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CORRELATION ANALYSIS OF AGRO-MORPHOLOGICAL TRAITS IN SEGREGATING TOMATO (*SOLANUM LYCOPERSICUM* L.) LINES

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ABSTRACT

Correlation analysis among vegetative, reproductive, yield and quality traits in tomato (*Solanum lycopersicum* L.) revealed several significant associations useful for selection in breeding programs. Plant height showed a significant positive correlation with the number of primary branches (0.56), but weak associations with fruit weight, fruit diameter, pericarp thickness and TSS, indicating limited direct influence on yield. The number of flowers per inflorescence showed positive correlations with fruit length (0.32) and pericarp thickness (0.36). Fruit length was strongly correlated with fruit diameter (0.65), fruit weight (0.59) and pericarp thickness (0.76). Fruit diameter had the highest positive correlation with fruit weight (0.83), and was also positively associated with pericarp thickness (0.65) and number of locules (0.58). Fruit weight showed significant positive correlations with pericarp thickness (0.68) and number of locules (0.56). Pericarp thickness was positively correlated with TSS (0.44). Fruit weight (28.4%) contributed the highest variability, followed by TSS (15.6%) and number of flowers per plant (13.25%), indicating that yield and quality traits are the major determinants of genetic divergence in *Solanum lycopersicum*. Overall, fruit diameter, fruit weight and pericarp thickness emerged as key selection traits due to their strong positive interrelationships, indicating their major role in improving yield and quality in tomato breeding programs.

Key words : Correlation analysis, Vegetative, Quality traits, Tomato breeding.

Introduction

Tomato (*Solanum lycopersicum* L.) is a self-pollinated, diploid (2n = 24) vegetable crop belonging to the family Solanaceae and is widely cultivated across tropical, subtropical and temperate regions (Jenkins, 1948; Peralta *et al.*, 2008) It is one of the most commercially important vegetable crops due to its high productivity, wide adaptability and consumer preference (Ali *et al.*, 2020). Tomato fruits are valued for their nutritive qualities, being rich in vitamins, minerals, organic acids and antioxidants such as lycopene and β-carotene (Reddy *et al.*, 2024). Owing to its versatile use in fresh consumption as well as processing industries, improvement in yield and quality traits remains a primary objective in tomato breeding programs (Bertin and Génard, 2018; Reddy *et al.*, 2022).

Fruit yield in tomato is a complex polygenic trait influenced by several interrelated agro-morphological and reproductive characters (Pons *et al.*, 2023). Traits such as plant height, number of primary branches, days to 50% flowering, number of fruits per inflorescence, fruit length, fruit diameter, fruit weight, pericarp thickness, number of locules and total soluble solids (TSS) collectively determine productivity and market acceptability. Since these traits are quantitatively inherited and often exhibit varying degrees of association among themselves, direct selection for yield alone may not always be effective. Therefore, understanding the interrelationships among component traits becomes essential for designing efficient selection strategies (Cobb *et al.*, 2013).

Correlation analysis provides a statistical measure of the degree and direction of association between different characters (Ali *et al.*, 2017; Harini *et al.*, 2025). It helps in identifying traits that have a strong influence on yield and quality, thereby enabling indirect selection for complex characters (Fischer, 2001). Positive correlations between yield and its components facilitate simultaneous improvement, whereas negative correlations may pose constraints and require careful breeding approaches (Fasoula and Fasoula, 2002). In segregating populations, where high genetic variability exists due to recombination and segregation, correlation studies are particularly valuable for identifying promising lines and understanding trait dynamics (Ajie, 2025).

Agro-morphological traits in segregating lines often exhibit wide variability, offering substantial scope for genetic improvement. Evaluating the magnitude and significance of correlations among these traits helps in identifying key yield-contributing characters and understanding their mutual relationships. Such information is crucial for breeders to prioritize selection criteria and enhance breeding efficiency. Therefore, the present investigation was undertaken to study the correlation among important agro-morphological traits in tomato segregating lines and to identify reliable selection indices for yield and quality improvement.

Materials and Methods

Parental lines and development of segregation population

The experimental material comprised three elite lines, namely Kashi Amul, AVTO1219 and LA4025, which were utilised as parental sources for the development of a triple cross F_1 population in tomato (*Solanum lycopersicum* L.). These donor lines were selected based on their superior agronomic performance, adaptability under open field conditions and their potential to contribute favourable alleles governing important growth, yield and fruit quality traits. Each parent possessed distinct desirable characteristics, thereby providing a strong genetic base for recombination breeding. The breeding programme was initiated by generating a single cross between two selected parental lines. Subsequently, the resulting F_1 hybrid was crossed with the third donor parent to develop the triple cross F_1 population, designated as (Kashi Amul × AVTO1219) × LA4025. The triple cross strategy was adopted to enhance genetic variability, promote recombination and facilitate the accumulation of favourable allelic combinations for quantitative traits. This approach increases the probability of recovering superior recombinants with improved yield potential and horticultural attributes.

A total of 150 triple-cross F_1 plants were raised and evaluated under open field conditions. The crop was grown following recommended agronomic practices to ensure uniform plant growth and optimal expression of genetic potential. The primary objective of the evaluation was to assess variability among the progenies and to identify superior individual plants exhibiting enhanced performance for yield-contributing and growth-related traits. Comprehensive phenotypic evaluation was carried out throughout the crop growth period. 22 superior plants were selected based on overall plant vigour, earliness, fruiting behaviour, fruit size, fruit weight and yield performance. The selected plants were considered promising for further evaluation and advancement in the breeding programme.

Data collection

Plant height (cm), number of primary branches, days to 50% flowering, number of flowers per inflorescence, fruit weight (g), fruit length (cm), fruit diameter (cm), number of locules, pericarp thickness (cm), and total soluble solids (TSS) (°Brix) were among the ten horticultural traits that were measured in tomato genotypes.

Experimental field and data collection

The field experiment was conducted during the crop season under a paired-row planting system at the ICAR–Indian Institute of Vegetable Research (IIVR), Varanasi, located at 25.18° N latitude and 82.83° E longitude. The experimental site represents subtropical climatic conditions with favourable temperature and soil characteristics for tomato cultivation. Seeds were sown in mid-July in nursery beds, and healthy seedlings were transplanted during the first week of October. Each accession was represented by ten plants grown in two replications under the paired-row system on raised beds, maintaining a spacing of 60 cm × 45 cm to ensure adequate aeration, light penetration and nutrient availability. Standard cultural practices, including irrigation, fertilization, intercultural operations and plant protection measures, were adopted as per the recommended package of practices for tomato to minimise environmental variation and ensure reliable phenotypic evaluation. For each replication, information was gathered from five randomly chosen plants. Data recorded protocols were mentioned in Table 1.

Statistical analysis

Principal component analysis was carried out by using

Table 1 : Followed the data collection protocol for each trait.

S. no.	Trait	Protocol
1	Plant height	Plant height was measured from the collar region to the tip of the tagged plants at the time of final harvest and denoted in cm.
2	Number of primary branches	The total number of branches in five randomly selected plants was counted at the time of final harvest, and the mean was calculated.
3	Days to 50% flowering	The number of days taken from transplanting to the flowering of 50% of plants was recorded in each replication.
4	Number of flowers per inflorescence	The number of flowers per inflorescence was recorded by counting all flowers arising from the five inflorescences (truss) and the mean was calculated.
5	Fruit length	Fruit length was measured from the stalk or stem end to the blossom end of the fruit at the second harvest by using vernier callipers and the average of ten fruits was computed and expressed in centimeters.
6	Fruit diameter	The mean equatorial fruit diameter in centimetres of ten fruits selected randomly, cut at maximum perimeter and the diameter was measured using a vernier calliper.
7	Fruit weight	The weight of randomly selected 10 individual fruits of each replication was taken and the average was calculated.
8	Pericarp thickness	Ten randomly chosen fruits from each treatment were cut horizontally into 2 halves and the pericarp thickness was measured using a Vernier calliper. Then the average pericarp thickness was calculated for each genotype.
9	Number of locules	Ten ripe fruits of each replication were cut transversely and locules were counted in all the treatments. Then the average number of locules was calculated.
10	Total soluble solids	Total soluble solids were recorded from five randomly selected ripe fruits. Juice from these fruits was used to measure TSS with a hand-held refractometer.

the GRAPES software, version 1.0.0. (Gopinath *et al.*, 2020).

Results and Discussion

The correlation analysis among vegetative, reproductive, yield and quality traits revealed important interrelationships that help in identifying key selection criteria for yield improvement in tomato. Plant height showed a significant and positive correlation with the number of primary branches (0.56), indicating that taller plants tended to produce more branches (Table 2). This suggests that plant vigour contributes to branching ability. However, plant height exhibited weak and non-significant correlations with fruit weight, fruit diameter, pericarp thickness and TSS, indicating that vegetative growth alone does not directly translate into higher yield. The slight negative association with the number of locules (-0.23) suggests that taller plants may not necessarily produce multilocular fruits. Therefore, plant height may be considered a secondary trait in yield improvement programs. The number of primary branches showed a moderate positive correlation with the number of flowers per inflorescence (0.32), suggesting that increased branching may support greater reproductive structures. However, its weak association with fruit weight and pericarp thickness indicates that although branching contributes to fruit number, it may not significantly influence fruit size or weight (Bernousi *et al.*, 2011). Hence, selection solely based on branching may not ensure yield enhancement unless combined with fruit size traits (Kouam *et al.*, 2018).

Days to 50% flowering exhibited negative correlations with fruit diameter (-0.348), fruit weight (-0.254) and pericarp thickness (-0.29). This indicates that early-maturing genotypes tended to produce larger and heavier fruits. The negative association suggests that earliness may be advantageous for yield improvement. Early-picking genotypes may escape late-season stresses and allocate more resources toward fruit development, thus enhancing productivity. NFPI showed positive correlations with fruit length (0.32) and pericarp thickness (0.36), indicating that clusters bearing more fruits may also support better-developed fruits. However, its association with fruit weight was relatively low, suggesting that fruit number per cluster does not necessarily increase individual fruit weight. Therefore, a balance between fruit number and fruit size is essential for achieving higher yield (Grozeva *et al.*, 2020). These results are similar to the reports of Harini *et al.* (2025) and Islam *et al.* (2022).

Table 2 : Correlation matrix for agro-morphological traits.

Traits	PH	NPB	DFPF	NFPI	FL	FD	FW	PT	NL	TSS
PH	1	0.56**	0.11	0.17	0.29	0.02	0.01	0.16	-0.23	0.01
NPB	0.56**	1	0.13	0.32	0.21	0.08	0.10	0.16	0.06	-0.01
DFPF	0.11	0.13	1	0.20	-0.14	-0.35	-0.25	-0.29	-0.10	-0.21
NFPI	0.17	0.32	0.20	1	0.32	0.15	0.15	0.36	-0.10	-0.07
FL	0.29	0.21	-0.14	0.32	1	0.65**	0.59**	0.76***	-0.08	0.05
FD	0.02	0.08	-0.35	0.15	0.65**	1	0.83***	0.65**	0.58**	0.39
FW	0.01	0.10	-0.25	0.15	0.59**	0.83***	1	0.68***	0.56**	0.40
PT	0.16	0.16	-0.29	0.36	0.76***	0.65**	0.68***	1	0.09	0.44*
NL	-0.23	0.06	-0.10	-0.10	-0.08	0.58**	0.56**	0.09	1	0.36
TSS	0.01	-0.01	-0.21	-0.07	0.05	0.39	0.40	0.44*	0.35	1

*** indicates correlation is significant at 0.001 level, ** indicates correlation is significant at 0.01 level, * indicates correlation is significant at 0.05 level, PH-Plant height (cm); NPB-Number of primary branches; DFPF-Days to 50% flowering, NFPI-Number of flowers per inflorescence; FL-Fruit length; FD-Fruit diameter; FW-Fruit weight; PT-Pericarp thickness (cm); NL-Number of locules; TSS-Total soluble solids (^{0}Brix)

Fruit length exhibited strong and highly significant positive correlations with fruit diameter (0.65), fruit weight (0.59) and pericarp thickness (0.76). This indicates that longer fruits were generally thicker, heavier and had thicker pericarps. The strong association with pericarp thickness suggests structural robustness of elongated fruits. Thus, fruit length plays an important role in determining overall fruit size and yield potential. Fruit diameter showed a very strong positive correlation with fruit weight (0.83), which was the highest correlation observed among all traits. This clearly indicates that fruit diameter is a major determinant of fruit weight and overall productivity. Fruit diameter also exhibited significant positive associations with pericarp thickness (0.65) and number of locules (0.58), suggesting that wider fruits tend to have more locules and thicker flesh, contributing to higher marketable yield. Therefore, fruit diameter can serve as a reliable selection criterion in breeding programs (Hussain *et al*., 2018). These findings are similar to the reports of Al-Aysh *et al*. (2012).

Fruit weight had strong positive correlations with pericarp thickness (0.68), number of locules (0.56) and fruit diameter (0.83). These results indicate that heavier fruits are associated with larger size and better internal structure. Since fruit weight directly contributes to total yield, its strong association with structural fruit traits confirms its importance as a primary selection parameter. Pericarp thickness showed significant positive correlations with fruit length (0.76), fruit weight (0.68), fruit diameter (0.65) and TSS (0.44). This indicates that a thicker pericarp not only contributes to fruit size and weight but may also enhance fruit quality in terms of soluble solids. Thick pericarp is also desirable for better. The number of locules exhibited significant positive correlations with fruit diameter (0.58) and fruit weight (0.56), indicating that multilocular fruits tend to be larger and heavier. However, its correlation with fruit length and pericarp thickness was comparatively lower, suggesting that locule number mainly influences fruit width rather than elongation. TSS showed a significant positive correlation with pericarp thickness (0.44), indicating that thicker fruits may accumulate more soluble solids. However, TSS had weak correlations with vegetative and most yield traits, suggesting that fruit quality in terms of sweetness is relatively independent of plant growth parameters (Kumar et al., 2013). This independence is beneficial in breeding programs, as yield and quality can be improved simultaneously without strong negative associations (Marinela and Ciulca, 2023). These findings are similar to the reports of Singh *et al*. (2024).

Contribution of traits towards the total divergence

The principal component based contribution of different agro-morphological traits in *Solanum lycopersicum* revealed substantial variability among the evaluated genotypes (Fig. 1). The pie chart indicated that fruit weight (FW) contributed the highest proportion (28.4%) toward total variability, followed by total soluble solids (TSS) (15.6%) and number of fruits per plant (NFPI) (13.25%). Plant height accounted for 11.8%, while number of primary branches and fruit diameter contributed 8.45% and 7.3%, respectively. Fruit length (FL) showed a moderate contribution of 6.85%, whereas pericarp thickness (4.1%), days to first flowering (DFFP) (2.95%), and number of locules (1.3%) contributed relatively less to the overall variation.

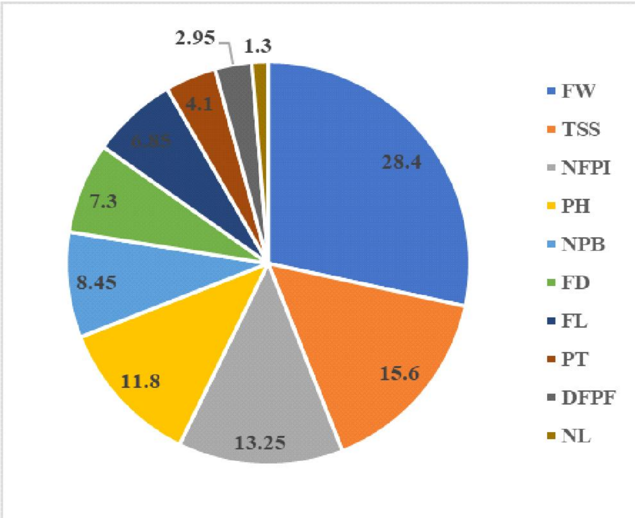

Fig. 1 : Pie chart showing the contribution of each variable towards the divergence.

The predominance of fruit weight suggests that it is the most influential trait governing variability and overall yield performance among the genotypes. The considerable contribution of TSS and number of flowers per plant further indicates the importance of both yield and quality parameters in differentiating the genotypes. Moderate contributions from plant height, branching and fruit size traits highlight their supportive role in yield determination. Conversely, the lower contribution of flowering time and locule number suggests limited variability for these traits in the studied material. Overall, the results emphasize that selection focusing on fruit weight, TSS, and fruit number would be highly effective for improving yield and quality in tomato breeding programs. These results are similar to the findings of Harini e*t al*. (2025).

Conclusion

The correlation analysis revealed that fruit size and structural traits, particularly fruit diameter, fruit weight, fruit length, and pericarp thickness, exhibited strong and significant positive associations, indicating their major contribution to yield improvement in tomato. Among all traits, fruit diameter showed the highest positive correlation with fruit weight, confirming its importance as a reliable selection criterion. Pericarp thickness was also positively associated with total soluble solids, suggesting the possibility of simultaneous improvement of yield and quality. In contrast, vegetative traits such as plant height and number of primary branches had a limited direct influence on yield. Therefore, emphasis on fruit size and structural attributes would be most effective for developing high-yielding and quality tomato genotypes.

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