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Association of characters and path coefficient analysis of tomato genotypes

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Abstract
Tomato (*Solanum lycopersicum* L.) an autogamous diploid (2n = 2X = 24) vegetable belonging to nightshade family (Solanaceae) is an important warm season vegetable, suitable for growing throughout the world. The yield of Indian Tomato falls short of the global average. To increase productivity, better varieties and hybrids must be developed. The type, extent, and transmissibility of genetic diversity as well as the degree of targeted character transmission all affect selection efficiency. Since yield has a complex character, improving it directly is challenging. To investigate the kind and extent of variability, correlation and path coefficient analysis between yield and yield-contributing characters, 30 genotypes and 4 checks of tomatoes were examined. The experiment's statistical analysis was set up using an Augmented-II design (Also known as an Augmented RBD), which was seeded in 3 rows and 5 blocks. All of the genotypes for the characters had significant differences, according to the analysis of variance. a stronger link between days to first and the positive. On a genotypic and phenotypic basis, there is a higher amount of positive association between the days to first flowering, days to 50% blooming, days to first fruit set, and days to first picking. At the genotypic level, a negative correlation between fruit production per plant and days till the first harvesting was discovered (-0.447*G). Genotypically, the quantity of fruits per plant (0.7386) and days to first flowering (-0.5494) had the greatest positive and negative direct effects on yield, respectively.

Keywords: Improving, level, negative

Introduction
Tomato (*Solanum lycopersicum* L.) is an autogamous diploid (2n = 2X = 24) vegetable belonging to nightshade family (Solanaceae). The Andean Mountain ranges of Peru, Ecuador, and Bolivia are the regions, tomato is said to have originated. Mexico, the secondary centre of origin of the cultivated tomato, has the highest density of wild species. Almost all agro-ecological zones, including tropical, subtropical, and temperate temperatures, are feasible for producing tomatoes (Rick, 1969) [17]. In India, currently tomato is grown in 8,65,000 ha of area having a production of 21.06 million MT (Anonymous, 2021) [2]. Andhra Pradesh (3146.96 ton), Madhya Pradesh (2511.89 ton) and Karnataka (1775.79 ton) are the top three tomato producing states in India with a percentage share of 16.22%, 12.95% and 9.16% respectively (Anonymous, 2019) [1].
An important warm season vegetable, tomato is suitable for growing throughout the world. A major boost to tomato cultivation in the country was achieved by the introduction of high yielding and superior quality exotic cultivars like Sioux, Best of All, Roma, Money Maker and Marglobe from 1950 onwards. Over the years, indigenous high-yielding cultivars have been developed from the local cultivars, land races, early introductions and more significantly, the newly introduced cultivars and breeding lines.
Tomato has been developed to increase production, fruit quality, and resilience to biotic and abiotic stress owing to its significance as a staple food. It is a treasure trove of nutrients and yet regarded as a magnificent fruit-bearing crop (Kimura & Sinha, 2008) [9]. This research assessed the intensity to which morphological and biochemical parameters in tomato were associated with one another in order to investigate potential relationship.

Materials and Methods
The present investigation was carried out at the Vegetable Research Centre, Govind Ballabh Pant University of Agriculture & Technology Pantnagar. In the proposed study, the experiment samples were comprised of 30 genotypes and four checks were sown in Augmented-II design with five blocks during Rabi season, 2021.

Each genotype was sown in 3rows by following the spacing of 50 x 50 centimeters. All the recommended cultural practices as per Vegetable Research Centre, GBPUA &T, Pantnagar, were followed.

Statistical analysis of the experiment was laid out in Augmented –II design (Augmented RBD). The genotypes were sown in 3 rows and in 5 blocks of length 20m x 3m at spacing of 50 x 50 cm. Four checks were replicated in five blocks randomly. Data was collected on 5 randomly chosen plants from each entry for all the parameters. For statistical evaluation, the mean values of five plants were used.

Results and Discussion

Correlation is a statistical word that refers to the extent to which two variables move in lockstep. A positive correlation exists when the two variables move in the same direction. A negative correlation exists when they move in opposite directions. The correlation coefficient, r, varies from –1 to +1; r = 1 denotes a perfect (100 per cent) correlation, meaning that both features vary in the same direction positively (positive correlation). On the other hand, r = –1 indicates that two characters have a 100 per cent association but differ in opposite directions (negative correlation). And r = 0 implies that the two characters have no relationship at all, that they are completely independent of one another.

Positive correlation

The perusal of the data represented in the table 1, signifies higher level of positive correlation between days to first flowering, days to 50% flowering, days to first fruit set and days to first picking on genotypic and phenotypic basis. This value indicates the earliness in first flowering will induce earliness in first fruit set and first picking. These results are in close proximity with the finding of Namdev and Dongre, (2018) [12]. Similarly, the yield per plant was significantly and positively correlated with the number of fruits per plant (0.731**G, 0.687**P) and average fruits weight (0.516*G, 0.479*P) on both genotypic and phenotypic level. As a result, the findings show that selecting the genotypes on the basis of average number of fruit per plant and average fruit weight would result in enhanced tomato yield. The outcomes are aligned with Patil and Bajappa (1993) [14], Singh *et al.* (1997) [18], Ara *et al.* (2009) [3] and Khapte and Jansirani (2014) [8]. It is also found that, average number of fruits per plant also positively associated with pericarp thickness (0.388*G, 0.3192 P).

TSS content showed positive significant correlation with plant height (0.356*G) genotypically along with pericarp thickness (0.457*P) phenotypically, whereas acidity has positive and significant correlation with number of locules per fruit (0.456*P) at phenotypic level. Ascorbic acid was found to be positively associated with plant height (0.348*G) genotypically as well as a very high, significant and positive correlation seen between ascorbic acid and acidity of fruit (0.646**G) at genotypic level. Lycopene content showed highly positive association with total carotenoids (0.884**G, 0.938**P) on both phenotypic and genotypic level, while a positive correlation found between total carotenoids and acidity of fruit (0.391*P) at phenotypic level. Lycopene content of tomato also showed a positive correlation with yield per plant (0.371*G) at genotypic level.

Negative correlation: Number of fruits per plant was found negatively correlated with days to first picking (-0.447*G) at genotypic level, whereas number of locules negatively correlated with pericarp thickness (-0.637**P) and TSS (-0.730**P) at phenotypic level of correlation. In both genotypic and phenotypic level, TSS is significantly and negatively associated with acidity (-0.492*P, -0.778**G) while in genotypic level TSS is negatively correlated with ascorbic acid content (- 0.946**G). The results are in accordance with Padda *et al.* (1971) [13] and Reddy *et al.* (2013) [16]

At phenotypic level of correlation matrix, total carotenoid content was resulted a negative correlation with TSS (-0.378*P). Total phenol content at genotypic level, negatively correlated with plant height (cm) (-0.428*G) and TSS (-0.820**G). At the same time there is a negative correlation seen between total phenol and ascorbic acid content (-0.795**G, -0.413*P) at both genotypic and phenotypic level.

Path coefficient analysis study

Path coefficient analysis is a methodology of multiple regression statistical analysis that examines the interactions between a dependent variable and two or more independent variables to investigate causal explanations. This method can be used to calculate the level and significance of relationships among the variables. In contrast to other methodologies, path analysis demands us to specify relationships between all of the independent variables. As a result, a model was constructed that shows how independent variables generate both direct and indirect impacts on a dependent variable.

The path coefficient study exhibits two types of effect on yield *viz*. direct and indirect effect. The direct effect of a variable assumed to be a cause on another variable assumed to be an effect is shown by a path coefficient while paths through intermediate variables cause an indirect effect (IE).

On the basis of genotypic path coefficient analysis (table 2), the highest direct positive effect on yield was concluded from number of fruits per plant (0.7508) followed by average fruit weight (0.6388) while the lowest direct positive effect was reported from Days to first fruit set (0.0116).The direct negative effect was noticed in lycopene content (-0.1570), total phenol content (-0.2164), days to first flowering (-0.479), acidity (-0.1145), pericarp thickness (-0.1479) along with ascorbic acid content (-0.0740) and TSS (-0.0334).

Phenotypically, the highest positive direct effect on yield (table 3) was recorded to be 0.7386 from number of fruits per plant followed by 0.6496 from average fruit weight (g) and 0.4519 from lycopene content of fruit. Total phenol content contributes lowest positive direct effect (0.0594) on yield per plant along with pericarp thickness (0.0627). Negative direct effect was noticed from Days to first flowering (-0.5494), TSS (-0.3678), days to first picking (-0.3374), total carotenoids (-0.2536), number of locules (-0.2290), acidity (-0.2079) and plant height (-0.1083). This results are in accordance with Kumar *et al.* (2013) [11], Tiwari and Upadhyay (2011) [19], Ghosh *et al.* (2010) [4], Rani *et al.* (2008) [15], Golani *et al.* (2007) [5] and Kumar *et al.* (2003) [10], Joshi and Singh (2003) [7] came up with similar results. Hayder *et al.* (2007) [6] also demonstrated that plant height, fruit weight and fruit length were all factors directly influence in determining tomato fruit yield.

Table 1: Genotypical and Phenotypical correlation between different pairs of character in tomato

		Days to first flowering	Days to 50% flowering	Days to first fruit set	Days to first picking	Plant height (cm)	Number fruits per plant	Average fruit weight (g)	Number of locules	Pericarp thickness (mm)	TSS (^{0} Brix)	Acidity (%)	Ascorbic acid (mg/ 100 g fruit wt)	Total carotenoides (mg/ 100 g wt)	Lycopene content (mg/ 100 g fruit wt)	Total phenol (mg/ 100 g fruit wt)	Yield per plant (Kg)
Days to first flowering	GP	1.0000	0.950** 0.699**	0.804** 0.736**	0.589** 0.495*	-0.0881 -0.104	-0.2788 -0.2393	0.1655 0.1559	-0.2684 -0.524*	0.1903 0.1300	0.0307 0.2767	0.0501 -0.143	0.1333 0.0524	0.0421 0.0702	0.0520 0.0665	0.1271 0.1213	-0.1917 -0.191
Days to percent flowering	GP		1.0000	0.755** 0.607**	0.5152* 0.2306	0.0046 -0.025	-0.3340 -0.1469	0.1043 0.1579	-0.0978 -0.478*	0.1740 0.1502	0.1651 0.366*	-0.056 -0.175	0.2596 0.1051	-0.0611 0.0046	-0.0181 0.0535	0.0192 0.1435	-0.2713 -0.148
Days to first fruit set	GP			1.0000	0.735** 0.430*	-0.2187 -0.220	-0.3042 -0.3114	0.0872 0.0706	-0.2067 -0.3069	-0.0823 -0.0867	-0.013 0.1126	0.0926 0.0919	0.0056 -0.103	-0.0238 0.0041	-0.0319 -0.0096	0.2100 0.2080	-0.2687 -0.263
Days to first picking	GP				1.0000	-0.1366 -0.1413	-0.447* -0.2642	0.2838 0.0743	-0.432* -0.2154	0.2238 0.1360	-0.034 -0.003	0.0159 -0.042	-0.052 0.0648	0.1465 0.1359	0.1095 0.0201	0.2005 0.0858	-0.2820 -0.014
Plant height (cm)	GP					1.0000	0.0493 0.2342	0.1519 0.1642	0.3070 -0.0937	0.2828 0.3276	0.356* 0.1997	-0.432* -0.484*	0.348* 0.2740	0.1573 0.0646	0.1818 0.1533	-0.428* -0.3295	0.0813 0.3351
Number of fruits per plant	GP						1.0000	-0.162 -0.136	-0.0409 0.0857	-0.0092 0.0527	0.1629 0.0856	0.0421 0.0648	0.1167 -0.0602	-0.0406 0.0251	0.0488 0.0632	-0.2226 -0.2533	0.731** 0.687**
Average fruit weight (g)	GP							1.0000	-0.0081 -0.1866	0.388* 0.3192	0.1472 0.0454	-0.1355 -0.1719	0.1529 0.2810	0.466* 0.2859	0.447* 0.373*	0.0411 0.0299	0.516* 0.479*
Number of locules	GP								1.0000	-0.0627 -0.637**	-0.1159 -0.730**	0.0384 0.456*	-0.1161 0.1092	0.2418 0.2437	0.1550 0.1302	0.0946 -0.0044	-0.0847 0.1279
Pericarp thickness(mm)	GP									1.0000	-0.0321 0.457*	0.0453 -0.397*	-0.0309 -0.0550	0.0699 -0.0512	0.1130 0.0496	-0.0149 -0.0541	0.1674 0.1385
TSS (^{0} Brix)	GP										1.0000	-0.778** -0.492*	-0.946** -0.1554	-0.0351 -0.378*	0.0279 -0.2971	-0.820** -0.1244	0.2844 -0.0320
Acidity (%)	GP											1.0000	0.646** -0.2689	0.2141 0.391*	0.1411 0.2632	0.620** 0.2745	-0.1012 -0.0763
Ascorbic acid (mg/100 g fruit weight)	GP												1.0000	0.0505 0.1324	0.0986 0.2024	-0.795** -0.413*	0.2598 0.2125
Total carotenoids (mg/100 g fruit weight)	GP													1.0000	0.884** 0.938**	0.0575 0.0583	0.3159 0.2561
Lycopene content (mg/100g fruit weight)	GP														1.0000	-0.0056 -0.0231	0.371* 0.2964
Total phenol (mg/100 g fruit weight)	GP															1.0000	-0.1982 -0.366*
Yield per plant (Kg)	GP																1.0000

* Significance at 5% level ** Significance at 1% level

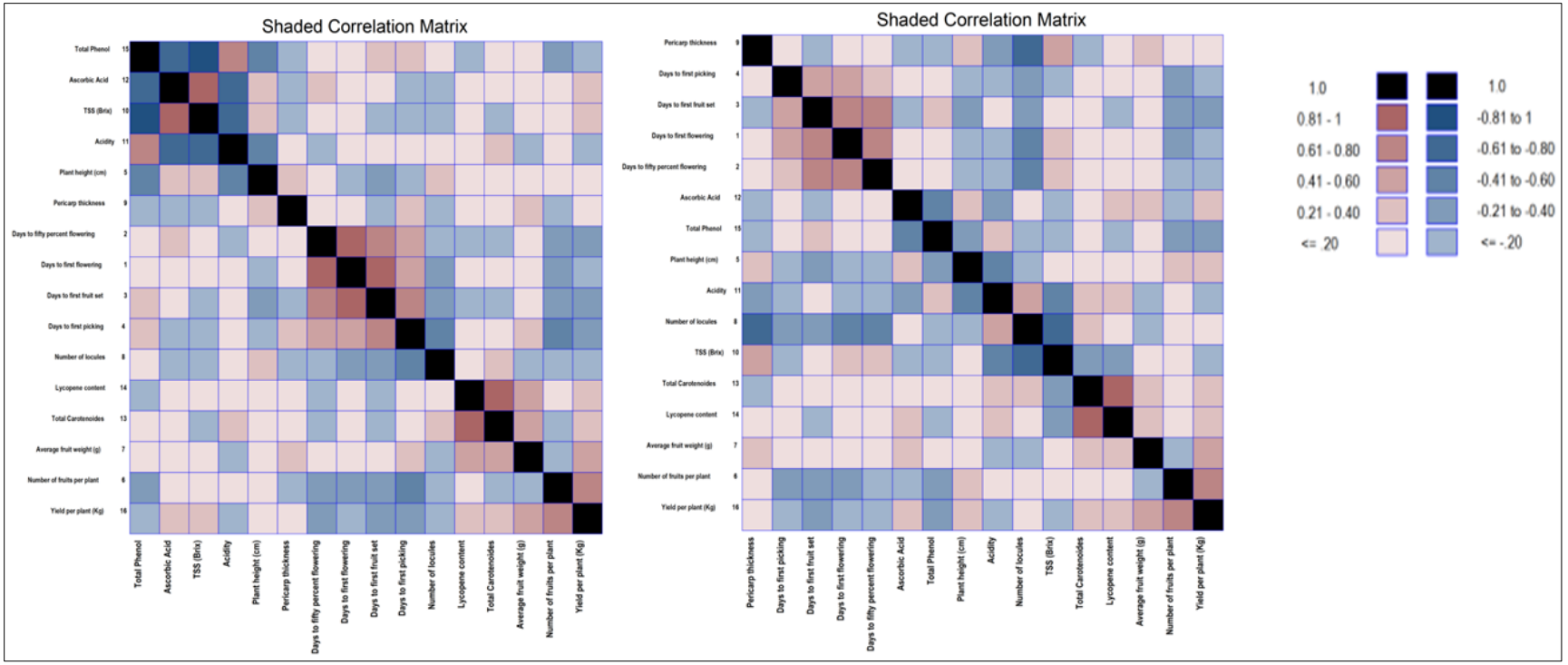

Fig 1: Standard genotypic and phenotypic correlation matrix graph of tomato genotypes for various traits

Table 2: Path coefficient (Genotypic) analysis for different pairs of characters in tomato

		Days to first flowering	Days to 50% flowering	Days to first fruit set	Days to first picking	Plant height (cm)	Number of fruits per plant	Average fruit weight (g)	Number of locules	Pericarp thickness (mm)	TSS (º Brix)	Acidity (%)	Ascorbic acid (mg/ 100 g fruit weight)	Total carotenoides (mg/ 100 g fruit weight)	Lycopene content (mg/ 100 g fruit weight)	Total phenol (mg/ 100 g fruit weight)	Yield per plant (Kg)
Days to first flowering	P	-0.5494	-0.5218	-0.442	-0.323	0.048	0.1532	-0.0909	0.1475	-0.1045	-0.016	-0.027	-0.0732	-0.0232	-0.0286	-0.069	-0.191
	G	-0.1479	-0.1035	-0.108	-0.073	0.015	0.0354	-0.023	0.0775	-0.0192	-0.040	0.021	-0.0077	-0.0104	-0.0098	-0.0179	-0.1914
Days to 50% flowering	P	0.2957	0.3114	0.235	0.160	0.001	-0.1040	0.0325	-0.0305	0.0542	0.051	-0.017	0.0808	-0.0190	-0.0056	0.0060	-0.271
	G	0.0110	0.0157	0.009	0.003	-0.000	-0.002	0.0025	-0.0075	0.0024	0.005	-0.0021	0.0017	0.0001	0.0008	0.0023	-0.1482
Days to first fruit set	P	0.2388	0.2242	0.296	0.218	-0.064	-0.0903	0.0259	-0.0613	-0.0244	-0.004	0.0273	0.0017	-0.0071	-0.0095	0.0623	-0.268
	G	0.0085	0.0070	0.011	0.005	-0.002	-0.003	0.0008	-0.0035	-0.0010	0.001	0.0015	-0.0012	0.0000	-0.0001	0.0024	-0.2633
Days to first picking	P	-0.1986	-0.1736	-0.248	-0.337	0.046	0.1509	-0.0957	0.1459	-0.0755	0.011	-0.0052	0.0175	-0.0494	-0.0370	-0.067	-0.282
	G	0.1171	0.0545	0.101	0.236	-0.033	-0.062	0.0176	-0.0510	0.0322	-0.008	-0.010	0.0153	0.0321	0.0048	0.0203	-0.0148

Plant height (cm)	P	0.0095	-0.0005	0.023	0.0148	-0.108	-0.0053	-0.0165	-0.0332	-0.0306	-0.038	0.046	-0.0376	-0.0170	-0.0197	0.0463	0.0813
	G	-0.0023	-0.0006	-0.005	-0.003	0.022	0.0053	0.0037	-0.0021	0.0074	0.004	-0.010	0.0062	0.0015	0.0034	-0.007	0.3351
Number of fruits per plant	P	-0.2060	-0.2467	-0.224	-0.330	0.036	0.7386	-0.1199	-0.0302	-0.0068	0.120	0.0311	0.0862	-0.0300	0.0361	-0.164	0.731**
	G	-0.1796	-0.1103	-0.2338	-0.1983	0.1758	0.7508	-0.102	0.0643	0.0396	0.0642	0.0487	-0.0452	0.0188	0.0474	-0.1902	0.687**
Average fruit weight (g)	P	0.1075	0.0678	0.0566	0.1844	0.0987	-0.1054	0.6496	-0.0052	0.2521	0.0956	-0.0880	0.0993	0.3029	0.2903	0.0267	0.516*
	G	0.0996	0.1008	0.0451	0.0475	0.1049	-0.087	0.6388	-0.1192	0.2039	0.0290	-0.1098	0.1795	0.1826	0.2384	0.0191	0.479*
Number of locules	P	0.0615	0.0224	0.0473	0.0990	-0.0703	0.0094	0.0018	-0.2290	0.0144	0.0265	-0.0088	0.0266	-0.0554	-0.0355	-0.0217	-0.0847
	G	-0.0689	-0.0627	-0.0403	-0.0283	-0.0123	0.0113	-0.024	0.1314	-0.0837	-0.0959	0.0599	0.0144	0.0320	0.0171	-0.0006	0.1279
Pericarp thickness (mm)	P	0.0119	0.0109	-0.0052	0.0140	0.0177	-0.0006	0.0243	-0.0039	0.0627	-0.0020	0.0028	-0.0019	0.0044	0.0071	-0.0009	0.1674
	G	-0.0092	-0.0107	0.0062	-0.0097	-0.0233	-0.003	-0.022	0.0453	-0.0710	-0.0325	0.0282	0.0039	0.0036	-0.0035	0.0038	0.1385
TSS (^{o} Brix)	P	-0.0113	-0.0607	0.0050	0.0126	-0.1310	-0.0599	-0.0541	0.0426	0.0118	-0.3678	0.2863	-0.3478	0.0129	-0.0103	0.3017	0.2844
	G	-0.0092	-0.0122	-0.0038	0.0001	-0.0067	-0.002	-0.001	0.0244	-0.0152	-0.0334	0.0164	0.0052	0.0126	0.0099	0.0042	-0.0320
Acidity (%)	P	-0.0104	0.0117	-0.0193	-0.0033	0.0897	-0.0088	0.0282	-0.0080	-0.0094	0.1618	-0.2079	0.1342	-0.0445	-0.0293	-0.1290	-0.1012
	G	0.0164	0.0200	-0.0105	0.0048	0.0554	-0.007	0.0197	-0.0522	0.0454	0.0563	-0.1145	0.0308	-0.0447	-0.0301	-0.0314	-0.0763
Ascorbic acid (mg/ 100 g fruit weight)	P	0.0386	0.0752	0.0016	-0.0150	0.1006	0.0338	0.0443	-0.0336	-0.0089	0.2738	-0.1869	0.2895	0.0146	0.0286	-0.2302	0.2598
	G	-0.0039	-0.0078	0.0076	-0.0048	-0.0203	0.0045	-0.020	-0.0081	0.0041	0.0115	0.0199	-0.0740	-0.0098	-0.0150	0.0306	0.2125
Total carotenoides (mg/ 100 g fruit weight)	P	-0.0107	0.0155	0.0060	-0.0372	-0.0399	0.0103	-0.1182	-0.0613	-0.0177	0.0089	-0.0543	-0.0128	-0.2536	-0.2676	-0.0146	0.3159
	G	0.0139	0.0009	0.0008	0.0268	0.0127	0.0050	0.0564	0.0481	-0.0101	-0.0746	0.0771	0.0261	0.1974	0.1851	0.0115	0.2561
Lycopene content (mg/ 100 g fruit weight)	P	0.0235	-0.0082	-0.0144	0.0495	0.0821	0.0221	0.2019	0.0701	0.0511	0.0126	0.0638	0.0446	0.4769	0.4519	-0.0026	0.371*
	G	-0.0104	-0.0084	0.0015	-0.0032	-0.0241	-0.0099	-0.0586	-0.0204	-0.0078	0.0466	-0.0413	-0.0318	0.1472	0.1570	0.0036	0.2964
Total phenol (mg/ 100 g fruit weight)	P	0.0076	0.0011	0.0125	0.0119	-0.0254	-0.0132	0.0024	0.0056	-0.0009	-0.0487	0.0369	-0.0472	0.0034	-0.0003	0.0594	-0.1982
	G	-0.0262	-0.0311	-0.0450	-0.0186	0.0713	0.0548	-0.0065	0.0009	0.0117	0.0269	-0.0594	0.0895	-0.0126	0.0050	-0.2164	-0.366*
Yield per plant (Kg	P	-0.1917	-0.2713	-0.2687	-0.2820	0.0813	0.731**	0.516*	-0.0847	0.1674	0.2844	-0.1012	0.2598	0.3159	0.371*	-0.1982	1.0000
	G	-0.1914	-0.1482	-0.2633	-0.0148	0.3351	0.687**	0.479*	0.1279	0.1385	-0.0320	-0.0763	0.2125	0.2561	0.2964	-0.366*	1.0000

Genotypic Residual Effect: 0.031 Phenotypic Residual Effect: 0.259

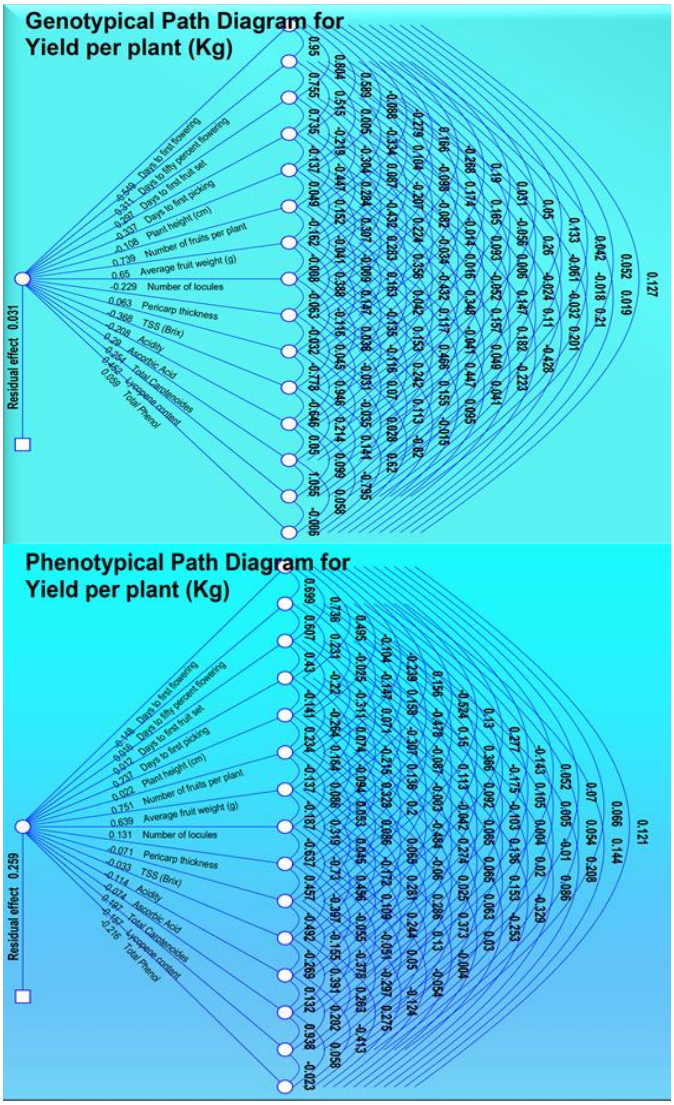

Fig 2: Genotypic path diagram representing direct and indirect effect for fruit yield in tomato genotypes

Conclusion

One of the most nutrient-dense vegetables, tomatoes are high in protein, fat, carbohydrates, calories from food, vitamins A and C, as well as other vital nutrients and minerals. The type, extent, and transmissibility of genetic diversity as well as the degree of targeted character transmission all affect selection efficiency. Since yield has a complex character, it can be enhanced by selecting on the basis of correlated parameters. The outcomes of the current research on tomato genotypes implied that, on both a genotypic and phenotypic level, the yield per plant was significantly and positively linked with the number of fruits per plant and average number of fruits per plant also has a high direct positive effect on yield. As a consequence, the results demonstrate that identifying genotypes based on average fruit weight and average fruit number will maximize yield.

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