Plant Archives Vol. 26, Supplement 2, 2026 pp.512-522 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-2.055

INFLUENCE OF PRE-HARVEST FYM-BASED ORGANIC MODULES AND STORAGE CONDITIONS ON BIOCHEMICAL QUALITY OF TOMATO

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(Date of Receiving : 10-05-2026; Date of Revision : 26-06-2026; Date of Acceptance : 31-07-2026)

ABSTRACT

Tomato biochemical quality continues to change during postharvest ripening. This study evaluated the combined influence of FYM-based organic modules and three storage conditions on total soluble solids (TSS), ascorbic acid and lycopene content. A factorial completely randomized design comprising 12 pre-harvest treatment combinations, three storage conditions and three replications was evaluated during 2020-21 and 2021-22. Tomato fruits originated from field experiments conducted at the Regional Agricultural Research Station, Warangal, Telangana, India. Postharvest observations were recorded at 0, 4, 8 and, where fruits remained suitable, 12 days after storage (DAS). Fruits from FYM equivalent to 100, 75 or 50% recommended dose of nitrogen (L1, L2 and L3) integrated with four organic modules (M1-M4) were stored open at room temperature (S1), in perforated polybags at room temperature (S2), or in perforated polybags under refrigeration (S3). Data were analyzed for treatment, storage and interaction effects, using the reported critical difference at 5%. In pooled data, L1M3 recorded the maximum TSS means at 0, 4 and 8 DAS (3.76, 3.94 and 4.12 °Brix). L1M1 recorded the highest pooled ascorbic acid means (27.08, 26.08 and 24.91 mg 100 g^{-1}) and lycopene means (6.84, 7.41 and 7.75 mg 100 g^{-1}). At 8 DAS, TSS was 3.59 °Brix under each storage condition, while S3 retained 20.71 mg 100 g^{-1} ascorbic acid and 6.38 mg 100 g^{-1} lycopene. Only L1M1S3 and L1M3S3 remained available at 12 DAS.

L1M1 and L1M3 maintained the strongest biochemical quality within the evaluated treatments, while refrigerated perforated-polybag storage favoured ascorbic acid retention and gradual lycopene accumulation.

***Keywords* :** ascorbic acid; lycopene; refrigerated storage; tomato; total soluble solids.

Introduction

Tomato (*Solanum lycopersicum* L.) is widely valued for its nutritional importance and is an important dietary source of vitamins, minerals and antioxidant compounds. Despite these benefits, tomato fruits are highly perishable and continue to ripen after harvest. During storage, moisture loss, respiration and other ripening-related processes gradually affect fruit appearance, marketability and biochemical quality. Changes in total soluble solids (TSS), organic acids, ascorbic acid and carotenoid pigments are particularly important because they influence flavour, nutritional value and consumer acceptance. These postharvest changes are shaped not only by the storage environment but also by growing conditions and crop-management practices before harvest (Arah *et al.*, 2015; Bertin and Génard, 2018).

The way a tomato crop is nourished can influence the quality of the fruit that eventually enters storage. Farmyard manure (FYM) supplies organic matter and nutrients, while its integration with microbial and organic formulations offers a biologically based approach to crop management. Sainju *et al.* (2003) reported that plant nutrition has an important influence on tomato fruit composition, taste and postharvest quality. Similarly, Gao *et al*. (2023), based on a meta-analysis of 107 studies, showed that organic fertilizer application can influence several quality attributes of tomato, including soluble solids, vitamin C and lycopene. This suggests that differences established during fruit development may continue to influence fruit behaviour after harvest.

Once harvested, appropriate packaging and storage temperature become important for maintaining quality. Perforated polymeric packaging can reduce excessive moisture loss while allowing ventilation, and packaging method has been reported to influence weight loss and marketability of stored tomatoes (Haile, 2018; Poudel *et al*., 2022; Dladla *et al*., 2023). Refrigeration generally slows respiration and senescence, but individual biochemical constituents may respond differently to temperature. Lycopene formation, for example, is closely linked with ripening and is strongly temperature dependent (Toor and Savage, 2006; Pék *et al.*, 2010). It is therefore useful to consider pre-harvest nutrition and postharvest storage together when evaluating changes in tomato fruit quality.

With this perspective, the present study examined tomatoes obtained from 12 pre-harvest combinations of three FYM levels equivalent to 100, 75 and 50% of the recommended dose of nitrogen (RDN) and four organic modules. After harvest, the fruits were maintained under open room conditions (S1), in perforated polybags at room temperature (S2), or in perforated polybags under refrigerated conditions (S3). The study aimed to determine how these pre-harvest treatments and storage environments influenced TSS, ascorbic acid and lycopene content of tomato during storage.

Materials and Methods

Experimental material and pre-harvest treatments

Tomato fruits were obtained during 2020-21 and 2021-22 from the field experiment conducted at the Regional Agricultural Research Station, Warangal, Telangana, India. The pre-harvest factor comprised 12 combinations of three FYM levels and four organic modules. The FYM levels were L1, FYM equivalent to 100% recommended dose of nitrogen (RDN); L2, FYM equivalent to 75% RDN; and L3, FYM equivalent to 50% RDN integrated with four organic modules, namely M1: (Soil application of *Trichoderma viride* @ 2kg/ton of FYM+250 kg/ha neem cake+ Spraying *Trichoderma viride 5g/litre* + 3% Panchagavya + 5% neem oil + Bt @1g/litre at 10 days interval), M2: (Soil application of *Pseudomonas fluorescens* @ 2.0 kg enriched in 1 ton + 250 kg/ha neem cake+ Spraying *Pseudomonas fluorescens 5g/litre* + 10% Vermiwash + @ 500 ml GCG extract per 10litres of water + NPV @ 250 LE/ha at 10 days interval), M3: (Soil Application of VAM @ 10 Kg/ton of FYM + 250 kg/ha neem cake + Spraying 10% Jeevamruth + 5% NSKE + *5g/litre* Metarhizium anisopliae+ *Trichoderma* + *Pseudomonas spp*. @ 5g/litre at 10 days interval) and M4: (Application of Waste decomposer @ 40l/ton of FYM +Spraying 10% Amruthpani + 5% Neemastra + 5g/litre *Beauveria bassiana* + *Spraying* mass multiplied waste decomposer culture is diluted @ 1:3 ratio with water at 10 days interval).

Storage treatments and experimental design

One kilogram of tomato fruits from each pre-harvest treatment were harvested at pink stage were used for evaluating in a factorial completely randomized design with three replications. Storage treatments comprised S1 (open storage at room temperature), S2 (storage in perforated polyethene bags under room temperature) and S3 (storage in perforated polyethene bags under refrigerated conditions at 7^{o}C). Thus, 12 pre-harvest combinations × 3 storage conditions produced 36 treatment combinations in each season.

Observations and statistical analysis

TSS (°Brix): The total soluble solids of the fruits were determined with the help of Erma hand refractometer and expressed as °Brix.

Ascorbic acid content (mg/100g)

Ascorbic acid was estimated by method outlined by Ranganna, (1986). Ten grams of fruit pulp was grounded well and blended with 3 percent met phosphoric acid (HPO3) and volume was made up to 100 ml. The contents were shaken well and filtered through filter paper. An aliquot of 10 ml was taken and titrated against standard dye solution (2,6 di-chloro phenol indophenol dye) till the light pink colour persisted for at least 15 seconds and was expressed in terms of milligram of ascorbic acid per 100 g of fruit pulp.

Ascorbic acid (mg 100g^{-1}) = (Titre x dye factor x volume made up x 100)/

(Aliquot of extract taken for estimation x weight of sample taken)

Dye factor = 0.5 / Titre value

Lycopene content (mg/100g)

A sample of 5 to 10 g was taken and crushed repeatedly in acetone in a pestle and mortar until the residue was colourless. Transfer the acetone extract to a separatory funnel containing 10 to 15 ml of petroleum ether. Mix gently to take up the pigments into the petroleum ether phase. Transfer the lower (acetone) phase to a 100 ml volumetric flask and extract it repeatedly with petroleum ether until colourless. Combine the petroleum ether extracts and dry over a small quantity of anhydrous sodium sulphate. Make up to 100 ml with petroleum ether and measure the O.D. of the solution at 503 nm using petroleum ether as blank.

Milligrams of lycopene per 100gm sample, using the formula

Lycopene (mg 100 g^{-1}) = (3.1206 × OD of sample × Vol. made up × Dilution × 100) / (weight of sample ×1000)

O.D. of 1.0 = 3.1206 µg of lycopene/ml

Pearson correlation: Pearson's correlation analysis was performed using R statistical software to determine the relationships using TSS, ascorbic acid and lycopene at 8 DAS were used for the correlation analysis. Twelve-DAS observations were excluded.

The Pearson coefficient is:

$$r = \sum(xi - x^{-})\sum(yi - y^{-})/\sqrt{\sum(xi - x^{-})2(yi - y^{-})2}$$

Correlations were interpreted as associations rather than causation.

Results and Discussion

Total soluble solids (°Brix):

During 2020–21, TSS was significantly influenced by FYM-based treatments and storage conditions at 0, 4 and 8 DAS, while the interaction was non-significant (Table 1.a). L1M3 recorded the maximum TSS at 0, 4 and 8 DAS (3.80, 3.98 and 4.16 °Brix, respectively), followed by L1M1 (3.76, 3.94 and 4.12 °Brix), whereas L3M3 recorded the minimum values (2.70, 2.86 and 3.04 °Brix). Storage means increased from about 3.24–3.26 °Brix at 0 DAS to 3.59–3.61 °Brix at 8 DAS. At 12 DAS, fruits were available only in L1M1S3 (4.30 °Brix) and L1M3S3 (4.34 °Brix); fruits under the remaining combinations were spoiled or rejected.

A similar trend was observed during 2021–22 (Table 1.b). L1M1 and L1M3 recorded the maximum TSS at 0, 4 and 8 DAS (3.73, 3.90 and 4.08 °Brix, respectively), while L3M3 recorded the minimum (2.53, 2.70 and 2.88 °Brix). Storage means ranged from 3.21–3.24 °Brix at 0 DAS to 3.56–3.59 °Brix at 8 DAS. At 12 DAS, only L1M1S3 and L1M3S3 remained available, both recording 4.26 °Brix.

In the pooled analysis (Table 1.c), L1M3 maintained the highest TSS at 0, 4 and 8 DAS (3.76, 3.94 and 4.12 °Brix), closely followed by L1M1 (3.74, 3.92 and 4.10 °Brix). The lowest values were consistently recorded in L3M3 (2.61, 2.78 and 2.96 °Brix). Treatment, storage and interaction effects were significant in the pooled analysis. At 12 DAS, observations were confined to refrigerated fruits of L1M1S3 (4.28 °Brix) and L1M3S3 (4.30 °Brix).

The progressive increase in TSS during storage is consistent with ripening-associated changes in carbohydrate metabolism and concentration of soluble constituents as moisture is lost. Beckles (2012) emphasized the importance of sugar metabolism in determining soluble solids and flavour development in tomato. Higher TSS in L1M3 and L1M1 indicates a favourable association between adequate FYM nutrition combined with organic modules and fruit soluble solids. However, this experiment did not directly measure the physiological mechanisms responsible for these differences; hence, effects through improved nutrient uptake or carbohydrate synthesis should be considered possible explanations rather than demonstrated mechanisms. The increase can be related to ripening-associated conversion of reserve constituents into soluble forms and concentration through moisture loss. Packaged fruits may show slower changes because ripening and water loss are moderated (Poudel *et al.*, 2022). The comparatively slower changes under refrigerated storage are consistent with reduced metabolic activity at lower temperatures. Pradhan and Srijaya (2022) similarly observed differences in TSS and other postharvest quality attributes of organically produced tomatoes during ambient and refrigerated storage. Overall, L1M3 and L1M1 consistently maintained comparatively higher TSS, while refrigerated storage enabled these treatment combinations to remain available for assessment at 12 DAS.

Ascorbic acid content (mg 100 g^{-1})

Ascorbic acid content was significantly influenced by FYM-based treatments, storage conditions and their interaction during both years. In 2020–21 (Table 2.a), L1M1 consistently recorded the highest treatment mean, declining from 26.98 mg 100 g^{-1} at 0 DAS to 24.82 mg 100 g^{-1} at 8 DAS, followed by L1M3 (25.56 to 23.17 mg 100 g^{-1}). The lowest values at 8 DAS occurred in L3M3 (16.38 mg 100 g^{-1}). Refrigerated storage (S3) showed better vitamin C retention as storage progressed, recording 21.76 and 20.96 mg 100 g^{-1} at 4 and 8 DAS, respectively. The highest interaction value at 8 DAS was recorded in L1M1S3 (25.96 mg 100 g^{-1}).

A similar pattern was evident during 2021–22 (Table 2.b). L1M1 retained the highest ascorbic acid at 0, 4 and 8 DAS (27.17, 26.17 and 25.00 mg 100 g^{-1}), followed by L1M3 (25.74, 24.76 and 23.36 mg 100 g^{-1}). At 8 DAS, S3 maintained 20.45 mg 100 g^{-1} compared with 19.21 and 18.92 mg 100 g^{-1} under S2 and S1, respectively. L1M1S3 recorded the highest interaction value (26.17 mg 100 g^{-1}).

The pooled results (Table 2.c) confirmed these trends. Ascorbic acid in L1M1 declined from 27.08 mg 100 g^{-1} at 0 DAS to 24.91 mg 100 g^{-1} at 8 DAS, while L1M3 declined from 25.65 to 23.27 mg 100 g^{-1}. Refrigerated storage (S3) retained the highest mean ascorbic acid at 4 and 8 DAS (21.45 and 20.71 mg 100 g^{-1}), compared with S2 (20.97 and 19.49 mg 100 g^{-1}) and S1 (20.72 and 19.13 mg 100 g^{-1}). At 8 DAS, the interaction ranged from 16.17 mg 100 g^{-1} in L3M4S1 to 26.06 mg 100 g^{-1} in L1M1S3. By 12 DAS, fruits suitable for analysis remained only in L1M1S3 and L1M3S3, which recorded pooled values of 25.22 and 23.86 mg 100 g^{-1}, respectively; fruits from the remaining combinations had deteriorated before evaluation.

The gradual decline in ascorbic acid during storage reflects the sensitivity of vitamin C to postharvest deterioration. L1M1 and L1M3 consistently maintained higher ascorbic acid contents, indicating that fruits receiving FYM equivalent to 100% RDN in combination with Organic Modules I and III entered storage with a comparatively better vitamin C status. Differences in tomato ascorbic acid content in response to production practices have also been documented by Chassy *et al*. (2006), although the response varied with cultivar, highlighting the influence of both crop management and genotype.

Storage temperature had a clearer effect as storage progressed. At 4 and 8 DAS, fruits kept in perforated polybags under refrigeration (S3) retained more ascorbic acid than those stored at room temperature. Li *et al*. (2025) similarly observed a progressive decline in tomato ascorbic acid during storage and demonstrated that low-temperature storage significantly delayed vitamin C loss compared with higher temperatures. Thus, the greater retention observed under L1M1S3 and L1M3S3 can reasonably be associated with the combined advantage of their higher initial ascorbic acid content and refrigerated storage. Importantly, these were also the only combinations in which fruits remained suitable for analysis at 12 DAS.

Lycopene content (mg 100g^{-1})

Lycopene content was significantly influenced by the FYM-based treatments during both years, while the effect of storage condition became more evident as storage progressed. During 2020–21, L1M1 recorded the highest lycopene content at 0, 4 and 8 DAS (6.80, 7.14 and 7.71 mg 100 g^{-1}), followed by L1M3 (6.51, 6.88 and 7.45 mg 100 g^{-1}), whereas L3M4 recorded the lowest values. At 8 DAS, S3 recorded the highest storage mean (6.58 mg 100 g^{-1}), and the significant interaction ranged from 4.82 mg 100 g^{-1} in L3M4S1 to 7.99 mg 100 g^{-1} in L1M1S3 (Table 3.a).

A comparable treatment response was observed during 2021–22 (Table 3.b), with L1M1 recording 6.87, 7.22 and 7.78 mg 100 g^{-1} at 0, 4 and 8 DAS, respectively, followed by L1M3. However, the storage response differed from the first year: at 8 DAS, S2 recorded the highest mean (6.36 mg 100 g^{-1}), followed by S1 (6.25 mg 100 g^{-1}) and S3 (6.18 mg 100 g^{-1}), indicating some year-to-year variation in the response to storage environment.

The pooled data (Table 3.c) showed a progressive increase in lycopene with storage. L1M1 remained superior, increasing from 6.84 mg 100 g^{-1} at 0 DAS to 7.75 mg 100 g^{-1} at 8 DAS, followed by L1M3 (6.54 to 7.48 mg 100 g^{-1}). L3M4 recorded the lowest value at 8 DAS (5.03 mg 100 g^{-1}). At this stage, S3 recorded the highest pooled storage mean (6.38 mg 100 g^{-1}), followed by S2 (6.29 mg 100 g^{-1}) and S1 (6.15 mg 100 g^{-1}). L1M1S3 recorded the highest interaction value (7.91 mg 100 g^{-1}). At 12 DAS, fruits suitable for evaluation remained only in L1M1S3 (8.32 mg 100 g^{-1}) and L1M3S3 (8.07 mg 100 g^{-1}); fruits in the remaining combinations had spoiled or were rejected.

The increase in lycopene from harvest to 8 DAS is consistent with continued carotenoid development during tomato ripening. The consistently greater lycopene content of L1M1 and L1M3 also points to an influence of pre-harvest nutrient management. This interpretation is supported by Gao *et al.* (2023), whose meta-analysis of 107 studies found that organic fertilizer application significantly increased tomato lycopene content overall, although the magnitude of the response depended on fertilizer type and growing conditions. Thus, the present treatment differences should be interpreted as an association with the FYM-based organic management system rather than attributed to any single component of the organic modules.

Storage temperature also influences lycopene metabolism, but its effect is not uniform. Toor and Savage (2006) observed continued lycopene accumulation during tomato storage, with substantially greater accumulation at 15–25 °C than at 7 °C. More recent work by Li *et al.* (2025) similarly demonstrated that temperature strongly influences carotenoid metabolism, although lower temperatures reduced the subsequent degradation of existing carotenoids. These findings help explain why storage responses can vary with temperature, maturity and duration. In the present study, S3 gave the highest pooled lycopene at 8 DAS, but this trend was not identical in both years; therefore, it is more appropriate to describe refrigeration as having maintained higher pooled lycopene under the conditions of this experiment, rather than concluding that refrigeration generally enhances lycopene synthesis.

Overall, L1M1 and L1M3 consistently maintained higher lycopene concentrations, while only their refrigerated combinations remained suitable for evaluation at 12 DAS. This indicates a favourable association between these pre-harvest FYM-based treatments, refrigerated storage and maintenance of tomato quality during extended storage.

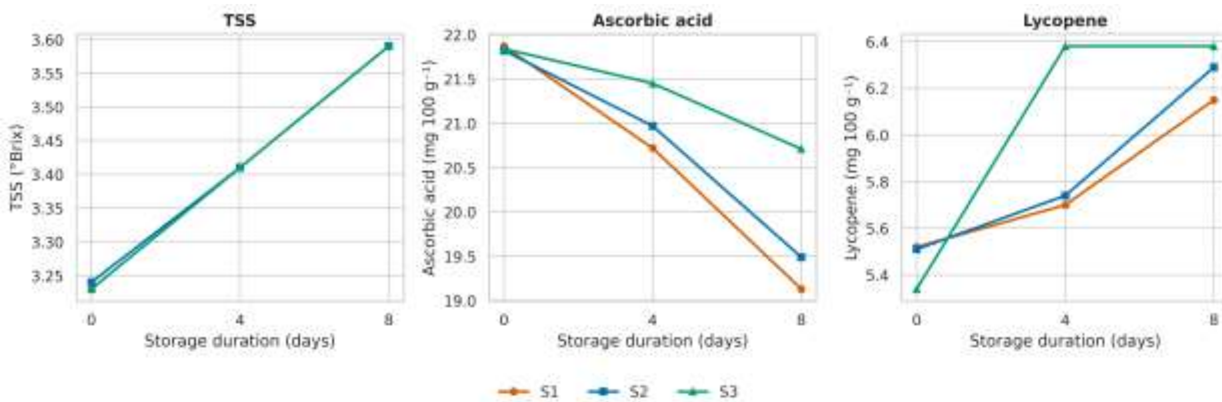

Fig. 1 : Changes in pooled storage-condition means for total soluble solids (TSS), ascorbic acid and lycopene during 0-8 DAS. S1 = open storage at room temperature; S2 = perforated polybags at room temperature; S3 = perforated polybags under refrigeration.

Interrelationships among biochemical quality attributes

Pearson correlation analysis of the 12 pooled treatment means at 8 DAS revealed significant positive associations among the biochemical quality attributes. TSS was moderately and positively correlated with ascorbic acid ($r = 0.66$, $P = 0.020$) and lycopene ($r = 0.65$, $P = 0.023$). A particularly strong positive relationship was observed between ascorbic acid and lycopene ($r = 0.95$, $P < 0.001$), indicating that treatments with higher ascorbic acid generally also maintained higher lycopene content (Table 4).

The positive relationships among TSS, ascorbic acid and lycopene suggest that the biochemical quality attributes tended to respond in the same direction across the FYM-based treatment combinations. The particularly strong association between ascorbic acid and lycopene ($r = 0.95$) indicates that treatments maintaining greater vitamin C also tended to maintain greater lycopene. However, the correlations represent treatment-mean associations and should not be interpreted as evidence that changes in one constituent caused changes in another.

A comparable relationship among tomato quality traits was reported by Akhtar and Hazra (2015), whose correlation and path analyses identified TSS together with lycopene and ascorbic acid as important attributes for improving tomato fruit quality. The present relationships are also consistent with the broader findings of Gao *et al.* (2023), whose meta-analysis of 107 studies showed that organic fertilizer application influenced several tomato quality attributes simultaneously, including soluble solids, lycopene and vitamin C. Sainju *et al.* (2003) similarly emphasized that tomato mineral nutrition can influence fruit composition, taste and postharvest quality. Together, these studies support the view that pre-harvest nutrient management can produce coordinated changes in several biochemical quality characteristics, while the strength and direction of individual relationships remain dependent on the production system and experimental conditions.

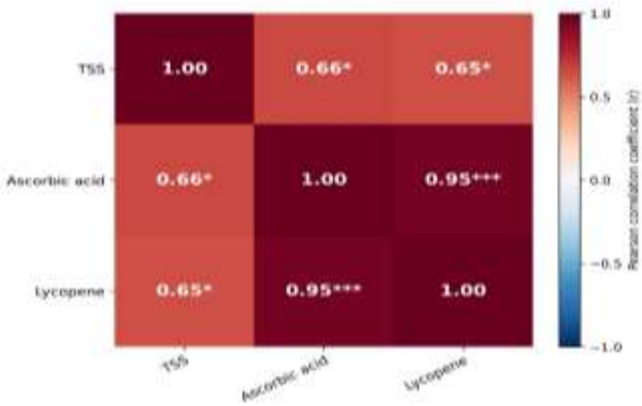

Fig. 2 : Pearson correlation heatmap among TSS, ascorbic acid and lycopene of tomato at 8 DAS based on 12 pooled treatment means (n = 12). *P < 0.05; ***P < 0.001.

Scope and limitations

The study provides two-season evidence from a factorial combination of pre-harvest organic management and postharvest storage. Nevertheless, interpretation is limited by the absence of recorded firmness, colour, respiration, ethylene and microbial measurements in the present dataset. Further, most treatment-storage combinations became unavailable before 12 DAS, preventing a complete factorial comparison at the final observation. The 12-DAS results therefore document survival and retained quality only for L1M1S3 and L1M3S3 and do not establish a statistical ranking against spoiled treatments.

Conclusion

Pre-harvest FYM-organic module treatments and storage conditions influenced TSS, ascorbic acid and lycopene during storage. L1M3 recorded the maximum TSS, whereas L1M1 retained the greatest ascorbic acid and lycopene means. Under S3, ascorbic acid retention and lycopene accumulation were favourable at 8 DAS, and only L1M1S3 and L1M3S3 remained available at 12 DAS. No missing biochemical observation was estimated.

Table 1.a : Effect of different levels of FYM integrated with organic modules and different storage, packing conditions on TSS at 0,4,8,12 days of storage in tomato for the year 2020-21.

Treatment	TSS at 0 days				TSS at 4 days				TSS at 8 days				TSS at 12 days		
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3
L1M1	3.77	3.75	3.76	**3.76**	3.95	3.93	3.94	**3.94**	4.13	4.11	4.12	**4.12**	*	*	**4.30**
L1M2	3.25	3.23	3.24	**3.24**	3.43	3.41	3.42	**3.42**	3.61	3.59	3.60	**3.60**	*	*	*
L1M3	3.81	3.79	3.80	**3.80**	3.99	3.97	3.98	**3.98**	4.17	4.15	4.16	**4.16**	*	*	**4.34**
L1M4	3.08	3.06	3.07	**3.07**	3.26	3.24	3.25	**3.25**	3.44	3.42	3.43	**3.43**	*	*	*
L2M1	3.00	2.98	2.99	**2.99**	3.18	3.16	3.17	**3.17**	3.36	3.34	3.35	**3.35**	*	*	*
L2M2	3.53	3.51	3.52	**3.52**	3.71	3.69	3.70	**3.70**	3.89	3.87	3.88	**3.88**	*	*	*
L2M3	3.61	3.59	3.60	**3.60**	3.79	3.77	3.78	**3.78**	3.97	3.95	3.96	**3.96**	*	*	*
L2M4	2.93	2.91	2.92	**2.92**	3.11	3.09	3.10	**3.10**	3.29	3.27	3.28	**3.28**	*	*	*
L3M1	3.72	3.70	3.71	**3.71**	3.88	3.86	3.87	**3.87**	4.06	4.04	4.05	**4.05**	*	*	*
L3M2	2.75	2.73	2.74	**2.74**	2.91	2.89	2.90	**2.90**	3.09	3.07	3.08	**3.08**	*	*	*
L3M3	2.71	2.69	2.70	**2.70**	2.87	2.85	2.86	**2.86**	3.05	3.03	3.04	**3.04**	*	*	*
L3M4	2.91	2.89	2.90	**2.90**	3.07	3.05	3.06	**3.06**	3.25	3.23	3.24	**3.24**	*	*	*
Mean	**3.26**	**3.24**	**3.25**		**3.43**	**3.41**	**3.42**		**3.61**	**3.59**	**3.60**				
	A	S	AXS		A	S	AXS		A	S	AXS				
SE(m)±	0.01	0.00	0.01		0.01	0.01	0.02		0.01	0.01	0.02				
C.D. @5%	0.02	0.01	N/A		0.03	0.01	N/A		0.03	0.01	N/A				

* Tomato fruits were unavailable for observation because all fruits had spoiled

Table 1.b : Effect of different levels of FYM integrated with organic modules and different storage, packing conditions on TSS at 0,4,8,12 days of storage in tomato for the year 2021-22

Treatment	TSS at 0 days				TSS4 at 4 days				TSS at 8 days				TSS at 12 days		
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3
L1M1	3.71	3.74	3.72	**3.73**	3.89	3.92	3.90	**3.90**	4.07	4.10	4.08	**4.08**	*	*	**4.26**
L1M2	3.23	3.26	3.24	**3.25**	3.41	3.44	3.42	**3.42**	3.59	3.62	3.60	**3.60**	*	*	*
L1M3	3.71	3.74	3.72	**3.73**	3.89	3.92	3.90	**3.90**	4.07	4.10	4.08	**4.08**	*	*	**4.26**

Treatment	TSS at 0 days				TSS4 at 4 days				TSS at 8 days				TSS at 12 days		
L1M4	3.18	3.21	3.19	**3.19**	3.36	3.39	3.37	**3.37**	3.54	3.57	3.55	**3.55**	*	*	*
L2M1	2.91	2.94	2.92	**2.93**	3.09	3.12	3.10	**3.10**	3.27	3.30	3.28	**3.28**	*	*	*
L2M2	3.47	3.50	3.48	**3.49**	3.65	3.68	3.66	**3.66**	3.83	3.86	3.84	**3.84**	*	*	*
L2M3	3.53	3.56	3.54	**3.54**	3.71	3.74	3.72	**3.72**	3.89	3.92	3.90	**3.90**	*	*	*
L2M4	2.95	2.98	2.96	**2.97**	3.13	3.16	3.14	**3.14**	3.31	3.34	3.32	**3.32**	*	*	*
L3M1	3.63	3.66	3.64	**3.65**	3.81	3.84	3.82	**3.82**	3.99	4.02	4.00	**4.00**	*	*	*
L3M2	2.66	2.69	2.67	**2.67**	2.84	2.87	2.85	**2.85**	3.02	3.05	3.03	**3.03**	*	*	*
L3M3	2.51	2.54	2.52	**2.53**	2.69	2.72	2.70	**2.70**	2.87	2.90	2.88	**2.88**	*	*	*
L3M4	2.95	2.98	2.96	**2.97**	3.13	3.16	3.14	**3.14**	3.31	3.34	3.32	**3.32**	*	*	*
Mean	**3.21**	**3.24**	**3.22**		**3.38**	**3.41**	**3.39**		**3.56**	**3.59**	**3.57**				
	A	S	AXS		A	S	AXS		A	S	AXS				
SE(m)±	0.01	0.00	0.01		0.01	0.01	0.02		10.00	0.01	0.02				
C.D. @5%	0.02	0.01	N/A		0.03	0.01	N/A		0.03	0.01	N/A				

* Tomato fruits were unavailable for observation because all fruits had spoiled.

Table 1.c : Effect of different levels of FYM integrated with organic modules and different storage, packing conditions on TSS at 0,4,8,12 days of storage in tomato (Pooled)

Treatment	TSS at 0 days				TSS at 4 days				TSS at 8 days				TSS at 12 days		
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3
L1M1	3.74	3.75	3.74	**3.74**	3.92	3.92	3.92	**3.92**	4.10	4.11	4.10	**4.10**	*	*	**4.28**
L1M2	3.24	3.25	3.24	**3.24**	3.42	3.42	3.42	**3.42**	3.60	3.60	3.60	**3.60**	*	*	*
L1M3	3.76	3.77	3.76	**3.76**	3.94	3.95	3.94	**3.94**	4.12	4.12	4.12	**4.12**	*	*	**4.30**
L1M4	3.13	3.13	3.13	**3.13**	3.31	3.32	3.31	**3.31**	3.49	3.50	3.49	**3.49**	*	*	*
L2M1	2.96	2.96	2.96	**2.96**	3.13	3.14	3.13	**3.13**	3.32	3.32	3.32	**3.32**	*	*	*
L2M2	3.50	3.51	3.50	**3.50**	3.68	3.68	3.68	**3.68**	3.86	3.87	3.86	**3.86**	*	*	*
L2M3	3.57	3.58	3.57	**3.57**	3.75	3.76	3.75	**3.75**	3.93	3.94	3.93	**3.93**	*	*	*
L2M4	2.94	2.95	2.94	**2.94**	3.12	3.12	3.12	**3.12**	3.30	3.31	3.30	**3.30**	*	*	*
L3M1	3.68	3.68	3.68	**3.68**	3.84	3.85	3.84	**3.84**	4.03	4.03	4.03	**4.03**	*	*	*
L3M2	2.70	2.71	2.70	**2.70**	2.88	2.88	2.88	**2.88**	3.06	3.06	3.05	**3.06**	*	*	*
L3M3	2.61	2.62	2.61	**2.61**	2.78	2.79	2.78	**2.78**	2.96	2.96	2.96	**2.96**	*	*	*
L3M4	2.93	2.94	2.93	**2.93**	3.10	3.10	3.10	**3.10**	3.28	3.29	3.28	**3.28**	*	*	*
Mean	**3.23**	**3.24**	**3.23**		**3.41**	**3.41**	**3.41**		**3.59**	**3.59**	**3.59**				
	A	S	AXS		A	S	AXS		A	S	AXS				
SE(m)±	0.08	0.04	0.27		0.08	0.04	0.27		0.08	0.04	0.27				
C.D. @5%	0.15	0.08	0.52		0.15	0.08	0.52		0.15	0.08	0.52				

* Tomato fruits were unavailable for observation because all fruits had spoiled.

Table 2.a : Effect of different levels of FYM integrated with organic modules and different storage, packing conditions on Ascorbic acid (mg/100g) at 0,4,8,12 days of storage in tomato for the year 2020-21.

Treatment	AA at 0 days				AA at 4 days				AA at 8 days				AA at 12 days		
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3
L1M1	27.02	26.93	27.01	**26.98**	25.42	25.88	26.66	**25.98**	23.82	24.68	25.96	**24.82**	*	*	**25.12**
L1M2	24.62	24.64	24.68	**24.65**	23.07	23.59	24.33	**23.66**	21.02	21.94	23.88	**22.28**	*	*	*
L1M3	25.47	25.56	25.64	**25.56**	23.92	24.51	25.29	**24.57**	21.97	22.96	24.59	**23.17**	*	*	**23.75**
L1M4	25.47	25.56	25.64	**25.56**	23.07	23.76	24.59	**23.81**	21.97	22.86	24.09	**22.97**	*	*	*
L2M1	20.62	20.62	20.54	**20.59**	19.77	20.07	20.89	**20.24**	18.22	18.52	19.94	**18.89**	*	*	*
L2M2	23.20	23.16	23.08	**23.15**	22.35	22.51	22.73	**22.53**	20.80	20.96	21.88	**21.21**	*	*	*
L2M3	20.32	20.30	20.30	**20.31**	19.47	19.75	20.55	**19.92**	17.92	18.20	19.50	**18.54**	*	*	*
L2M4	21.80	21.58	21.52	**21.63**	20.95	20.93	21.17	**21.02**	19.40	19.38	20.32	**19.70**	*	*	*
L3M1	19.82	19.76	19.70	**19.76**	18.97	19.21	19.35	**19.18**	17.42	17.66	18.50	**17.86**	*	*	*
L3M2	19.41	19.42	19.40	**19.41**	18.56	18.77	19.05	**18.79**	17.01	17.22	18.20	**17.48**	*	*	*

Treatment	AA at 0 days				AA at 4 days				AA at 8 days				AA at 12 days		
L3M3	18.36	18.30	18.18	**18.28**	17.51	17.75	17.93	**17.73**	15.96	16.20	16.98	**16.38**	*	*	*
L3M4	18.90	18.88	18.92	**18.90**	18.05	18.23	18.57	**18.28**	16.50	16.68	17.72	**16.97**	*	*	*
Mean	**22.08**	**22.06**	**22.05**		**20.93**	**21.25**	**21.76**		**19.33**	**19.77**	**20.96**				
	A	**S**	**AXS**		**A**	**S**	**AXS**		**A**	**S**	**AXS**				
SE(m)±	0.01	0.01	0.02		0.01	0.01	0.02		0.01	0.01	0.02				
C.D. @5%	0.04	0.02	0.07		0.04	0.02	0.07		0.04	0.02	0.07				

* Tomato fruits were unavailable for observation because all fruits had spoiled.

Table 2.b : Effect of different levels of FYM integrated with organic modules and different storage, packing conditions on Ascorbic acid (mg/100g) at 0,4,8,12 days of storage in tomato for the year 2021-22.

Treatment	AA at 0 days				AA at 4 days				AA at 8 days				AA at 12 days		
	S1	**S2**	**S3**	**Mean**	**S1**	**S2**	**S3**	**Mean**	**S1**	**S2**	**S3**	**Mean**	**S1**	**S2**	**S3**
L1M1	27.22	27.08	27.22	**27.17**	25.62	26.03	26.87	**26.17**	24.02	24.83	26.17	**25.00**	*	*	**25.33**
L1M2	24.82	24.79	24.89	**24.83**	23.27	23.74	24.54	**23.85**	21.22	22.09	24.09	**22.47**	*	*	*
L1M3	25.67	25.71	25.85	**25.74**	24.12	24.66	25.50	**24.76**	22.17	23.11	24.80	**23.36**	*	*	**23.96**
L1M4	20.82	20.77	20.75	**20.78**	18.42	18.57	18.95	**18.65**	17.32	17.67	18.45	**17.81**	*	*	*
L2M1	23.40	23.31	23.29	**23.33**	22.55	22.66	22.94	**22.72**	21.00	21.11	22.09	**21.40**	*	*	*
L2M2	20.52	20.45	20.51	**20.49**	19.67	19.80	20.16	**19.88**	18.12	18.25	19.61	**18.66**	*	*	*
L2M3	22.00	21.73	21.73	**21.82**	21.15	20.98	21.38	**21.17**	19.60	19.43	20.83	**19.95**	*	*	*
L2M4	20.02	19.91	19.91	**19.95**	19.17	19.26	19.56	**19.33**	17.62	17.71	18.71	**18.01**	*	*	*
L3M1	19.61	19.57	19.61	**19.60**	18.76	18.92	19.26	**18.98**	17.21	17.37	18.51	**17.70**	*	*	*
L3M2	18.56	18.45	18.39	**18.47**	17.71	17.80	18.04	**17.85**	16.16	16.25	17.19	**16.53**	*	*	*
L3M3	19.10	19.03	19.13	**19.09**	18.25	18.38	18.78	**18.47**	16.70	16.83	17.93	**17.15**	*	*	*
L3M4	18.24	18.11	18.13	**18.16**	17.39	17.46	17.78	**17.54**	15.84	15.91	17.03	**16.26**	*	*	*
Mean	**21.67**	**21.58**	**21.62**		**20.51**	**20.69**	**21.15**		**18.92**	**19.21**	**20.45**				
	A	**S**	**AXS**		**A**	**S**	**AXS**		**A**	**S**	**AXS**				
SE(m)±	0.01	0.01	0.02		0.01	0.01	0.02		0.01	0.01	0.02				
C.D. @5%	0.04	0.02	0.07		0.04	0.02	0.07		0.04	0.02	0.07				

* Tomato fruits were unavailable for observation because all fruits had spoiled.

Table 2.c : Effect of different levels of FYM integrated with organic modules and different storage, packing conditions on Ascorbic acid (mg/100g) at 0,4,8,12 days of storage in tomato (Pooled).

Treatment	AA at 0 days				AA at 4 days				AA at 8 days				AA at 12 days		
	S1	**S2**	**S3**	**Mean**	**S1**	**S2**	**S3**	**Mean**	**S1**	**S2**	**S3**	**Mean**	**S1**	**S2**	**S3**
L1M1	27.12	27.00	27.11	**27.08**	25.52	25.95	26.76	**26.08**	23.92	24.75	26.06	**24.91**	*	*	**25.22**
L1M2	24.72	24.72	24.78	**24.74**	23.17	23.66	24.43	**23.75**	21.12	22.02	23.98	**22.37**	*	*	*
L1M3	25.57	25.64	25.75	**25.65**	24.02	24.59	25.40	**24.67**	22.07	23.04	24.70	**23.27**	*	*	**23.86**
L1M4	23.14	23.16	23.20	**23.17**	20.75	21.16	21.77	**21.23**	19.64	20.26	21.27	**20.39**	*	*	*
L2M1	22.01	21.96	21.91	**21.96**	21.16	21.37	21.91	**21.48**	19.61	19.81	21.02	**20.15**	*	*	*
L2M2	21.86	21.80	21.80	**21.82**	21.01	21.16	21.44	**21.20**	19.46	19.60	20.75	**19.94**	*	*	*
L2M3	21.16	21.02	21.02	**21.07**	20.31	20.37	20.96	**20.55**	18.76	18.81	20.16	**19.24**	*	*	*
L2M4	20.91	20.75	20.72	**20.79**	20.06	20.09	20.37	**20.17**	18.51	18.55	19.52	**18.86**	*	*	*
L3M1	19.72	19.66	19.66	**19.68**	18.87	19.07	19.30	**19.08**	17.32	17.52	18.50	**17.78**	*	*	*
L3M2	18.98	18.93	18.90	**18.94**	18.14	18.28	18.55	**18.32**	16.59	16.74	17.70	**17.01**	*	*	*
L3M3	18.73	18.66	18.66	**18.68**	17.88	18.07	18.36	**18.10**	16.33	16.52	17.45	**16.77**	*	*	*
L3M4	18.57	18.50	18.52	**18.53**	17.72	17.84	18.18	**17.91**	16.17	16.29	17.38	**16.61**	*	*	*
Mean	**21.87**	**21.82**	**21.84**		**20.72**	**20.97**	**21.45**		**19.13**	**19.49**	**20.71**				
	A	**S**	**AXS**		**A**	**S**	**AXS**		**A**	**S**	**AXS**				
SE(m)±	0.28	0.14	0.96		0.29	0.14	1.00		0.29	0.14	1.00				
C.D. @5%	0.55	0.27	1.89		0.57	0.29	1.98		0.57	0.28	1.96				

* Tomato fruits were unavailable for observation because all fruits had spoiled.

Table 3.a : Effect of different levels of FYM integrated with organic modules and different storage, packing conditions on lycopene content (mg/100g) at 0,4,8,12 days of storage in tomato for the year 2020-21

Treatment	Lycopene at 0 days				Lycopene at 4 days				Lycopene at 8 days				Lycopene at 12 days		
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3
L1M1	6.79	6.79	6.82	**6.80**	7.04	7.10	7.29	**7.14**	7.49	7.65	7.99	**7.71**	*	*	**8.39**
L1M2	6.27	6.25	6.26	**6.26**	6.43	6.49	6.71	**6.54**	6.88	7.04	7.41	**7.11**	*	*	*
L1M3	6.51	6.51	6.50	**6.51**	6.76	6.83	7.05	**6.88**	7.21	7.38	7.75	**7.45**	*	*	**8.15**
L1M4	5.41	5.41	5.41	**5.41**	5.54	5.62	5.86	**5.67**	5.99	6.17	6.56	**6.24**	*	*	*
L2M1	6.01	6.01	6.01	**6.01**	6.18	6.25	6.44	**6.29**	6.63	6.80	7.14	**6.86**	*	*	*
L2M2	5.21	5.21	5.21	**5.21**	5.38	5.45	5.65	**5.49**	5.83	6.00	6.35	**6.06**	*	*	*
L2M3	5.81	5.81	5.81	**5.81**	5.99	6.06	6.26	**6.10**	6.44	6.61	6.96	**6.67**	*	*	*
L2M4	5.01	5.01	5.01	**5.01**	5.17	5.24	5.44	**5.28**	5.62	5.79	6.14	**5.85**	*	*	*
L3M1	4.81	4.81	4.81	**4.81**	4.97	5.04	5.25	**5.09**	5.42	5.59	5.95	**5.65**	*	*	*
L3M2	4.41	4.41	4.41	**4.41**	4.57	4.65	4.85	**4.69**	5.02	5.20	5.55	**5.26**	*	*	*
L3M3	4.61	4.61	4.61	**4.61**	4.78	4.85	5.05	**4.89**	5.23	5.40	5.75	**5.46**	*	*	*
L3M4	4.21	4.21	4.21	**4.21**	4.37	4.45	4.65	**4.49**	4.82	5.00	5.35	**5.06**	*	*	*
Mean	**5.42**	**5.42**	**5.42**		**5.60**	**5.67**	**5.88**		**6.05**	**6.22**	**6.58**				
	A	**S**	**AXS**		**A**	**S**	**AXS**		**A**	**S**	**AXS**				
SE(m)±	0.00	0.00	0.01		0.00	0.00	0.01		0.00	0.00	0.01				
C.D. @5%	0.01	NS	NS		0.01	0.05	NS		0.01	0.05	0.02				

* Tomato fruits were unavailable for observation because all fruits had spoiled.

Table 3.b : Effect of different levels of FYM integrated with organic modules and different storage, packing conditions on lycopene content (mg/100g) at 0,4,8,12 days of storage in tomato for the year 2021-22.

Treatment	Lycopene at 0 days				Lycopene at 4 days				Lycopene at 8 days				Lycopene at 12 days		
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3
L1M1	6.99	6.97	6.65	**6.87**	7.24	7.28	7.13	**7.22**	7.69	7.83	7.83	**7.78**	*	*	**8.24**
L1M2	6.47	6.44	6.09	**6.33**	6.63	6.68	6.54	**6.62**	7.08	7.23	7.24	**7.18**	*	*	*
L1M3	6.71	6.69	6.33	**6.58**	6.96	7.01	6.88	**6.95**	7.41	7.56	7.58	**7.52**	*	*	**7.99**
L1M4	5.61	5.59	5.24	**5.48**	5.74	5.80	5.39	**5.64**	6.19	6.35	6.09	**6.21**	*	*	*
L2M1	6.21	6.19	5.84	**6.08**	6.38	6.36	5.98	**6.24**	6.83	6.91	6.68	**6.81**	*	*	*
L2M2	5.41	5.39	5.04	**5.28**	5.58	5.56	5.18	**5.44**	6.03	6.11	5.88	**6.01**	*	*	*
L2M3	6.01	5.99	5.64	**5.88**	6.18	6.16	5.78	**6.04**	6.63	6.71	6.48	**6.61**	*	*	*
L2M4	5.21	5.19	4.84	**5.08**	5.38	5.36	4.98	**5.24**	5.83	5.91	5.68	**5.81**	*	*	*
L3M1	5.01	4.99	4.64	**4.88**	5.18	5.16	4.78	**5.04**	5.63	5.71	5.48	**5.61**	*	*	*
L3M2	4.61	4.59	4.24	**4.48**	4.78	4.76	4.38	**4.64**	5.23	5.31	5.08	**5.21**	*	*	*
L3M3	4.81	4.79	4.44	**4.68**	4.98	4.96	4.58	**4.84**	5.43	5.51	5.28	**5.41**	*	*	*
L3M4	4.41	4.39	4.04	**4.28**	4.58	4.56	4.18	**4.44**	5.03	5.11	4.88	**5.01**	*	*	*
Mean	**5.62**	**5.60**	**5.25**		**5.80**	**5.81**	**5.48**		**6.25**	**6.36**	**6.18**				
	A	**S**	**AXS**		**A**	**S**	**AXS**		**A**	**S**	**AXS**				
SE(m)±	0.00	0.00	0.01		0.00	0.00	0.01		0.00	0.00	0.01				
C.D. @5%	0.01	0.05	NS		0.01	0.05	0.02		0.01	0.05	0.02				

* Tomato fruits were unavailable for observation because all fruits had spoiled.

Table 3.c : Effect of different levels of FYM integrated with organic modules and different storage, packing conditions on lycopene content (mg/100g) at 0,4,8,12 days of storage in tomato (Pooled).

Treatment	Lycopene at 0 days				Lycopene at 4 days				Lycopene at 8 days				Lycopene at 12 days		
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3
L1M1	6.89	6.88	6.74	**6.84**	7.14	7.19	7.91	**7.41**	7.59	7.74	7.91	**7.75**	*	*	**8.32**
L1M2	6.37	6.35	6.18	**6.30**	6.53	6.59	7.33	**6.82**	6.98	7.14	7.33	**7.15**	*	*	*
L1M3	6.61	6.60	6.42	**6.54**	6.86	6.92	7.67	**7.15**	7.31	7.47	7.67	**7.48**	*	*	**8.07**

Treatment	Lycopene at 0 days				Lycopene at 4 days				Lycopene at 8 days				Lycopene at 12 days		
L1M4	5.51	5.50	5.32	**5.44**	5.64	5.71	6.32	**5.89**	6.09	6.26	6.32	**6.22**	*	*	*
L2M1	6.11	6.10	5.92	**6.04**	6.28	6.31	6.91	**6.50**	6.73	6.86	6.91	**6.83**	*	*	*
L2M2	5.31	5.30	5.12	**5.24**	5.48	5.51	6.11	**5.70**	5.93	6.06	6.11	**6.03**	*	*	*
L2M3	5.91	5.90	5.72	**5.84**	6.08	6.11	6.72	**6.30**	6.54	6.66	6.72	**6.64**	*	*	*
L2M4	5.11	5.10	4.92	**5.04**	5.28	5.30	5.91	**5.50**	5.72	5.85	5.91	**5.83**	*	*	*
L3M1	4.91	4.90	4.72	**4.84**	5.08	5.10	5.71	**5.30**	5.53	5.65	5.71	**5.63**	*	*	*
L3M2	4.51	4.50	4.32	**4.44**	4.68	4.71	5.31	**4.90**	5.12	5.26	5.31	**5.23**	*	*	*
L3M3	4.71	4.70	4.52	**4.64**	4.88	4.91	5.51	**5.10**	5.33	5.46	5.51	**5.43**	*	*	*
L3M4	4.31	4.30	4.12	**4.24**	4.47	4.51	5.11	**4.70**	4.92	5.06	5.11	**5.03**	*	*	*
Mean	**5.52**	**5.51**	**5.34**		**5.70**	**5.74**	**6.38**		**6.15**	**6.29**	**6.38**				
	A	**S**	**AXS**		**A**	**S**	**AXS**		**A**	**S**	**AXS**				
SE(m)±	0.07	0.03	0.24		0.08	0.04	0.26		0.08	0.04	0.26				
C.D. @5%	0.14	0.07	0.48		0.15	0.07	0.52		0.15	0.07	0.51				

* Tomato fruits were unavailable for observation because all fruits had spoiled.

Table 4 : Pearson correlations among biochemical quality attributes at 8 DAS (n = 12)

Variable	TSS	Ascorbic acid	Lycopene
TSS	1.00	0.66*	0.65*
Ascorbic acid	0.66*	1.00	0.95***
Lycopene	0.65*	0.95***	1.00

*P < 0.05; ***P < 0.001. All attributes were based on the 12 pooled treatment means at 8 DAS. Twelve-DAS observations were excluded because only L1M1S3 and L1M3S3 remained suitable for evaluation.

Disclaimer (Artificial Intelligence)

Grammarly and ChatGPT were used to assist language preparation, manuscript organization and figure design. The authors reviewed and verified the scientific content, analyses and source data and remain responsible for the final manuscript.

Competing Interests

Authors have declared that no competing interests exist.

Acknowledgements

The author acknowledges the facilities provided by the Regional Agricultural Research Station, Warangal, PJTAU, and SKLTGHU to complete the PhD research work.

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