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Correlation studies in tomato (*Solanum lycopersicum* L.) for yield and quality

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Abstract
A total of 45 experimental hybrids generated by diallel mating design using 10 inbred lines of sweet corn were evaluated with 10 parents and 2 checks during Rabi 2010-11 at Vegetable Research Station, Dr. Y.S.R. Horticultural University, Rajendranagar, Hyderabad. The yield per hectare displayed positive correlation with plant height, No. of primary branches/plant, No. of flowers/cluster, No. of fruits/clusters, fruit length, fruit width, average fruit weight, No. of locules/fruit, pericarp thickness, total soluble solids, titrable acidity, total sugars, lycopene content. Higher correlation coefficient was observed between fruit yield and No. of flowers/cluster and No. of fruits/cluster. Since plant height, number of flowers per cluster, number of fruits per cluster, total soluble solids showed highest significant positive correlation with yield selection for these characters will be beneficial for improving the yield in tomato without compromising for quality.

Keywords: Diallel mating design sweet corn, plant height yield correlation, fruits cluster positive correlation, tomato yield improvement traits, selection beneficial tomato yield

Introduction
The tomato (*Solanum lycopersicum* L.) (2n=2x=24) is one of the most significant solanaceous vegetable crops, originated from the Peru-Ecuador region. It is widely cultivated in tropical and subtropical regions. In many countries, it is referred to as the "poor man's orange" due to its appealing appearance and high nutritional value (Singh *et al*., 2004) [15]. Tomato ranks second next to potato in global vegetable production. In India, where there is year-round demand for fresh tomatoes, the crop is cultivated on 0.85 million hectares, yielding a production of 20 million metric tonnes. Tomatoes are commonly used in sandwiches, salads, and various processed products such as paste, purée, soup, sauce, juice, ketchup, canned whole fruits, and beverages (Bose *et al*., 2002) [1].

Tomatoes are considered moderately nutritious and serve as an important source of vitamins A and C, as well as essential minerals (Hari, 1997) [4]. In India, tomatoes are predominantly consumed raw or used in the preparation of chutneys, pickles, and other dishes. Additionally, tomatoes are rich in lycopene, a compound known for its anti-cancer properties (Bose *et al*., 2002) [1]. Lycopene functions as an antioxidant, neutralizing free radicals that are often linked to the development of cancer. As a result, lycopene contributes significantly to human health. Tomatoes are widely regarded as a "Protective Food" due to their richness in minerals, vitamins, antioxidants, and organic acids Sharma, 2021. Beyond providing essential nutrients, color, and flavor to the diet, tomatoes are also a significant source of antioxidants and chemo-protective compounds, classifying them as a functional food.

The tomato crop holds great potential for heterosis breeding, with the enhancement of productivity through the exploitation of hybrid vigor being one of the most effective strategies in crop improvement. This approach can be successfully applied to boost both the quality and yield of tomatoes. Although tomatoes are primarily a self-pollinated crop, the exceptionally high heterosis observed is believed to stem from the fact that tomatoes were originally a highly outcrossing genus, which gradually evolved into a self-pollinated species.

Tomato breeding programs have traditionally prioritized the development of hybrids with enhanced agronomic traits, particularly focusing on yield and fruit quality. To achieve this, understanding the nature and strength of correlations between key traits is crucial.

Selecting for one trait can either enhance or diminish the expression of another, depending on the genetic correlations that exist between them (Souza *et al*., 2012) [16].

Yield is a complex trait influenced by multiple contributing factors and their interactions. Conducting correlation analysis among various quantitative traits provides insights into their associations, which can be effectively leveraged to develop selection strategies for improving yield components. In any successful selection program, assessing the extent to which different traits are connected to yield is essential. With this backdrop the present investigation was taken up to analyse the correlation among yield and quality traits.

Materials and Methods

The field experiment was conducted at the Vegetable Research Station, Dr. Y.S.R. Horticultural University, Rajendranagar, Hyderabad. The experimental material comprised ten lines (L1 to L10). These ten parental lines were crossed in a diallel mating design (excluding reciprocals) during the Rabi season of 2010-11 at the same location. The resulting 45 F_1 hybrids, along with the ten parents and two check varieties (Siri and US-618), were evaluated for yield, yield-contributing traits, and quality parameters using a randomized block design with three replications. Each entry was planted in two rows, with 10 plants per row, maintaining a spacing of 60 cm between rows and 45 cm between plants. Standard cultural practices and plant protection measures, as recommended by Dr. YSRHU, were uniformly applied across all treatments.

In each entry, five plants were tagged randomly and data was collected on plant height (cm), days to 50% flowering, number of flowers primary branches per plant, number of flowers per cluster, number of fruits per cluster, fruit length (cm), fruit width (cm), average fruit weight (g), fruit yield per plant (kg), total soluble solids (ºBrix), lycopene content (mg/100 g).

To assess the association between green ear yield and its component traits, genotypic correlation coefficients were estimated using the formula proposed by Johnson *et al*. (1955) [5]. Correlation co-efficients were analysed using R software version 4.1.2.

$$rg = \frac{Cov\ g.a.b.}{\sqrt{(\sigma^2 g_a) \times (\sigma^{2} g_b)}}$$

$$rp = \frac{Cov\ p.a.b.}{\sqrt{(\sigma^2 p_a) \times (\sigma^{2} p_b)}}$$

Where,

Cov. p.a.b = Phenotypic covariance between traits a and b

$\sigma^2 p_a$, $\sigma^{2} p_b$ = Phenotypic covariance for trait a and b.

Results

Correlation among yield and yield related traits

The correlation coefficients among the different characters were worked out and presented in Table 1 (genotypic correlation) and Figure 1 (Phenotypic correlation)

A detailed perusal of the data (Table 1) revealed that the genotypic correlation coefficients among 16 traits revealed that days to 50% flowering exhibited significantly negative correlation with fruit yield (-0.55**) and fruit length (-0.55**). Also significant correlation in negative direction was observed with the traits *viz*., No. of flowers/cluster, No. of fruits/cluster, fruit width, average fruit weight, total soluble solids and total sugars whereas non-significant negative correlation was observed with rest of the traits studied. No. of primary branches/plant showed significant genotypic correlation in positive direction with No. of flowers/cluster (0.77), No. of fruits/cluster (0.62), fruit length (0.84), fruit width (0.52) and average fruit weight (0.48).

Significantly correlation in positive direction was observed between plant height and No. of primary branches (0.84), No. of flowers/cluster (0.93), No. of fruits/cluster (0.81), fruit length (0.76), fruit width (0.44) and average fruit weight (0.51).

No. of flowers/cluster showed significant correlation in positive direction with No. of fruits/cluster (0.86), fruit length (0.67), fruit width (0.29), average fruit weight (0.26) while negative non-significant correlation was observed with No. of locules/fruit (-0.42)

No. of fruits/cluster showed positive significant correlation with fruit length (0.52) and average fruit weight (0.41) whereas negative correlation was observed with No. of locules/fruit (-0.48). Fruit length and fruit width showed positive significant correlation with average fruit weight (0.58, 0.63). Negative correlation was observed with No. of locules/fruit (-0.25, -0.10).

For all the traits studied genotypic correlation was greater than phenotypic correlation.

Correlation among quality traits and yield

Pericarp thickness showed positive correlation with plant height (0.49), No. of primary branches/plant (0.34), No. of flowers/cluster (0.30), fruit length (0.52), fruit width (0.35), average fruit weight (0.31), titrable acidity (0.28), fruit yield (0.56) while negative correlation was observed with days to 50% flowering (-0.21), No. of locules/fruit (-0.06), total soluble solids (-0.12), ascorbic acid content (-0.14) and lycopene content (-0.11).

The trait total soluble solids showed positive significant correlation with lycopene content (0.33), fruit yield (0.85), total sugars (0.49) while negative significant correlation was observed with titrable acidity (-0.87) and days to 50% flowering (-0.37). Negative significant correlation was observed between titrable acidity and total sugars (-0.30) and lycopene content (-0.27) while positive significant correlation was observed with fruit yield (0.84)

Ascorbic acid content showed negative correlation with fruit yield (-0.55). Non-significant correlation both in negative and positive directions was observed with rest of traits.

Total sugars showed significant positive correlation with fruit yield (0.76) and negative non-significant correlation with ascorbic acid (-0.09).

Lycopene content showed positive significant correlation with fruit yield (0.95) and average fruit weight (0.37) and total soluble sugars (0.33) while negative correlation was observed with titrable acidity (-0.27) and non-significant correlation with rest of the traits.

Fruit yield showed positive significant correlation with pericarp thickness (0.56), total soluble sugars (0.85), titrable acidity (084), total soluble sugars (0.76), lycopene content (0.95), while negative correlation was observed with ascorbic content (-0.55).

Discussion

Yield being a complex character is governed by a large

number of genes. The influence of each character on yield could be known through correlation studies with a view to determine the extent and nature of relationships prevailing among yield and yield attributing characters.

A perusal of the data revealed that genotypic correlation coefficients (table 1) were higher than phenotypic correlation coefficients (Fig 1). This might be due to the masking effect of environment in the total expression of the genotypes resulting in the reduced phenotypic association. The yield per hectare displayed positive correlation with plant height, No. of primary branches/plant, No. of flowers/cluster, No. of fruits/clusters, fruit length, fruit width, average fruit weight, No. of locules/fruit, pericarp thickness, total soluble solids, titrable acidity, total sugars, lycopene content. However fruit yield showed negative correlation with days to 50% flowering and ascorbic acid. Similar association among different traits was also reported by (Samadia *et al*., 2006) [11].

Higher correlation coefficient was observed between fruit yield and No. of flowers/cluster and No. of fruits/cluster indicating that fruit yield is effected by No. of flowers and fruits/cluster. Emphasis for selection of these traits in desired direction for higher yield had also been suggested by earlier workers (Singh, 2007; Madhurina and Paul, 2012; Narolia *et al*., 2012) [14, 6, 7].

Average fruit weight showed non-significant correlation with ascorbic acid content, on the other hand, fruit yield showed negative correlation with ascorbic acid content indicating that small fruits have high ascorbic content. Also lowest correlation was observed between fruit yield and fruit weight. This situation indicate that fruit yield has less influence on fruit yield (Gautier *et al*., 2008) [3].

Fruit yield showed negative correlation with days to 50% flowering indicating that as number of days to flowering increased, fruit yield decreased. Hence, early maturing tomato varieties will give high yield (Rathod *et al*., 2016, Nevani and O Sridevi, 2021 and Reddy *et al*., 2013) [9, 8, 10].

Titrable acidity showed negative significant correlation with total sugars and total soluble solids. This shows that as the fruit ripens sugar content increase at the cost of acid percentage indicating that sugars develop while acids are used up during maturation (Nevani and O Sridevi, 2021) [8].

Highest correlation coefficient was also observed between No. of flowers/cluster and No. of fruits/cluster indicating that least flower drop and most of flowers in the truss develop into flowers. A negative correlation was observed between No. of locules/fruit and No. of fruits/cluster explaining that as the number of fruits within a cluster increased, the No. of locules per fruit decreases. This might be resulting from the fact when a plant produces more number of fruits within a cluster, it need to distribute its resources more evenly among them resulting in smaller fruits with fewer locules per fruit (Vinod Kumar Rathod *et al*., 2018 and Sharma *et al*., 2024) [17, 13]. Plant height and No. of primary branches/plant showed positive significant correlation with each other. Surprisingly fruit yield also showed highest significant positive correlation with the two traits indicating that taller plants put forth for more no. of primary branches per plant thus contributing for high yields (Fandan *et al*., 2024) [2].

Since plant height, number of flowers per cluster, number of fruits per cluster, total soluble solids showed highest significant positive correlation with yield selection for these characters will be beneficial for improving the yield in tomato without compromising for quality.

Table 1: Genotypic (G) correlation coefficients among yield, yield attributes and quality characters 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)	1.00															
(2)	0.84**	1.00														
(3)	-0.59**	-0.55**	1.00													
(4)	0.93**	0.77**	-0.52**	1.00												
(5)	0.81**	0.62**	-0.34**	0.86**	1.00											
(6)	0.76**	0.84**	-0.55**	0.67**	0.52**	1.00										
(7)	0.44**	0.52**	-0.48**	0.29*	0.24	0.73**	1.00									
(8)	0.51**	0.48**	-0.49**	0.26*	0.41**	0.58**	0.63**	1.00								
(9)	-0.38**	-0.26	-0.07	-0.42**	-0.48**	-0.25	-0.10	-0.15	1.00							
(10)	0.49**	0.34**	-0.21	0.30**	0.22	0.52**	0.35**	0.31*	-0.06	1.00						
(11)	0.45**	0.51**	-0.37**	0.37**	0.39**	0.29*	0.32**	0.28*	-0.14	-0.12	1.00					
(12)	-0.19	-0.32*	-0.02	-0.22	-0.27*	-0.02	0.14	0.06	0.21	0.28*	-0.87**	1.00				
(13)	-0.11	-0.16	0.21	0.05	0.21	-0.03	-0.15	0.006	-0.18	-0.14	-0.06	0.15	1.00			
(14)	0.48**	0.38**	-0.42**	0.44**	0.41**	0.27*	0.01	0.09	-0.03	0.24	0.49**	-0.30*	-0.09	1.00		
(15)	0.13	-0.01	-0.12	0.02	0.23	0.03	0.02	0.37**	-0.04	-0.11	0.33*	-0.27*	0.07	0.15	1.00	
(16)	0.95**	0.76**	-0.55**	0.84**	0.85**	0.56**	0.49**	0.45**	0.49**	0.56**	0.85**	0.84**	-0.55**	0.76**	0.95**	1.00

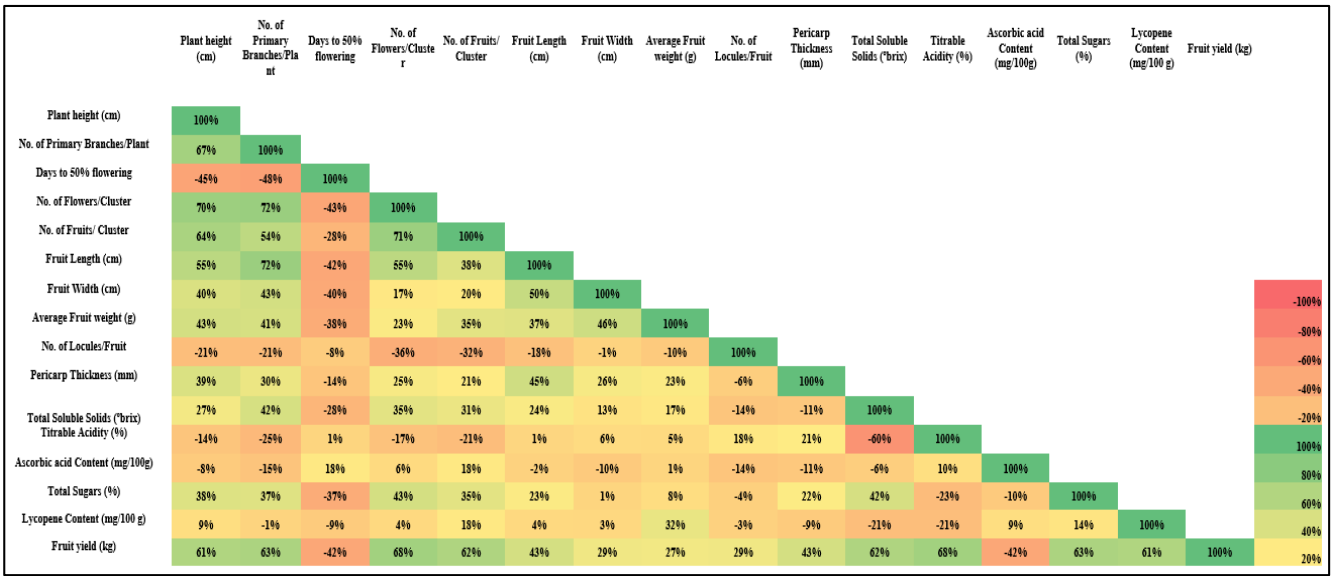

Fig 1: Phenotypic correlation coefficients for yield and quality traits in tomato

Conclusion

The study revealed significant correlations between various yield-related traits and fruit yield in tomatoes. Plant height, number of primary branches, flowers per cluster, and fruits per cluster exhibited strong positive correlations with fruit yield, indicating their importance in yield improvement. Total soluble solids and lycopene content also showed positive correlations with yield, while days to 50% flowering and ascorbic acid content had negative correlations with yield. These findings suggest that selecting for traits such as plant height, number of flowers and fruits per cluster, and total soluble solids could enhance tomato yield without compromising quality.

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