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CORRELATION AND PATH ANALYSIS OF MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS WITH YIELD IN TOMATOES: INSIGHTS FROM *SOLANUM LYCOPERSICON*

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ABSTRACT

This study investigates the relationships between various traits and yield per plant in tomatoes (*Solanum lycopersicon*). The results reveal a significant positive correlation between plant height and yield per plant at both phenotypic (0.0144**) and genotypic (0.0141**) levels. Plant height is also positively linked to the number of flowers per cluster (0.3426**) and primary branches per plant (0.2761**), as well as average fruit weight and number of fruits per plant (0.0511**). Conversely, it negatively correlates with leaf curl virus incidence (-0.0339**) and flowering traits. The number of primary branches per plant shows a positive association with yield per plant (0.2455**) and various fruit traits but is negatively correlated with flowering dates and leaf curl virus incidence. Additionally, days to first flowering and days to 50% flowering positively correlate with yield and other key traits while negatively affecting fruit weight and flower counts. Days to first fruit harvest positively relates to yield per plant (0.1057**) but negatively affects fruit firmness and leaf curl virus incidence. Average fruit weight strongly correlates with yield per plant (0.4943**) and the number of locules per fruit (0.2870**), but it is negatively associated with fruit firmness and leaf curl virus incidence. The number of fruits per plant shows a significant positive correlation with yield (0.3024**) and a negative correlation with leaf curl virus incidence (-0.4904**). Importantly, leaf curl virus incidence has a detrimental effect on yield (-0.4555**), highlighting the importance of selecting for resistance to this virus. Overall, these findings reinforce the selection of specific traits to enhance tomato yield, aligning with previous research.

***Key words*:** Correlation, path analysis, yield traits, Tomato leaf cur virus

Introduction

Tomato (*Solanum lycopersicum* L), a significant member of the Solanaceae family with a chromosome counts of 2n=2x=24, is believed to have originated from the wild form *Solanum lycopersicum var. cerasiforme* in the Peru Equator region of the Andes. Today, it is cultivated globally (Robertson and Labate, 2007). Tomatoes are rich in minerals, vitamins, sugars, and organic acids, and they serve as a reservoir of diverse antioxidants, including lycopene, ascorbic acid, carotenoids, flavonoids, and phenolic acids, earning them the designation of “protective food” (Thamburaj and Singh, 2013). They can be consumed raw in salads and sandwiches or processed into various forms such as paste, puree, syrup, juice, and ketchup. Additionally, tomato soup is considered an effective remedy for constipation. As one of the most popular vegetables worldwide, tomatoes have been extensively researched, highlighting their significance in global agriculture.

Material and Methods

The experimental materials were evaluated from August 2021 to January 2023 at the College of Horticulture, Venkataramannagudem, located in the West Godavari District of Andhra Pradesh. This site lies within Agro-climatic Zone-10, characterized as humid East Coast Plain and Hills (Krishna-Godavari zone), receiving an average rainfall of 900 mm. Geographically, it is situated at 16° 63' 120" N latitude and 81° 27' 568" E longitude, at an altitude of 34 meters (112 feet) above sea level. The area experiences short humid summers and mild winters.

Correlation studies

To determine the association of characters with yield and also among the yield components, the correlation coefficient was calculated.

Phenotypic and genotypic correlations were worked out by using formula as suggested by Al-jibouri *et al.*, (1958).

Phenotypic coefficient of correlation (rp)

$$r\,(Xi.Xj)p = \frac{CoV\,(Xi.Xj)p}{\sqrt{V\,(Xi)p \times V\,(Xj)p}}$$

Where,

r (xi.xj)p = Phenotypic correlation between i^{th} and j^{th} character.

CoV (xi.xj) p = Phenotypic *Cov*ariance between i^{th} and j^{th} character.

V (xi) p = Phenotypic variance of i^{th} character.

V (xj) p = Phenotypic variance of j^{th} character

Genotypic coefficient of correlation (rg)

$$r\,(Xi.Xj)g = \frac{COV\,(Xi.Xj)g}{\sqrt{V\,(Xi)g \times V\,(Xj)g}}$$

Where,

r (xi.xj)p = Genotypic correlation between i^{th} and j^{th} character.

COV (xi.xj) p = Genotypic *Cov*ariance between i^{th} and j^{th} character.

V (xi) p = Genotypic variance of i^{th} character.

V (xj) p = Genotypic variance of j^{th} character

Path coefficient analysis

Path coefficient analysis was carried out using phenotypic correlation values of yield components on yield as suggested by Wright (1921) and illustrated by Dewey *et al.*, (1959). Standard path coefficients which were standardized partial regression coefficients, were obtained using statistical software package called INDOSTAT. These values were obtained by solving the following set of 'p' simultaneous equation using the above package.

P01+ P02 r12+ + P0P r1P = r01

P01+ P12 r02+ + P0P r2P = r02

↓

P01+ r1P + P02 r2P + + P0P = r0P

Where,

P01, P02, ---------- P0P are the direct effects of variables 1,2 ----- p on the dependent variable 0 and r12, r13, ---------- r1P ---------- r P(P-1) are the possible correlation coefficients between various independent variables and r01, r02, r03 r0P are the correlation between dependent and independent variables. The indirect effects of the i^{th} variable via j^{th} variable was attained as (Poj × rij).

The contribution of remaining unknown factor was measured as the residual factor, which was calculated as given below.

P^2 ox = 1-[P^2 01+2P01P02r12+2P01P03r13+ ------+ P^2 02+ 2P02P03r13+ +P^2 0P]

Residual factor = $\sqrt{P^2_{ox}}$

The direct and indirect effects were ranked based on the scales of Lenka and Mishra (1973) as given below.

Values of direct (or) indirect effects	Rate (or) scale
0.00 to 0.09	Negligible
0.10 to 0.19	Low
0.20 to 0.29	Moderate
0.30 to 0.99	High
> 1.00	Very high

Result and Discussion

Plant height

Plant height exhibited a significant positive correlation with yield per plant, observed at both the phenotypic (0.0144**) and genotypic (0.0141**) levels. Additionally, this trait demonstrated a strong positive association with the number of flowers per cluster (0.3426** and 0.3435**) and the number of primary branches per plant (0.2761** and 0.2764**) across both levels. Such relationships suggest that increases in one trait can lead to increases in the other, indicating the potential for simultaneous selection of these characteristics. Moreover, plant height showed a notable positive correlation with average fruit weight and the number of fruits per plant at both the phenotypic and genotypic levels (0.0511**). This suggests that the observed associations between plant height and

Table 1: Phenotypic Correlation co-efficient among yield and its components in tomato genotypes.

Character	PH	DF	DFF	PFS	DFH	AFW	NFP	LCV	FYP
PH	**1.00**	-0.0344*	-0.0199**	-0.2088**	-0.1207**	0.0511**	0.0212*	-0.0339*	0.0144**
DF		**1.00**	0.3122**	0.2516**	0.0984**	-0.1674*	0.0628*	0.2248**	0.1164**
DFF			**1.00**	0.1748*	-0.1471*	-0.2318**	-0.3091**	0.5485**	0.2235**
NFP				0.4506**	0.1763*	0.3586**	1.0000**	-0.4904**	0.3024**
DFH					**1.00**	0.0349**	0.1763*	-0.1710**	0.1057*
AFW						**1.00**	0.3586**	-0.3163**	0.4943**
NFP							**1.00**	-0.4904**	0.3024**
LCV								**1.00**	-0.4555**
FYP									**1.00**

* and ** significance at 1% and 5 %
PH- Plant height, DF= days to first flowering, DFF= Days to 50% flowering, DFH= Days to first harvest,
AFW= Average fruit weight, NFP= Number of fruits per plant, LCV= Leaf curl virus and FYP= Fruit yield per plant

these fruit-related traits are influenced not only by genetic factors but also by favourable environmental conditions. Table 1 and 2. These findings are consistent with previous studies by Renuka and Sadashiva (2016), Kumar *et al.,* (2017), Singh (2017), Sunilkumar *et al.,* (2019), and Sharma *et al.,* (2019) on tomatoes.

In contrast, plant height also displayed a significant negative association with leaf curl virus incidence (-0.0339** and -0.0368**), days to first flowering (-0.0344 and -0.0350), days to 50% flowering (-0.0199** and -0.0200**), and percentage of fruit set (-0.2088 and -0.2134**) at both the phenotypic and genotypic levels Table 3 and 4. These results align with the observations of earlier researchers, including Renuka and Sadashiva (2016), Kumar *et al*., (2017), Singh (2017), Sunilkumar *et al*., (2019), and Sharma *et al.,* (2019) in the context of tomato studies.

Number of primary branches per plant

The number of primary branches per plant exhibited a significant positive association with yield per plant at both the phenotypic (0.2455**) and genotypic (0.2459**) levels. This clearly indicates that selecting for fruit yield based on the number of primary branches per plant is a reliable strategy. This trait also showed a significant positive correlation with several other important traits: the number of flowers per cluster (0.4685** and 0.4686*), the number of fruits per cluster (0.2431** and 0.2434**), days to first fruit harvest (0.1427** and 0.1428*), average fruit weight (0.1431* and 0.1434**), number of locules per fruit (0.3967** and 0.3969*), pericarp thickness (0.3148** and 0.3149**), fruit firmness (0.2100** and 0.2108*), and the number of fruits per plant (0.2431** and 0.2434**) at both phenotypic and genotypic levels, respectively Table 1 and 2.

Conversely, the number of primary branches per plant demonstrated a significant negative association with days to first flowering (-0.2603** and -0.2609**), days to 50% flowering (-0.5890** and -0.5896**), percentage of fruit set (-0.2443** and -0.2379**), fruit length (-0.0439** and -0.0440**), fruit diameter (-0.0336* and -0.0337**), and leaf curl virus incidence (-0.4186** and -0.4412**) at both phenotypic and genotypic levels, respectively Table 3 and 4. Similar findings have been reported by Renuka and Sadashiva (2016), Kumar *et al.,* (2017), Singh (2017), Sunilkumar *et al.,* (2019), and Sharma *et al.,* (2019) in studies on tomatoes.

Table 2: Genotypic Correlation co-efficient among yield and its components in tomato genotypes.

Character	PH	DF	DFF	PFS	DFH	AFW	NFP	LCV	FYP
PH	**1.00**	-0.0350*	-0.0200**	0.0212**	-0.1212**	0.0511**	0.0212*	-0.0368**	0.0141**
DF		**1.00**	0.3128**	0.0631**	0.0986**	-0.1686*	0.0631**	0.2367*	0.1171**
DFF			**1.00**	-0.3097*	-0.1472**	-0.2322*	-0.3097*	0.5776**	0.2240**
NFP				**1.00**	0.1766**	0.3587*	1.0000**	-0.5177**	0.3025*
DFH					**1.00**	0.0352*	0.1766*	-0.1795**	0.1059**
AFW						**1.00**	0.3587**	-0.3342**	0.4944**
LCV								**1.00**	-0.4822**
FYP									**1.00**

* and ** significance at 1% and 5 %
PH- Plant height, DF= days to first flowering, DFF= Days to 50% flowering, DFH= Days to first harvest,
AFW= Average fruit weight, NFP= Number of fruits per plant, LCV= Leaf curl virus and FYP= Fruit yield per plant

Table 3: Phenotypic path coefficient analysis of characters on fruit yield of tomato (*Solanum lycopersicum* L.) genotypes.

Character	PH	DF	DFF	NFP	DFH	AFW	NFP	LCV
PH	**-0.1003***	0.0035	0.0020	-0.0021	0.0122	-0.0051	-0.0021	0.0037
DF	-0.0039	**0.1105***	0.0346	0.0070	0.0109	-0.0186	0.0070	0.0262
DFF	-0.0024	0.0376	**0.1203****	-0.0373	-0.0177	-0.0279	-0.0373	0.0695
DFH	0.0364	-0.0296	0.0442	-0.0531	**-0.3004****	-0.0105	-0.0531	0.0539
AFW	0.0127	-0.0420	-0.0579	0.0894	0.0087	**0.2492****	0.0894	-0.0833
NFP	-0.0070	-0.0104	0.0220	-0.0297	0.0109	0.0053	**-0.0344****	-0.0291
LCV	0.0193	-0.1240	-0.3027	0.2713	0.0940	0.1751	0.2713	**-0.5240****
FYP	**0.0144**	**-0.1171**	**-0.2240**	**0.3025**	**-0.1059**	**0.4944**	**0.3025**	**-0.4822**

* and ** significance at 1% and 5 %

PH- Plant height, DF= days to first flowering, DFF= Days to 50% flowering, DFH= Days to first harvest, AFW= Average fruit weight, NFP= Number of fruits per plant, LCV= Leaf curl virus and FYP= Fruit yield per plant

Days to first flowering

Days to first flowering exhibited a significant positive association with yield per plant at both the phenotypic (0.1164**) and genotypic (0.1171**) levels, indicating that selecting for fruit yield based on this trait is a reliable approach. This trait also showed a significant positive correlation with several key characteristics, including the number of fruits per cluster (0.0628** and 0.0631**), percentage of fruit set (0.2516** and 0.2560**), days to first fruit harvest (0.0984** and 0.0986*), fruit length (0.0652 and 0.0654*), fruit diameter (0.0126* and 0.0128**), number of fruits per plant (0.0628* and 0.0631**), and leaf curl virus incidence (0.2248 and 0.2367*) at both phenotypic and genotypic levels, respectively Table 1 and 2.

Conversely, days to first flowering demonstrated a significant negative association with the number of flowers per cluster (-0.2442** and -0.2452**), average fruit weight (-0.1674** and -0.1686**), number of locules per fruit (-0.3266** and -0.3276**), pericarp thickness (-0.2123** and -0.2126**), and fruit firmness (-0.1735* and -0.1738**) at both phenotypic and genotypic levels, respectively Table 3 and 4. These results are consistent with the findings of previous researchers, including Renuka and Sadashiva (2016), Kumar *et al.*, (2017), Singh (2017), Sunilkumar *et al.*, (2019), and Sharma *et al.*, (2019) on tomatoes.

Days to 50% flowering

Days to 50% flowering exhibited a significant positive association with yield per plant at both the phenotypic (0.2235**) and genotypic (0.2240**) levels, indicating that selecting for fruit yield based on days to 50% flowering is a reliable strategy. Conversely, days to 50% flowering showed significant negative associations with several important traits, including the number of flowers per cluster (-0.3814** and -0.3817**), number of fruits per cluster (-0.3091** and -0.3097**), days to first fruit harvest (-0.1471* and -0.1472*), fruit length (-0.1990 and -0.1990**), fruit diameter (-0.0069* and -0.0069**), average fruit weight (-0.2318** and -0.2322**), number of locules per fruit (-0.3385** and -0.3385**), pericarp thickness (-0.1996** and -0.1998*), fruit firmness (-0.1507* and -0.1509**), and the number of fruits per plant (-0.3091** and -0.3097**) at both the phenotypic

Table 4: Genotypic path coefficient analysis of characters on fruit yield of tomato (*Solanum lycopersicum* L.) genotypes.

Character	PH	DF	DFF	NFP	DFH	AFW	NFP	LCV
PH	**-0.1010****	0.0035	0.0020	-0.0021	0.0122	-0.0052	-0.0021	0.0034
DF	-0.0034	**0.0978****	0.0305	0.0061	0.0096	-0.0164	0.0061	0.0220
DFF	-0.0018	0.0288	**0.0921****	-0.0285	-0.0136	-0.0214	-0.0285	0.0505
NFP	-0.0030	-0.0089	0.0438	**-0.1418****	-0.0250	-0.0508	-0.1418	0.0695
DFH	0.0341	-0.0278	0.0416	-0.0498	**-0.2826****	-0.0099	-0.0498	0.0483
AFW	0.0131	-0.0429	-0.0593	0.0918	0.0089	**0.2560***	0.0918	-0.0810
NFP	-0.0108	-0.0155	0.0338	-0.0152	0.0168	0.0078	**-0.0534***	-0.0452
LCV	0.0143	-0.0968	-0.2362	0.2112	0.0736	0.1362	0.2112	**-0.4307****
FYP	**0.0144**	**-0.1164**	**-0.2235**	**0.3024**	**-0.1057**	**0.4943**	**0.3024**	**-0.4555**

* and ** significance at 1% and 5 %

PH- Plant height, DF= days to first flowering, DFF= Days to 50% flowering, DFH= Days to first harvest, AFW= Average fruit weight, NFP= Number of fruits per plant, LCV= Leaf curl virus and FYP= Fruit yield per plant

and genotypic levels, respectively Table 1 and 2.

Additionally, this trait demonstrated a significant positive association with percentage of fruit set (0.1748* and 0.1774**) and leaf curl virus incidence (0.5485** and 0.5776**) at both phenotypic and genotypic levels, respectively Table 3 and 4. These results align with the findings of previous researchers, including Renuka and Sadashiva (2016), Kumar *et al.,* (2017), Singh (2017), Sunilkumar *et al.,* (2019), and Sharma *et al.,* (2019) in studies on tomatoes.

Days to first fruit harvest

A significant positive association between days to first fruit harvest and yield per plant was observed at both the phenotypic (0.1057**) and genotypic (0.1059**) levels, indicating that selection for fruit yield based on days to first fruit harvest is reliable. Days to first fruit harvest also exhibited a significant negative association with fruit firmness (-0.0309** and -0.0309) and leaf curl virus incidence (-0.1710** and -0.1795**) at both the phenotypic and genotypic levels, respectively Table 1 and 2.

Additionally, this trait showed significant positive associations with fruit length (0.0478** and 0.0478**), average fruit weight (0.0349** and 0.0352**), fruit diameter (0.0176** and 0.0176*), number of locules per fruit (0.0022 and 0.0022**), pericarp thickness (0.1258* and 0.1259*), and the number of fruits per plant (0.1763* and 0.1766**) at both the phenotypic and genotypic levels, respectively Table 3 and 4. These findings are consistent with previous research by Renuka and Sadashiva (2016), Kumar *et al.,* (2017), Singh (2017), Sunilkumar *et al.,* (2019), and Sharma *et al.,* (2019) on tomatoes, which support the results of the present investigation.

Average fruit weight

Average fruit weight exhibited a significant positive association with yield per plant at both the phenotypic (0.4943**) and genotypic (0.4944**) levels, indicating that selection for fruit yield based on average fruit weight is reliable. This trait also showed significant positive associations with the number of locules per fruit fruits per plant (0.3586** and 0.3587**) at both phenotypic and genotypic levels, respectively Table 1 and 2.

In contrast, average fruit weight had a significant negative association with fruit firmness (-0.0454* and -0.4548*) and leaf curl virus incidence (-0.3163** and -0.3342**) at both phenotypic and genotypic levels, respectively. Overall, fruit characteristics such as fruit length, diameter, and weight demonstrated significant positive associations with yield per plant, making them reliable indicators for selecting tomatoes for fruit yield. Table 3 and 4 These observations align with previous findings by Renuka and Sadashiva (2016), Kumar *et al.,* (2017), Singh (2017), Sunilkumar *et al.,* (2019), and Sharma *et al.,* (2019) in tomato research.

Number of fruits per plant

The number of fruits per plant demonstrated a significant positive association with yield per plant at both the phenotypic (0.3024**) and genotypic (0.3025**) levels, clearly indicating that selection for fruit yield based on the number of fruits per plant is a reliable approach. Table 1 and 2. Additionally, the number of fruits per plant exhibited a significant negative association with leaf curl virus incidence (-0.4904** and -0.5177**) at both the phenotypic and genotypic levels, respectively. Table 3 and 4. These results align with the findings of previous researchers, including Renuka and Sadashiva (2016), Kumar *et al.,* (2017), Singh (2017), Sunilkumar *et al.,* (2019), and Sharma *et al.,* (2019) on tomatoes.

Per cent incidence of leaf curl virus incidence

Leaf curl virus incidence had significant negative association with yield per plant at both phenotypic (-0.4555**) and genotypic (-0.4822**) levels clearly indicating selection for fruit yield based on resistance to leaf curl virus is reliable. Table 1, 2,3 and 4.

Conclusion

This study highlights the significant relationships between various phenotypic and genotypic traits and yield per plant in tomatoes (*Solanum lycopersicon*). Key findings indicate that plant height, the number of primary branches, days to flowering, and average fruit weight all positively correlate with yield, suggesting that these traits can be effectively selected to enhance fruit production. Conversely, the negative associations of plant height, primary branches, and days to flowering with leaf curl virus incidence underscore the importance of incorporating disease resistance into breeding programs. The strong correlation of average fruit weight and the number of fruits per plant with yield further emphasizes their reliability as selection criteria. Overall, these findings provide valuable insights for breeders aiming to improve tomato yield through strategic trait selection, aligning with previous research in the field.

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