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Synergistic Organic-inorganic Nutrient Management Enhances Fruit Quality Attributes of Tomato cv. Kashi Aman

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

A field experiment was conducted during the *Rabi* season of 2025-26 at the Horticultural Experiment Field, Department of Horticulture, School of Advanced Agricultural Sciences and Technology, Chhatrapati Shahu Ji Maharaj University, Kanpur, Uttar Pradesh, India, to evaluate the effects of integrated organic and inorganic nutrient management on selected fruit quality attributes of tomato cv. Kashi Aman. The experiment was laid out in a randomised block design with three replications and ten treatments comprising different combinations of farmyard manure, vermicompost, and recommended doses of inorganic fertilisers. The treatments included an absolute control, individual organic sources, the full recommended dose of fertiliser, and different integrated nutrient combinations. Fruit quality parameters, including total soluble solids, lycopene content, ascorbic acid content, and fruit pH, were recorded and statistically analysed. The results showed that integrated nutrient application influenced the quality attributes of tomato fruits. Among the treatments, T9,

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consisting of vermicompost at 3 t/ha, farmyard manure at 6.25 t/ha, and 25% of the recommended dose of fertiliser, recorded the highest total soluble solids (5.12 °Brix), lycopene content (2.31 mg/100 g), and ascorbic acid content (19.06 mg/100 g). The same treatment also recorded the lowest fruit pH (4.04). The absolute control recorded comparatively lower values for total soluble solids, lycopene content, and ascorbic acid content. These findings indicate that combining organic manures with a reduced level of inorganic fertiliser may improve selected quality attributes of tomato cv. Kashi Aman under the conditions of the present study.

Keywords: Tomato; integrated nutrient management; vermicompost; farmyard manure; RDF; fruit quality; yield; sustainable agriculture.

1. Introduction

India is the second-largest producer of vegetables globally, after China. Its diverse agroclimatic conditions provide favourable environments for year-round vegetable production (Ministry of Agriculture & Farmers Welfare, 2023). Vegetable production in India continues to increase and is becoming an increasingly important enterprise for farmers. As public interest in health and nutrition grows, research is increasingly focused on quality and value-added products. Vegetables play a key role in nutritional security and generate substantial on-farm and off-farm employment. According to the Indian Council of Medical Research-National Institute of Nutrition (2024), a healthy individual should consume 400 g of vegetables daily, including 100 g of green leafy vegetables, 50 g of roots and tubers, and 250 g of other vegetables. Vegetables also provide potassium, folate, and other essential vitamins and nutrients (Willcox *et al.,* 2003).

Tomato *(Solanum lycopersicum* L.) is the second most important solanaceous vegetable crop after potato and is grown worldwide. It originated in the Peru-Ecuador region of South America and has a somatic chromosome number of 2n = 2x = 24 (Rick, 1969). The tomato plant is typically cultivated as an annual. It is also known as the wolf peach, the poor man's orange in India, and the love apple in England. Its adaptability and high productivity make it suitable for both fresh consumption and processing, providing income for farmers and nutrients for consumers (He *et al.,* 2003). Tomato is a warm-season vegetable that grows well at temperatures between 21 and 28 °C. It is a day-neutral plant and is therefore not affected by day length. The crop has poor tolerance to frost and prolonged waterlogging. Most genotypes are self-pollinated, although some exhibit cross-pollination. The plant has compound, serrated leaves and produces yellow, star-shaped flowers. Its fruits vary in shape, size, and colour, ranging from small cherry tomatoes to large beefsteak types. Fruit colours may include red, yellow, orange, purple, green, or striped (Jones, 2007). Tomato cultivars are often classified into two types according to growth habit: determinate (bush type) and indeterminate (vining type) (Stevens & Rick, 1986). Tomatoes play a vital role in the diet because of their nutritional composition, particularly in regions where populations are at risk of deficiencies in essential vitamins and minerals. The fruit is rich in potassium, magnesium, vitamins A, C, and E, and phytochemicals such as lycopene and β-carotene. Lycopene, a potent carotenoid antioxidant, has been widely studied for its association with a reduced risk of cardiovascular disease and certain cancers (Willcox *et al.,* 2003; Giovannucci, 1999).

A fully ripe tomato contains approximately 93.1% water, together with protein, carbohydrates, dietary fibre, vitamin C (31 mg/100 g), calcium, phosphorus, iron, potassium, and other essential micronutrients (Aykroyd, 1963). The crop is also important for processing because total soluble solids and pH are among the principal determinants of the quality of tomato-based products such as ketchup, paste, puree, and juice (De Pascale *et al.,* 2005).

Achieving high fruit quality in tomato requires careful soil-fertility management. Inorganic fertilisers provide readily available nutrients that support growth and yield (Stevens & Rick, 1986). However, reliance solely on chemical inputs can lead to soil degradation and increased environmental pollution. Conversely, organic manure alone may not satisfy the crop's nutrient requirements. Integrated nutrient management (INM) combines organic materials, such as farmyard manure (FYM) and vermicompost, with reduced quantities of chemical fertilisers. This approach has been proposed as an effective means of sustaining productivity while maintaining soil health (Xing *et al.,* 2025). Organic inputs improve soil structure, stimulate microbial activity, and enhance nutrient cycling, thereby creating a more favourable root environment (Peralta & Spooner, 2007).

Previous studies have reported improvements in tomato quality under integrated organic and inorganic nutrient management. Mengistu *et al.* (2017) recorded the highest total soluble solids and lycopene contents when vermicompost was applied with inorganic NP fertiliser. Likewise, Kushum *et al.* (2022) reported that treatments combining organic manure with recommended fertiliser rates produced higher ascorbic acid and TSS levels than treatments using either organic manure or chemical fertiliser alone. However, knowledge remains limited regarding the optimal combinations and rates of organic and inorganic inputs for individual tomato cultivars under specific agroclimatic conditions. Therefore, this study evaluated different levels and combinations of FYM, vermicompost, and RDF for their effects on the quality attributes of tomato cv. Kashi Aman under field conditions in the Central Plain Zone of Uttar Pradesh, with the objective of identifying an effective nutrient-management strategy for improving fruit quality sustainably.

2. Materials and Methods

The experiment was conducted during the *Rabi* season of 2025-26 at the Horticultural Experiment Field, School of Advanced Agricultural Sciences and Technology (SAAST), Chhatrapati Shahu Ji Maharaj University, Kanpur, Uttar Pradesh, India. The experimental site had sandy loam soil with a pH of 6.15, indicating slightly acidic conditions. Pre-sowing soil analysis revealed low organic carbon (1.41 g/kg), low available nitrogen (180.4 kg/ha), medium available phosphorus (14.93 kg/ha), and low available potassium (129.4 kg/ha). The physical and chemical characteristics of the soil are presented separately in Tables 1 and 2.

Table 1. Physical properties of the soil

Particulars	Value	Method used
I. Mechanical composition		
1. Sand (%)	52.2	
2. Silt (%)	25.3	Hydrometer method (Bouyoucos, 1962)
3. Clay (%)	22.5	
Texture	**Sandy loam**	
II. Soil moisture constants		
Water holding capacity (%)	26.0	Keen-Raczkowski box method (modified by Coutts, (1930)
Bulk density (mg/m^3)	1.50	Core Sampler (Blake, 1965)
Moisture content (%) at field capacity (0.033 MPa)	2.25	Pressure Membrane Plate Apparatus (Loveday, 1974)

Table 2. Chemical properties of the soil

S.no.	Particulars	Value	Method Used
1.	Soil pH (1:2.5, soil: water ratio)	6.15	Glass electrode pH meter (Jackson, 1973)
2.	Organic Carbon (g/kg)	1.41	Walkley and Black, (1934)
3.	Available N (kg/ha)	180.4	Kjeldahl Method (Jackson, 1973)
4.	Available P_2O_5 (kg/ha)	14.93	Bray’s P-1 (Jackson, 1973)
5.	Available K_2O (kg/ha)	129.4	Ammonium acetate method (Hanway, 1952)

The experiment was laid out in a randomised block design (RBD) with three replications. Ten treatment combinations were evaluated as follows: T1 - absolute control; T2 - FYM @ 25 t/ha; T3 - vermicompost @ 6 t/ha; T4 - 100% RDF @ 120:70:80 kg NPK/ha; T5 - FYM @ 12.5 t/ha + 50% RDF; T6 - vermicompost @ 3 t/ha + 50% RDF; T7 - FYM @ 18.75 t/ha + 25% RDF; T8 - vermicompost @ 4.5 t/ha + 25% RDF; T9 - vermicompost @ 3 t/ha + FYM @ 6.25 t/ha + 25% RDF; and T10 - FYM @ 12.5 t/ha + vermicompost @ 1.5 t/ha + 25% RDF. The tomato cultivar Kashi Aman was used in this study. Seedlings were transplanted at a spacing of 60 cm × 60 cm during the evening, and light irrigation was applied immediately after transplantation to ensure establishment. All standard agronomic practices were applied uniformly across treatments.

The quality parameters recorded were total soluble solids (TSS; expressed in °Brix and measured using a hand refractometer), lycopene content (mg/100 g fresh weight; determined by the acetone-hexane extraction method), ascorbic acid content (mg/100 g fresh weight; determined by titration against 2,6-dichlorophenol-indophenol dye), and fruit pH (measured using a digital pH meter). The data were subjected to analysis of variance (ANOVA), and treatment means were compared using the critical difference (CD) at the 5% probability level.

3. Results and Discussion

3.1 Quality Parameters

Total soluble solids (TSS) content is a commercially important quality index for processing tomatoes because even marginal increases can reduce dehydration costs and increase the yield of processed products such as paste and sauce (Young *et al.,* 1993). In the present study, treatment T9 (vermicompost @ 3 t/ha + FYM @ 6.25 t/ha + 25% RDF) recorded the highest TSS value (5.12 °Brix), followed by T10 (4.87 °Brix), whereas the absolute control, T1, recorded the lowest value (3.90 °Brix). These results are consistent with earlier reports indicating that tomatoes grown under integrated nutrient management tend to accumulate higher TSS than those grown under sole chemical fertilisation (Chassy *et al.,* 2006; Barrett *et al.,* 2007). Mengistu *et al.* (2017) likewise documented the highest TSS when vermicompost was combined with inorganic NP fertiliser. Kushum *et al.* (2022) observed significantly higher TSS in integrated treatments than in the control. The balanced availability of macro- and micronutrients under combined organic and inorganic management regulates carbohydrate metabolism and promotes the accumulation of soluble solids in ripening fruits (Tekale *et al.,* 2017).

Lycopene, the principal carotenoid pigment in ripe tomato fruits, is a potent antioxidant with documented associations with cardiovascular health and certain cancers (Willcox *et al.,* 2003). Treatment T9 recorded the highest lycopene content (2.31 mg/100 g fresh weight), followed by T10 (1.82 mg/100 g). The lowest value (1.33 mg/100 g) was observed in the absolute control, T1. Analysis of variance revealed highly significant differences among the treatments. Singh *et al.* (2025) similarly reported that integrating organic manure with chemical fertilisers significantly enhanced lycopene accumulation in tomato fruits. Mengistu *et al.* (2017) also noted that the combined use of vermicompost and inorganic NP fertiliser produced the highest lycopene content compared with sole organic or inorganic applications. Improved macro- and micronutrient availability associated with integrated nutrient management may stimulate carotenoid biosynthesis during fruit ripening (Ramesh & Sikder, 2021).

Ascorbic acid (vitamin C) is a key water-soluble antioxidant in tomato fruits and a widely used indicator of nutritional quality. In this study, the highest ascorbic acid content was recorded in T9 (19.06 mg/100 g), followed by T10 (18.43 mg/100 g). The absolute control recorded the lowest value (13.66 mg/100 g). The higher ascorbic acid content under integrated nutrient management treatments may be attributed to improved nutrient uptake efficiency, metabolic activity, and antioxidant capacity associated with combined organic and inorganic fertilisation. These findings corroborate the observations of Ramesh and Sikder (2021), who recorded significantly higher ascorbic acid content under integrated management than under sole inorganic fertilisation. Similar results were documented by Mukesh *et al.* (2023) and Kushum *et al.* (2022), who attributed the benefits to enhanced nutrient-use efficiency and improved biosynthesis of antioxidant compounds under integrated treatments.

Fruit pH is an important quality parameter, particularly for processing tomatoes, because values below 4.4 are considered necessary to inhibit the growth of thermophilic pathogens during thermal processing (Paulson & Stevens, 1974). In this study, the highest fruit pH was recorded under T1 (4.52), whereas the lowest pH was observed in T9 (4.04), followed by T10 (4.09) and T6 (4.13). The lower pH values under integrated treatments may reflect enhanced metabolic activity associated with combined organic and inorganic inputs, which may promote the accumulation of organic acids and other quality-related compounds in tomato fruits. Sahu *et al.* (2024) and Tekale *et al.* (2017) reported similar trends, noting that the integrated use of organic manures and inorganic fertilisers significantly influenced tomato fruit pH relative to the untreated control.

An overall assessment of the data presented in Table 3 and Fig. 1 indicates that the integrated treatments, particularly T9 and T10, consistently performed better than the sole chemical treatment (T4) and sole organic treatments (T2 and T3) across the measured quality parameters. This pattern suggests that combining organic and inorganic nutrient sources at appropriate rates may improve mineral nutrient availability and utilisation, thereby supporting the accumulation and biosynthesis of quality-related compounds in tomato fruits.

Table 3. Effect of integrated organic and inorganic nutrient management on quality parameters of tomato cv. Kashi Aman

S. No.	Treatment Details	TSS (°Brix)	Lycopene (mg/100g)	Ascorbic Acid (mg/100g)	pH Value
T_1	Absolute Control	3.90	1.33	13.66	4.52
T_2	FYM (@ 25 t/ha)	4.15	1.62	15.43	4.42
T_3	Vermicompost (@ 6 t/ha)	4.09	1.49	15.90	4.28
T_4	100 % RDF (@ 120:70:80 Kg/ha)	4.05	1.95	17.27	4.17
T_5	FYM (@ 12.5 t/ha) + 50 % RDF	4.17	2.06	17.90	4.19
T_6	Vermicompost (@3 t/ha) + 50 % RDF	4.18	2.08	17.89	4.13
T_7	FYM (@ 18.75 t/ha) + 25 % RDF	4.36	1.73	16.24	4.26
T_8	Vermicompost (@ 4.5 t/ha) + 25 % RDF	4.48	1.88	16.98	4.24
T_9	Vermicompost (@ 3 t/ha) + FYM (@ 6.25 t/ha) + 25 % RDF	5.12	2.31	19.06	4.04
T_{10}	FYM (@ 12.5 t/ha) + Vermicompost (@ 1.5 t/ha) + 25 % RDF	4.87	1.82	18.43	4.09
	CD (P = 0.05)	0.72	0.42	2.00	0.12
	SEm±	0.24	0.14	0.67	0.04

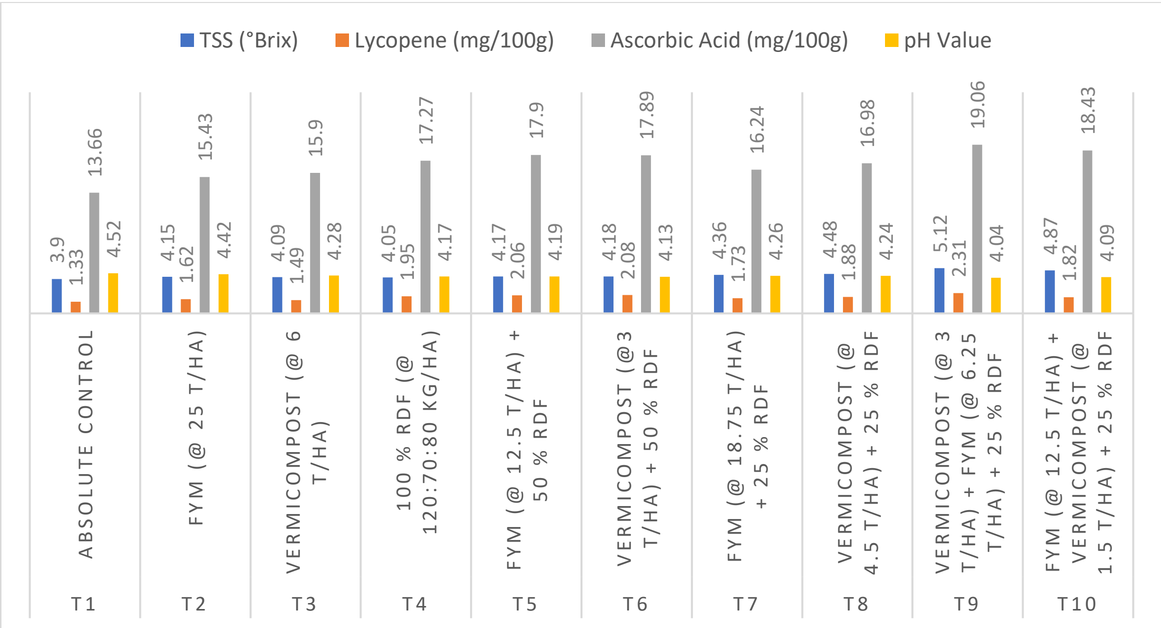

Fig. 1. Bar graph showing variation in treatment combinations

4. Conclusion

The study showed that integrating organic manures with reduced levels of inorganic fertiliser improved the selected fruit quality attributes of tomato cv. Kashi Aman under the experimental conditions. Among the ten treatments, T9, consisting of vermicompost at 3 t/ha, farmyard manure at 6.25 t/ha, and 25% of the recommended dose of fertiliser, performed best for total soluble solids, lycopene content, and ascorbic acid content. It recorded 5.12 °Brix total soluble solids, 2.31 mg/100 g lycopene, and 19.06 mg/100 g ascorbic acid, together with the lowest fruit pH of 4.04. Treatment T10 generally ranked next, whereas the absolute control produced comparatively lower values for the principal quality attributes. These results indicate that partial substitution of inorganic fertiliser with farmyard manure and vermicompost may support the accumulation of quality-related constituents in tomato fruits. However, the findings were obtained during one season at a single location. Therefore, T9 should be regarded as a promising nutrient combination under comparable conditions and validated through multi-season and multi-location trials before broader recommendation.

5. Limitations

This study was conducted during one Rabi season at a single location and evaluated only four fruit-quality attributes. It did not include detailed assessments of yield, plant growth, nutrient uptake, soil biological properties, post-harvest shelf life, economic returns, plot size, sampling intensity, fertiliser scheduling, or seasonal weather. Consequently, the findings may be specific to the local soil, climate, and management conditions. Multi-season and multi-location validation, together with soil-health and cost–benefit assessments, is required before the nutrient combination can be recommended more broadly.

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Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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