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Association studies in advanced inbred population of tomato (*Solanum lycopersicum* L.)

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Abstract
Correlation and path coefficient investigations were conducted on a combined population comprising 29 Advanced Breeding Lines (ABLs) along with five control varieties resulting from the cross 16P2 X Kashi Hemanth in tomato (*Solanum lycopersicum* L.). The experimentation took place in the agricultural fields of Kanaykanahalli village, Belur taluq, Hassan district, spanning from 2020 to 2022. The outcomes revealed notable and favorable correlations between yield per plant and traits including number of fruits, fruit length, average fruit weight, fruit width, plant height, number of branches, and days to 50 per cent blooming, observed both at the phenotypic and genotypic levels. These findings imply that selecting genotypes based on these attributes could facilitate the identification of high-yielding and stable plants. Path analysis further demonstrated that the number of fruits per plant exhibited the strongest positive direct effect on yield per plant, followed by fruit length, number of branches, average fruit weight, firmness, days to fifty per cent flowering, and Total Soluble Solids (TSS).

Keywords: Tomato, correlation, path analysis, ABLs

Introduction

Tomato (*Solanum lycopersicum* L.) is a significantly valuable vegetable in India and worldwide, belonging to the Solanaceae family with a diploid chromosome number of 24. This plant is primarily cultivated for its palatable fruit, which holds a multitude of culinary possibilities, including consumption in its raw form, cooking, and utilization in various processed forms such as juice, ketchup, sauces, pickles, pastes, purees, and powders. It's widely acknowledged for its nutritional value, particularly its rich content of minerals, organic acids, and essential vitamins, notably vitamins A and C.

The utilization of correlation coefficient analysis helps us grasp the interconnectedness between yield and its constituent characteristics (Ambresh *et al*., 2017) [1] enabling an estimation of the relative contribution of these component traits to the overall yield (Panse, 1957) [8]. Path coefficient analysis elucidates the causal relationships between variables and quantifies the relative significance of each variable (Wright, 1921) [16]. While correlation studies illuminate the interdependence of yield and its associated traits, path coefficient analysis dissects the total correlation into its direct and indirect effects. Thus, the combined use of correlation and path coefficient analysis emerges as a valuable tool for discerning both the interrelationships between traits and the direct/indirect impacts of one trait on another (Dewey and Lu, 1959) [2].

Materials and Methods

Experimental studies was under taken during the year 2020-2021 and 2021-22 at farmer's field, Kanaykanahalli, Belur taluk, Hassan district. The material comprised of 29 selected lycopene rich and high yielding F_6 lines (Meghana, 2019) [6] along with five checks *viz*., Arka Rakshak, Arka Samrat, Arka Apeksha, Pusa Ruby and Pusa Rohini were included. The experiment was executed out during three seasons including early *rabi*, *kharif* and late *rabi* seasons. The observations included plant height (cm), number of branches, days to fifty per cent flowering, number of fruits, fruit length (cm), fruit width (cm), average fruit weight (g), yield per plant (kg), number of locules, pericarp thickness (mm), TSS (° Brix), firmness (kg/cm^2) and lycopene content (mg/100g). The experiment was executed in Randomized Complete Block Design with two replications under study. Statistical analysis was carried out by using replication mean data.

Results and Discussion

Correlation: Yield per plant displayed a robust positive correlation with several traits, number of fruits (0.945, 0.993), fruit length (0.930, 0.912), average fruit weight (0.901, 0.953), fruit width (0.893, 0.997), plant height (0.859, 0918), number of branches (0.806, 0.853) and days to 50 per cent blooming (0.383, 0.403) at genotypic and phenotypic levels respectively. Similar results were obtained by Nevani and Sridevi (2022) [7].

Plant height demonstrated a robust positive correlation with several traits at genetic and physical levels, including the number of fruits per plant (0.946, 0.967), number of branches per plant (0.943, 0.968), average fruit weight (0.919, 0.957), fruit length (0.865, 0.900), fruit width (0.832, 0.906), days to fifty per cent flowering (0.310, 0.320) and fruit yield per plant at both genotypic and phenotypic levels respectively. This finding is consistent with previous studies, including Sinha *et al*. (2020) [12].

The study found a robust and positive correlation between the number of branches per plant and various traits, including the number of fruits per plant (0.872, 0.899), average fruit weight (0.831, 0.862), fruit width (0.791, 0.865), fruit length (0.774, 0.839) number of days to fifty per cent flowering (0.284, 0.304), and fruit yield per plant at both genotypic and phenotypic levels. Similar results were reported by Sahoo *et al*. (2022) [11].

At both genotypic and phenotypic levels, it was found that the fruit width (0.378, 0.318), average fruit weight (0.354, 0.384), fruit length (0.343, 0.313) the number of fruits per plant (0.335, 0.305) and fruit yield per plant were significantly and positively correlated with the days to 50% blooming. The conformity was made with venkadeswaran *et al*. (2021) [15].

The correlation analysis showed a robust and positive relationship between the number of fruits per plant was significantly and positively correlated with fruit yield per plant (0.945, 0.933), average fruit weight (0.942, 0.976), fruit length (0.918, 0.980), and fruit width (0.887, 0.945) at phenotypic and genotypic levels. Negative significant correlation was observed with firmness (0.255) at phenotypic level. These conclusions are in affirmative with the documented result by Islam *et al*. (2010) [4].

At both phenotypic and genotypic levels, there was a robust positive correlation between the fruit length and fruit yield per plant (0.930, 0.912), fruit width (0.922, 0.917) and average fruit weight (0.868, 0.931). A negative significant correlation was observed with pericarp thickness (0.261) and firmness (0.306) at phenotypic level. Comparable findings were documented by Islam *et al*. (2010) [4] and Rajolli *et al*. (2017) [9].

Fruit width showed a substantial negative link with firmness (0.314) at phenotypic level and a strong positive correlation with average fruit weight (0.900, 0.835) and fruit productivity per plant at both genotypic and phenotypic levels. Comparable reports for the trait were reported by Maurya *et al*. (2020) [5].

At genotypic and phenotypic levels, average fruit weight correlated significantly and positively with fruit yield per plant (0.901, 0.953) and a negative significant correlation with pericarp thickness (-0.246) and firmness content (-0.284) at phenotypic level. Similar results were reported Nevani and Sridevi (2022) [7].

The number of locules had significant and positive correlations with characters such as total soluble solids (0.319, 0.292) and pericarp thickness (0.273, 0.268) at both phenotypic and genotypic levels respectively. Tiwari and Upadhyay (2011) [14] came to similar conclusion.

Total soluble solids were robust and positively correlated with pericarp thickness (0.538, 0.443) and firmness (0.530, 0.443) at both phenotypic and genotypic levels. Corresponding findings were obtained by Venkadeswaran *et al*. (2021) [15].

The pericarp thickness had positive strong correlation with firmness (0.945, 0.983). Similar findings were published by Maurya *et al*. (2020) [5].

A positive robust correlation was observed between firmness and lycopene content at both genotypic (0.408) and phenotypic levels (0.249). Similar findings were published by Rajolli *et al*. (2017) [9].

Path analysis: The concept of path analysis was initially introduced by Wright (1921) [16] and subsequently refined by Dewey and Lu (1959) [2], offering a valuable tool to assess both direct and indirect influences within associations, thereby illuminating the comparative significance of each factor contributing to yield. To establish developmental connections, the interplay of cause and effect between yield and its contributing components was explored in tomato advanced breeding lines.

In the contemporary analysis, path coefficient analysis between the components of yield per plant in tomato was worked out (Table 3 and 4). From the pool of 13 selected traits subjected to path analysis, the traits, number of fruits per plant (0.742) followed by fruit length (0.489), number of branches (0.329), average fruit weight (0.232) and number of locules (0.037) shows the direct effect on yield per plant while other parameters like plant height, pericarp thickness, lycopene and fruit width had a direct negative effect in phenotypic path analysis. Genotypic path analysis revealed that the number of fruits per plant (2.051) followed by pericarp thickness (0.359), fruit length (0.270), number of branches (0.064), number of locules (0.029) and days to fifty per cent flowering (0.008) were showing the highest positive effect on yield per plant while other parameters like plant height, average fruit weight, firmness, TSS and lycopene had a direct negative effect in genotypic path analysis. Hence, the preceding discourse reveals that crucial direct and indirect components showcase significant positive influence through certain traits, while also exerting notable negative impacts via other attributes. The presence of both adverse and favourable direct and indirect effects stemming from yield components, acting through various traits, simultaneously presents an intricate scenario. This scenario necessitates a trade-off to achieve a harmonious equilibrium among diverse yield components, thereby establishing the ideal profile for achieving high fruit yield in tomatoes. The mentioned traits merit careful attention during the formulation of a selection strategy intended for the development of high-yielding tomato varieties. Parallel outcomes were documented by in investigations conducted by Ritonga *et al.* (2018) [10] and Maurya *et al.* (2020) [5].

Table 1: Phenotypic correlation coefficients between yield and fruit quality attributes over seasons in tomato

	a	b	c	d	e	f	g	h	i	j	k	l	m
a	1.000**	0.943 **	0.310 *	0.946**	0.865**	0.832**	0.919**	0.859**	-0.114	-0.163	-0.194	-0.233	-0.066
b		1.000 **	0.284*	0.872**	0.774**	0.791**	0.831**	0.806**	-0.123	-0.126	-0.133	-0.186	-0.113
c			1.000**	0.335**	0.343**	0.378**	0.354**	0.383**	-0.152	-0.175	-0.126	-0.161	-0.061
d				1.000**	0.918**	0.887**	0.942**	0.945**	-0.126	-0.164	-0.219	-0.255*	-0.044
e					1.000**	0.922**	0.868**	0.930**	-0.075	-0.142	-0.261*	-0.306*	-0.049
f						1.000**	0.835**	0.893**	-0.135	-0.146	-0.236	-0.314**	-0.172
g							1.000**	0.901**	-0.154	-0.227	-0.246*	-0.284*	-0.110
h								1.000**	-0.126	-0.113	-0.197	-0.232	-0.095
i									1.000**	0.319**	0.273*	-0.230	0.177
j										1.000**	0.538**	0.530**	0.189
k											1.000**	0.945**	0.147
l												1.000**	0.249*
m													1.000**

a. Plant height at last harvest (cm) b. Number of branches at last harvest c. Days to 50% flowering d. Number of fruits per plant
e. Fruit length (cm) f. Fruit width (cm) g. Average fruit weight (g) h. Yield per plant (kg/plant)
i. Number of locules per fruit j. Total soluble solids (^0B) k. Pericarp thickness (mm) l. Firmness (kg/cm^2)
m.. Lycopene (mg/100g)
*- Significant at 5% level **- Significant at 1% level

Table 2: Genotypic correlation coefficient between yield and fruit quality attributes over seasons in tomato

	a	b	c	d	e	f	g	h	i	j	k	l	m
a	1.000**	0.968**	0.320*	0.967**	0.900**	0.906**	0.957**	0.918**	-0.101	-0.155	-0.147	-0.166	-0.093
b		1.000**	0.304*	0.899**	0.839**	0.865**	0.862**	0.853**	-0.103	-0.163	-0.141	-0.111	-0.124
c			1.000**	0.305*	0.313*	0.318*	0.384**	0.403**	-0.113	-0.164	-0.341	-0.101	-0.091
d				1.000**	0.980**	0.945**	0.976**	0.993**	-0.162	-0.138	-0.162	-0.115	-0.051
e					1.000**	0.917**	0.931**	0.912**	-0.104	-0.122	-0.160	-0.164	-0.09
f						1.000**	0.900**	0.997**	-0.115	-0.162	-0.369	-0.106	-0.209
g							1.000**	0.953**	-0.138	-0.201	-0.131	-0.095	-0.105
h								1.000**	-0.134	-0.131	-0.132	-0.171	-0.080
i									1.000**	0.292**	0.268*	0.201	0.158
j										1.000**	0.443**	0.423**	0.198
k											1.000**	0.983**	0.131
l												1.000**	0.408*
m													1.000**

a. Plant height at last harvest (cm) b. Number of branches at last harvest c. Days to 50% flowering d. Number of fruits per plant
e. Fruit length (cm) f. Fruit width (cm) g. Average fruit weight (g) h. Yield per plant (kg/plant)
i. Number of locules per fruit j. Total soluble solids (^0B) k. Pericarp thickness (mm) l. Firmness (kg/cm^2)
m.. Lycopene (mg/100g)
*- Significant at 5% level, **- Significant at 1% level,

Table 3: Path coefficients of different traits on fruit yield of tomato.

	a	b	c	d	e	f	g	h	i	j	k	l	r
a	-0.744	0.31	0.017	0.702	0.423	-0.044	0.213	0.001	-0.007	0.026	-0.041	0.004	0.859**
b	-0.702	0.329	0.016	0.647	0.378	-0.041	0.192	0.001	-0.006	0.018	-0.033	0.007	0.806**
c	-0.196	0.079	0.048	0.210	0.142	-0.017	0.069	0.001	-0.007	0.014	-0.024	0.003	0.383**
d	-0.704	0.287	0.019	0.742	0.449	-0.047	0.218	0.001	-0.007	0.029	-0.045	0.003	0.945**
e	-0.644	0.254	0.019	0.681	0.489	-0.0486	0.201	0.001	-0.006	0.035	-0.055	0.003	0.930**
f	-0.620	0.260	0.021	0.658	0.451	-0.053	0.194	0.001	-0.006	0.032	-0.056	0.011	0.893**
g	-0.684	0.273	0.020	0.699	0.424	-0.044	0.232	0.001	-0.010	0.034	-0.050	0.007	0.901**
h	0.082	-0.040	-0.008	-0.092	-0.036	0.007	-0.035	-0.009	0.014	-0.037	0.040	-0.010	-0.126
i	0.098	-0.034	-0.008	-0.098	-0.056	0.006	-0.042	-0.002	0.037	-0.059	0.076	-0.009	-0.113
j	0.144	-0.044	-0.007	-0.162	-0.128	0.012	-0.057	-0.003	0.025	-0.135	0.166	-0.009	-0.197
k	0.173	-0.061	-0.009	-0.189	-0.151	0.017	-0.065	-0.002	0.024	-0.127	0.176	-0.015	-0.232
l	0.049	-0.037	-0.003	-0.032	-0.024	0.009	-0.025	-0.002	0.009	-0.020	0.044	-0.062	-0.095

Residual effect=0.048
a. Plant height at last harvest (cm) b. Number of branches at last harvest c. Days to flowering d. Number of fruits per plant
e. Fruit length (cm) f. Fruit width (cm) g. Average fruit weight (g) h. Number of locules per fruit
i. Total soluble solids (^0B) j. Pericarp thickness (mm) k. Firmness (kg/cm^2) l. Lycopene (mg/100g)
r= correlation with yield per plant

Table 4: Genotypic path coefficients of different traits on fruit yield of tomato.

	a	b	c	d	e	f	G	h	i	j	k	l	r
a	-0.712	0.062	-0.006	1.983	0.243	-0.378	-0.306	0.025	-0.031	-0.169	0.204	0.004	0.918**
b	-0.689	0.064	-0.006	1.844	0.226	-0.361	-0.276	0.027	-0.017	-0.122	0.157	0.006	0.853**
c	-0.557	0.047	0.008	1.608	0.197	-0.246	-0.262	-0.018	0.009	-0.004	0.017	0.002	0.403**
d	-0.689	0.058	-0.006	2.051	0.264	-0.395	-0.312	0.015	-0.020	-0.166	0.189	0.002	0.993**
e	-0.641	0.054	-0.006	2.010	0.270	-0.424	-0.298	0.021	-0.018	-0.165	0.204	0.004	0.912**
f	-0.645	0.056	-0.005	1.938	0.274	-0.418	-0.288	0.036	-0.015	-0.132	0.186	0.010	0.997**
g	-0.682	0.055	-0.006	2.001	0.251	-0.376	-0.320	0.021	-0.026	-0.155	0.183	0.005	0.953**
h	0.615	-0.059	-0.005	-1.068	-0.198	0.523	0.236	0.029	-0.218	0.099	-0.446	-0.031	-0.134
i	0.289	-0.014	-0.001	-0.545	-0.063	0.083	0.112	0.083	-0.076	-0.042	-0.014	-0.008	-0.131
j	0.336	-0.022	0.000	-0.947	-0.124	0.154	0.138	-0.008	-0.009	0.359	-0.303	-0.006	-0.132
k	0.472	-0.033	0.000	-1.262	-0.179	0.253	0.191	-0.042	0.004	0.353	-0.308	-0.019	-0.171
l	0.066	-0.008	0.000	-0.104	-0.025	0.087	0.034	-0.019	0.014	0.047	-0.125	-0.046	-0.080

Residual effect=0.0575

a. Plant height at last harvest (cm) b. Number of branches at last harvest c. Days to flowering d. Number of fruits per plant
e. Fruit length (cm) f. Fruit width (cm) g. Average fruit weight (g) h. Number of locules per fruit
i. Total soluble solids (^{0}B) j. Pericarp thickness (mm) k. Firmness (kg/cm^2) l. Lycopene (mg/100g)
r= correlation with yield per plant

Conclusion

The attributes displaying substantial direct influence on yield per plant suggest that directly selecting for these traits could be productive and offers potential for enhancing yield per plant through the targeted selection of these attributes. Therefore, it is essential to prioritize the selection of attributes such as days to number of fruits, fruit length and number of branches which are easily observable characters at the field level during selection for fruit yield per plant.

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