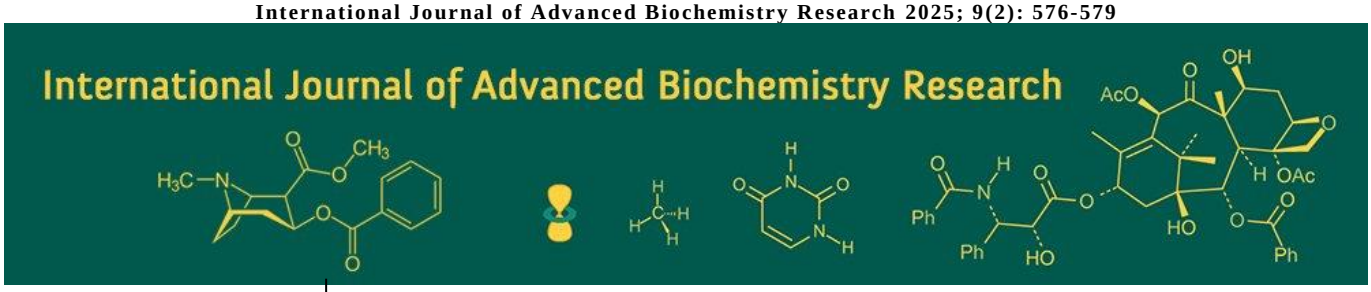

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Path coefficient analysis of yield and quality components in tomato (*Solanum lycopersicum* L.)

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Abstract
At the Vegetable Research Station of Dr. Y.S.R. Horticultural University in Rajendranagar, Hyderabad, 57 tomato (*Solanum lycopersicum* L.) genotypes were evaluated during Rabi 2010–11. Of all the characteristics examined, the number of fruits per cluster (0.2423, 0.7974) and the number of primary branches per plant (0.1611, 0.4320) had the strongest direct beneficial effects on fruit output at the phenotypic and genotypic levels, respectively. The number of primary branches per plant, plant height, number of flowers per cluster, average fruit weight, and fruit length were the main mediators of the strongest positive indirect effects on yield that were seen for the number of fruits per cluster. Additionally, strong genotypic correlation was found between plant height and seed yield, followed by lycopene content, total soluble solids (TSS), titratable acidity, flowers per cluster, and fruits per cluster. Selection for fruit production, number of flowers per cluster, and number of fruits per plant would be most effective based on the combined analysis of direct and indirect impacts as well as correlation coefficients.

Keywords: Tomato genotypes, fruit yield, direct effects, indirect effects, genotypic correlation

Introduction
A member of the Solanaceae family, the cultivated tomato (*Solanum lycopersicum* L.) is one of the most consumed vegetables in the world and a crop species that has been the subject of much genetic, breeding, and genomic (Foolad, 2007) [3]. Tomatoes have versatile applications in both fresh and processed food industries and are among the most nutritious vegetables, rich in Vitamin A, Vitamin C, protein, fat, carbohydrates and essential minerals (Rezk *et al*., 2021) [14]. For the crop's continued and future agronomic and genetic improvement, the systematic investigation and assessment of germplasm is essential (Reddy *et al*., 2013) [13].

The correlation coefficient aids breeders in identifying key traits for selection in breeding programs and in assigning appropriate weight to achieve optimal results. Path analysis further refines this process by partitioning correlation coefficients into direct and series of indirect effects of various traits on yield or other yield contributing traits, enabling a detailed assessment of specific traits contributing to a given correlation. Yield being a complex trait, directly improving it is challenging. Understanding the relationships between yield and other plant traits, as well as their relative contributions, is essential for developing an effective selection strategy aimed at yield enhancement.

Yield is a complex trait influenced by multiple factors and environmental conditions. Selecting a high-yielding genotype based solely on yield performance is often inefficient. However, selection based on yield component traits tends to be more effective (Maurya *et al*., 2020) [8]. To accumulate the optimal combination of yield-contributing traits in a single genotype, it is crucial to understand the interrelationships among various traits using standard partial regression analysis (path coefficient). With this backdrop, the present work was conducted to analyse path coefficients for all the studied traits.

Material and Methods
The experiment was carried out at Vegetable Research Station, Dr. Y.S.R. Horticultural University, Rajendranagar, Hyderabad during Rabi 2010-11 with 45 F_1's obtained by

crossing 10 inbred lines along with 2 checks of tomato in a Randomized Block Design (RCBD) with 3 replications sown with a spacing of 60 x 45 cm. Observations on 16yield related and quality traits were taken from five competitive plants selected on random from middle rows of each plot. The mean data from different traits was used for path coefficient analysis (Dewey and Lu, 1959) [2]. Path coefficients were analysed using R software version 4.1.2.

Results and Discussion

Positive phenotypic and genotypic direct effects were observed for Plant height (0.1628, 0.4320), No. of primary branches/plant (0.1611, 0.4320), No. of fruits/cluster (0.2423, 0.7974), fruit width (0.0799, 0.1260), total soluble sugars (0.1669, 0.5800), titrable acidity (0.0268, 0.4878) and lycopene content (0.0417, 0.0217). Whereas negative direct effects were observed for days to 50% flowering (-0.0978,-0.0785), fruit length (-0.0318,-0.3456), average fruit weight (-0.0797,-0.1876), No. of locules/fruit (-0.1357,-0.0815), pericarp thickness (-0.146,-0.0585), ascorbic acid content (-0.1252,-0.2628) and total sugars (-0.0578,-0.1794).

No. of flowers per cluster, No.of primary branches per plant,fruit width, pericarp thickness and plant height were found to have maximum positive phenotypic direct effect on fruit yield per plant. These results were similar to the reports of Haydar *et al*. (2007) [4] for number of flowers per cluster; Laxmikant and Mani (2004) [6] for fruit width; Kumar and Arya (2003) [5], Lakshmikant and Mani (2004) [6] for No. of primary branches per plant; Patil and Bojappa (1989) [11], Kumar *et al*. (2003) [5], for pericarp thickness; Patil and Bojappa (1989) [11], Kumar *et al*. (2003) [5] and Madhavi *et al*. (2013) [7] for plant height. This explains that direct selection of these traits will be rewarding for yield improvement in tomato.

Titrable acidity, number of locules per fruit and days to 50% flowering showed maximum negative phenotypic direct effect on fruit yield along with negative significant correlation on fruit yield. So, direct selection for these traits is not beneficial in tomato (Nevani and O. Sridevi, 2021) [10]. Fruit length showed a very high negative direct effect at the genotypic level, but it was positively correlated with fruit yield per plant. In this context, the indirect effects can be taken into account simultaneously for selection purposes. No. of fruits/cluster showed positive indirect effects on yield through plant height (0.6853), No. of primary branches (0.4957), No. of flowers/cluster (0.6860), fruit length (0.4168), fruit width (0.1962), average fruit weight (0.333), pericarp thickness (0.1829), total soluble solids (0.3142), total sugars (0.3253) at genotypic level.

No. of flowers/cluster showed negative indirect effect on yield through plant height (-0.0023), No. of primary branches/cluster (-0.0021), No. of fruits/cluster (-0.0024), fruit length (-0.0018), fruit width (-0.0008), average fruit weight (-0.0007), pericarp thickness (-0.0008), total soluble solids (-0.001), ascorbic acid content (-0.0002), total sugars (-0.0012) and lycopene content (-0.0001).Fruit width showed positive indirect effect on yield through plant height, No. of primary branches/plant, fruit length, No. of flowers/cluster, No. of fruits/cluster, average fruit weight, total soluble solids (TSS), pericarp thickness, total sugars, titrable acidity and lycopene content while negative indirect effects were observed for rest of the traits. Total soluble solids showed positive indirect effects on yield though plant height, No. of primary branches/plant, No. of flowers/cluster, No. of fruits/cluster, fruit length, fruit width, average fruit weight, total sugars.

Among the different traits studied, highest positive direct effects was observed for No. of fruits/cluster (0.2423, 0.7974) and No. of primary branches/plant (0.1611, 0.4320) at phenotypic and genotypic level. Highest positive indirect effects on yield was observed for No. of fruits/cluster through plant height, No. of primary branches/plant, No. of flowers/cluster, fruit length and average fruit weight. Also high genotypic correlation was observed between seed yield and plant height followed by No. of flowers/cluster, No. of fruits/cluster, total soluble solids, titrable acidity and lycopene content.

Hence direct selection for No. of fruits/cluster and No. of primary branches/plant will be effective in improving the yield. Similarly indirect selection is effective for No. of fruits/cluster. Also correlation coefficient is high between No. of flowers/cluster, No. of fruits/cluster and fruit yield/plant. So, based on direct and indirect effects coupled with correlation coefficients selection is effective for No. of flowers/cluster, No. of fruits/cluster and fruit yield/plant.

Table 1: Direct and indirect effects of various yield, yield attributes and quality characters on fruit yield in forty five genotypes in tomato.

		Plant height (cm) (1)	No. of Primary Branches/Plant (2)	Days to 50% flowering (3)	No. of Flowers/Cluster (4)	No. of Fruits/Cluster (5)	Fruit Length (cm) (6)	Fruit Width (cm) (7)	Average Fruit weight (g) (8)	No. of Locules/Fruit (9)	Pericarp Thickness (mm) (10)	Total Soluble Solids (ºbrix) (11)	Titrable Acidity (%) (12)	Ascorbic acid Content (mg/100 g) (13)	Total Sugars (%) (14)	Lycopene Content (mg/100 g) (15)	Fruit yield (kg) (16)
1	P	0.1628	0.1095	-0.0730	0.1147	0.1039	0.0903	0.0643	0.0704	-0.0340	0.0643	0.0441	-0.0233	-0.0138	0.0620	0.0152	0.6097
	G	0.0317	0.3298	0.0437	-0.0023	0.6853	-0.1967	0.0627	-0.0849	0.0320	-0.0094	0.3237	-0.1886	0.0270	-0.0693	0.0037	0.9528
2	P	0.1084	0.1611	-0.0775	0.1166	0.0867	0.1156	0.0696	0.0668	-0.0344	0.0488	0.0672	-0.0407	-0.0241	0.0600	-0.0010	0.6313
	G	0.3298	0.4320	-0.2400	0.3356	0.2686	0.3644	0.2268	0.2090	-0.1158	0.1503	0.2190	-0.1412	-0.0710	0.1653	-0.0052	0.7635
3	P	0.0439	0.0470	-0.0978	0.0419	0.0274	0.0410	0.0391	0.0369	0.0080	0.0135	0.0273	-0.0008	-0.0178	0.0365	0.0088	-0.4198
	G	0.0437	0.0436	-0.0785	0.0410	0.0272	0.0436	0.0380	0.0386	0.0063	0.0170	0.0291	0.0016	-0.0166	0.0337	0.0096	-0.5568
4	P	0.1559	0.1602	-0.0948	0.2213	0.1579	0.1214	0.0373	0.0516	-0.0787	0.0550	0.0771	-0.0378	0.0124	0.0945	0.0088	0.6803
	G	-0.0023	-0.0021	0.0014	-0.0027	-0.0024	-0.0018	-0.0008	-0.0007	0.0012	-0.0008	-0.0010	0.0006	-0.0002	-0.0012	-0.0001	0.8467
5	P	0.1547	0.1304	-0.0680	0.1729	0.2423	0.0919	0.0485	0.0847	-0.0782	0.0510	0.0755	-0.0513	0.0445	0.0846	0.0436	0.6180
	G	0.6853	0.4957	-0.2763	0.6860	0.7974	0.4168	0.1962	0.3330	-0.3849	0.1829	0.3142	-0.2175	0.1722	0.3253	0.1887	0.8595
6	P	-0.0177	-0.0228	0.0133	-0.0175	-0.0121	-0.0318	-0.0158	-0.0117	0.0056	-0.0144	-0.0075	-0.0004	0.0006	-0.0072	-0.0014	0.4270
	G	-0.1967	-0.2915	0.1920	-0.2325	-0.1806	-0.3456	-0.2545	-0.2031	0.0881	-0.1818	-0.1009	0.0079	0.0131	-0.0958	-0.0120	0.5691
7	P	0.0316	0.0345	-0.0320	0.0135	0.0160	0.0396	0.0799	0.0369	-0.0010	0.0204	0.0102	0.0050	-0.0077	0.0005	0.0028	0.2867
	G	0.0627	0.0661	-0.0609	0.0366	0.0310	0.0928	0.1260	0.0798	-0.0136	0.0453	0.0414	0.0177	-0.0189	0.0014	0.0025	0.4979
8	P	-0.0345	-0.0331	0.0301	-0.0186	-0.0279	-0.0294	-0.0368	-0.0797	0.0078	-0.0183	-0.0135	-0.0043	-0.0005	-0.0063	-0.0257	0.2733
	G	-0.0849	-0.0908	0.0922	-0.0497	-0.0783	-0.1103	-0.1188	-0.1876	0.0300	-0.0586	-0.0539	-0.0127	-0.0012	-0.0180	-0.0699	0.4527
9	P	0.0283	0.0290	0.0111	0.0482	0.0438	0.0238	0.0017	0.0133	-0.1357	0.0081	0.0193	-0.0239	0.0187	0.0060	0.0040	0.2867
	G	0.0320	0.0219	0.0065	0.0346	0.0394	0.0208	0.0088	0.0130	-0.0815	0.0055	0.0118	-0.0175	0.0147	0.0030	0.0038	0.4979
10	P	-0.0576	-0.0442	0.0202	-0.0363	-0.0307	-0.0661	-0.0373	-0.0335	0.0087	-0.1460	0.0164	-0.0308	0.0166	-0.0326	0.0129	0.4270
	G	-0.0094	-0.0203	0.0126	-0.0180	-0.0134	-0.0308	-0.0210	-0.0183	0.0040	-0.0585	0.0076	-0.0168	0.0088	-0.0141	0.0069	0.5691
11	P	0.0453	0.0696	-0.0466	0.0582	0.0520	0.0395	0.0212	0.0283	-0.0237	-0.0188	0.1669	-0.1008	-0.0096	0.0699	0.0406	0.6180
	G	0.3237	0.2940	-0.2147	0.2194	0.2285	0.1693	0.1908	0.1667	-0.0843	-0.0749	0.5800	-0.5046	-0.0355	0.2851	0.1944	08595
12	P	-0.0038	-0.0068	0.0002	-0.0046	-0.0057	0.0004	0.0017	0.0014	0.0047	0.0056	-0.0162	0.0268	0.0027	-0.0060	-0.0056	0.6803
	G	-0.1886	-0.1594	-0.0097	-0.1089	-0.1330	-0.0112	0.0686	0.0331	0.1049	0.1402	-0.4244	0.4878	0.0753	-0.1484	-0.1365	0.8467
13	P	0.0106	0.0187	-0.0228	-0.0070	-0.0230	0.0022	0.0120	-0.0008	0.0173	0.0142	0.0072	-0.0127	-0.1252	0.0122	-0.0112	-0.4198
	G	0.0270	0.0432	-0.0555	-0.0151	-0.0568	0.0100	0.0394	-0.0016	0.0475	0.0394	0.0161	-0.0406	-0.2628	0.0260	-0.0202	-0.5568
14	P	-0.0220	-0.0215	0.0216	-0.0247	-0.0202	-0.0131	-0.0003	-0.0045	0.0026	-0.0129	-0.0242	0.0131	0.0056	-0.0578	0.0000	0.6313
	G	-0.0693	-0.0686	0.0769	-0.0802	-0.0732	-0.0497	-0.0020	-0.0172	0.0067	-0.0433	-0.0882	0.0546	0.0177	-0.1794	-0.0282	0.7635
15	P	0.0039	-0.0003	-0.0038	0.0017	0.0075	0.0018	0.0014	0.0134	-0.0012	-0.0037	0.0101	-0.0088	0.0037	0.0060	0.0417	0.6097
	G	0.0034	-0.0003	-0.0027	0.0006	0.0051	0.0008	0.0004	0.0081	-0.0010	-0.0026	0.0073	-0.0061	0.0017	0.0034	0.0217	0.9528

Conclusion

The study identified that the number of fruits per cluster and the number of primary branches per plant had the highest positive direct effects on tomato yield at both phenotypic and genotypic levels. Strong positive indirect effects were observed for traits like plant height, number of flowers per cluster, and average fruit weight. In contrast, traits such as titrable acidity, number of locules per fruit, and days to 50% flowering showed negative direct effects, making them less favorable for selection. Therefore, direct selection for fruits per cluster and primary branches, along with indirect selection for related traits, would be most effective in improving tomato yield.

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