fruit yield per plant at both genotypic and phenotypic level which suggests that direct selection for these characters may be effective and may be considered as a prime trait for enhancing yield. So these genotypes can be used for parent for future breeding programme.

Table 1 : Analysis of variance for different characters in tomato hybrids

Source of variation	DF	Flowering days	Days to first fruiting	No. of cluster / plant	Number of flower/cluster	Number of fruits/ cluster	Total number of fruits / plants	Plant height
Replication	2	11.03	27.74	3.23	1.95	1.29	31.73	19.59
Treatment	9	213.25**	65.01**	6.01**	3.70**	1.12**	246.91**	3762.08**
Error	18	1.36	4.96	0.20	0.14	0.05	1.60	6.38
Total	29	67.79	25.17	2.21	1.37	0.47	79.81	1172.86

Source of variation	DF	Fruit length	Fruit diameter	Number of locule/fruit	Pericarp thickness	Total soluble solids	Average fruit weight	Fruit yield/ plant
Replication	2	0.27	0.080	0.342	0.006	0.075	13.17	0.037
Treatment	9	1.66**	0.952**	0.948**	0.016**	2.382**	129.94**	0.252**
Error	18	0.08	0.128	0.024	0.001	0.013	3.20	0.013
Total	29	0.58	0.380	0.333	0.006	0.753	43.22	0.089

*, ** significant at 5% and 1% level, respectively

Table 2 : Estimates of genetic variability for various character of tomato hybrids

Characters	Mean	Range		GCV (%)	PCV (%)	ECV (%)	Var (g)	Var (p)	H^2 Broad sense	GA	GA% mean
		Min	max								
Flowering days	37.86	27.67	54.50	22.20	22.41	3.08	70.63	71.99	98.11	17.15	45.29
Days to first fruiting	82.49	76.60	92.00	5.42	6.06	2.70	20.02	24.98	80.14	8.25	10.00
No. of cluster / plant	8.41	6.00	10.67	16.55	17.37	5.28	1.94	2.14	90.77	2.73	32.49
Number of flower/cluster	6.22	4.33	8.27	17.52	18.52	6.00	1.19	1.33	89.51	2.12	34.14
Number of fruits/ cluster	3.12	2.40	4.40	19.13	20.49	7.34	0.36	0.41	87.16	1.15	36.78
Total number of fruits / plants	25.56	13.53	44.33	35.38	35.72	4.95	81.77	83.37	98.08	18.45	72.18
Plant height	118.81	95.47	202.53	29.78	29.86	2.13	1251.90	1258.28	99.49	72.70	61.19
Fruit length	5.21	3.40	5.98	13.89	14.93	5.47	0.52	0.61	86.60	1.39	26.63
Fruit diameter	4.69	3.88	5.70	11.17	13.51	7.61	0.27	0.40	68.31	0.89	19.02
Number of locule/fruit	2.86	2.17	3.80	19.38	20.13	5.42	0.31	0.33	92.76	1.10	38.46
Pericarp thickness	0.67	0.58	0.79	10.79	11.41	3.70	0.01	0.01	89.49	0.14	21.03
Total soluble solids	3.28	2.39	5.08	27.06	27.29	3.51	0.79	0.80	98.35	1.82	55.29
Average fruit weight	81.29	71.87	95.40	8.00	8.29	2.20	42.24	45.45	92.95	12.91	15.88
Fruit yield/ plant	1.61	1.24	2.12	17.51	18.88	7.06	0.08	0.09	86.01	0.54	33.45

Table 3a : Phenotypic correlationsfor different characters of tomato hybrids

Characters	Flowering days	Days to first fruiting	No. of cluster / plant	Number of flower/ cluster	Number of fruits/ cluster	Total number of fruits / plants	Plant height	Fruit length	Fruit diameter	Number of locule / fruit	Pericarp thickness	Total soluble solids	Average fruit weight	Fruit yield / plant
Flowering days	1.000	0.737**	-0.560**	-0.777**	-0.658**	-0.608**	-0.286	-0.845**	-0.594**	-0.577**	-0.019	-0.526**	-0.463*	-0.150
Days to first fruiting			-0.366*	-0.561**	-0.361*	-0.388*	-0.153	-0.680**	-0.538**	-0.645**	-0.029	-0.353	-0.350	-0.174
No. of cluster / plant				0.762**	0.718**	0.912**	0.528**	0.489**	0.463*	0.306	0.583**	0.867**	0.277	0.670**
Number of flower/cluster					0.887**	0.877**	0.410*	0.675**	0.616**	0.415*	0.361	0.846**	0.425*	0.384*
Number of fruits/ cluster						0.900**	0.474**	0.513**	0.423*	0.284	0.487**	0.848**	0.431*	0.411*
Total number of fruits / plants							0.591**	0.460*	0.505**	0.321	0.631**	0.950**	0.451*	0.643**
Plant height								0.124	0.390*	0.025	0.476**	0.511**	0.539**	0.663**
Fruit length									0.470**	0.541**	-0.141	0.386*	0.245	0.117
Fruit diameter										0.479**	0.273	0.519**	0.563**	0.245
Number of locule/fruit											-0.060	0.184	0.381*	0.325
Pericarp thickness												0.682**	0.336	0.553**
Total soluble solids													0.477**	0.544**
Average fruit weight														0.313
Fruit yield/ plant														1.000

*, ** significant at 5% and 1% level, respectively

Table 3b : Genotypic correlations for different characters of tomato hybrids

Characters	Flowering days	Days to first fruiting	No. of cluster / plant	Number of flower/ cluster	Number of fruits/ cluster	Total number of fruits / plants	Plant height	Fruit length	Fruit diameter	Number of locule / fruit	Pericarp thickness	Total soluble solids	Average fruit weight	Fruit yield / plant
Flowering days	1.000	0.808**	-0.592**	-0.824**	-0.718**	-0.620**	-0.290	-0.913**	-0.730**	-0.621**	-0.028	-0.533**	-0.476**	-0.154
Days to first fruiting			-0.461*	-0.625**	-0.445*	-0.433*	-0.168	-0.846**	-0.888**	-0.826**	-0.080	-0.378*	-0.400*	-0.204
No. of cluster / plant				0.908**	0.864**	0.972**	0.553**	0.502**	0.597**	0.323	0.641**	0.914**	0.283	0.726**
Number of flower/cluster					0.948**	0.932**	0.433*	0.747**	0.790**	0.436*	0.410*	0.915**	0.453*	0.445*
Number of fruits/ cluster						0.948**	0.500**	0.603**	0.563**	0.277	0.602**	0.933**	0.497**	0.515**
Total number of fruits / plants							0.592**	0.521**	0.631**	0.323	0.691**	0.975**	0.491**	0.715**
Plant height								0.142	0.484**	0.023	0.510**	0.517**	0.565**	0.728**
Fruit length									0.566**	0.590**	-0.186	0.419*	0.213	0.126
Fruit diameter										0.577**	0.192	0.669**	0.726**	0.302
Number of locule/fruit											-0.051	0.208	0.416*	0.376*
Pericarp thickness												0.743**	0.345	0.654**
Total soluble solids													0.491**	0.586**
Average fruit weight														0.367*
Fruit yield/ plant														1.000

*, ** significant at 5% and 1% level, respectively

Table 4a : Direct and indirect effects of different trait on fruit yield per plant of tomato hybrids at genotypic level

Characters	Flowering days	Days to first fruiting	No. of cluster / plant	Number of flower/cluster	Number of fruits/ cluster	Total number of fruits / plants	Plant height	Fruit length	Fruit diameter	Number of locule/fruit	Pericarp thickness	Total soluble solids	Average fruit weight	R with Fruit yield/ plant
Flowering days	**0.6794**	0.1593	0.1120	0.0499	0.3293	-0.6266	-0.2164	-0.3183	0.2592	-0.5305	-0.0026	-0.1234	0.0746	-0.154
Days to first fruiting	0.5493	**0.1970**	0.0872	0.0379	0.2041	-0.4372	-0.1255	-0.2949	0.3151	-0.7054	-0.0073	-0.0876	0.0628	-0.204
No. of cluster / plant	-0.4021	-0.0908	**-0.1892**	-0.0550	-0.3965	0.9825	0.4128	0.1748	-0.2119	0.2761	0.0581	0.2119	-0.0445	0.726**
Number of flower/cluster	-0.5596	-0.1232	-0.1719	**-0.0606**	-0.4350	0.9415	0.3232	0.2605	-0.2804	0.3723	0.0372	0.2119	-0.0711	0.445*
Number of fruits/ cluster	-0.4875	-0.0877	-0.1635	-0.0574	**-0.4589**	0.9575	0.3733	0.2100	-0.1997	0.2366	0.0545	0.2162	-0.0780	0.515**
Total number of fruits / plants	-0.4213	-0.0853	-0.1840	-0.0564	-0.4349	**1.0104**	0.4419	0.1814	-0.2239	0.2755	0.0626	0.2260	-0.0771	0.715**
Plant height	-0.1971	-0.0332	-0.1047	-0.0262	-0.2296	0.5985	**0.7460**	0.0496	-0.1718	0.0195	0.0462	0.1199	-0.0887	0.728**
Fruit length	-0.6206	-0.1667	-0.0949	-0.0453	-0.2765	0.5259	0.1062	**0.3485**	-0.2009	0.5037	-0.0169	0.0971	-0.0334	0.126
Fruit diameter	-0.4963	-0.1750	-0.1130	-0.0479	-0.2582	0.6374	0.3611	0.1973	**-0.3549**	0.4930	0.0174	0.1550	-0.1140	0.302
Number of locule/fruit	-0.4222	-0.1628	-0.0612	-0.0264	-0.1272	0.3260	0.0171	0.2057	-0.2049	**0.8537**	-0.0046	0.0481	-0.0653	0.376*
Pericarp thickness	-0.0192	-0.0158	-0.1214	-0.0249	-0.2762	0.6982	0.3807	-0.0650	-0.0683	-0.0433	**0.0906**	0.1723	-0.0542	0.654**
Total soluble solids	-0.3618	-0.0745	-0.1730	-0.0554	-0.4281	0.9851	0.3859	0.1460	-0.2373	0.1772	0.0673	**0.2318**	-0.0771	0.586**
Average fruit weight	-0.3231	-0.0789	-0.0536	-0.0274	-0.2281	0.4963	0.4214	0.0742	-0.2577	0.3553	0.0313	0.1138	**-0.1570**	0.367*

Resi = 0.115*, ** significant at 5% and 1% level, respectively

Table 4b : Direct and indirect effects of different trait on fruit yield per plant of tomato hybrids at phenotypic level

Characters	Flowering days	Days to first fruiting	No. of cluster / plant	Number of flower/ cluster	Number of fruits/ cluster	Total number of fruits / plants	Plant height	Fruit length	Fruit diameter	Number of locule/ fruit	Pericarp thickness	Total soluble solids	Average fruit weight	R with Fruit yield/ plant
Flowering days	**0.4554**	0.0379	-0.0420	0.0222	0.2703	-0.3235	-0.1745	-0.1449	0.1407	-0.3330	-0.0022	-0.1187	0.0622	-0.150
Days to first fruiting	0.3356	**0.0514**	-0.0275	0.0161	0.1484	-0.2064	-0.0931	-0.1167	0.1274	-0.3726	-0.0034	-0.0797	0.0470	-0.174
No. of cluster / plant	-0.2551	-0.0188	**0.0750**	-0.0218	-0.2950	0.4852	0.3221	0.0840	-0.1097	0.1766	0.0693	0.1956	-0.0372	0.670**
Number of flower/cluster	-0.3537	-0.0288	0.0571	**-0.0286**	-0.3646	0.4666	0.2500	0.1157	-0.1460	0.2395	0.0429	0.1909	-0.0570	0.384*
Number of fruits/ cluster	-0.2996	-0.0186	0.0539	-0.0254	**-0.4109**	0.4791	0.2894	0.0880	-0.1003	0.1639	0.0579	0.1913	-0.0580	0.411*
Total number of fruits / plants	-0.2768	-0.0199	0.0684	-0.0251	-0.3699	**0.5322**	0.3607	0.0788	-0.1196	0.1855	0.0750	0.2143	-0.0606	0.643**
Plant height	-0.1302	-0.0078	0.0396	-0.0117	-0.1949	0.3147	**0.6101**	0.0213	-0.0923	0.0147	0.0566	0.1154	-0.0724	0.663**
Fruit length	-0.3847	-0.0350	0.0367	-0.0193	-0.2109	0.2446	0.0758	**0.1715**	-0.1113	0.3122	-0.0168	0.0871	-0.0329	0.117
Fruit diameter	-0.2703	-0.0276	0.0347	-0.0176	-0.1739	0.2686	0.2377	0.0806	**-0.2370**	0.2763	0.0324	0.1172	-0.0757	0.245
Number of locule/fruit	-0.2626	-0.0331	0.0229	-0.0119	-0.1166	0.1709	0.0155	0.0927	-0.1134	**0.5775**	-0.0071	0.0415	-0.0512	0.325
Pericarp thickness	-0.0085	-0.0015	0.0437	-0.0103	-0.2001	0.3357	0.2902	-0.0243	-0.0646	-0.0347	**0.1190**	0.1540	-0.0451	0.553**
Total soluble solids	-0.2395	-0.0182	0.0650	-0.0242	-0.3483	0.5054	0.3119	0.0662	-0.1231	0.1062	0.0812	**0.2257**	-0.0641	0.544**
Average fruit weight	-0.2107	-0.0180	0.0208	-0.0122	-0.1773	0.2402	0.3287	0.0420	-0.1334	0.2200	0.0399	0.1076	**-0.1343**	0.313

Resi = 0.164*, ** significant at 5% and 1% level, respectively

(Annexure-1)
Material used for experiment

Sr. no.	Name of Hybrids	Sources
1	NS 4266	Namdhari Seeds (I) Pvt Ltd
2	POLYANA	Fitto Seed Co. Bengaluru
3	HIMSHIKHER	Syngenta Seed Co. Ltd
4	US 1083	Us Agri Seed
5	US 3383	Us Agri Seed
6	ABHINAV	Syngenta Seed Co. Ltd
7	SHAKTIMAN	Namdhari Seeds (I) Pvt Ltd
8	NS-585	Namdhari Seeds (I) Pvt Ltd
9	LAXMI	Nunhems Seeds(I) Pvt Ltd
10	LOCAL	Local Purchase

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