



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; SP-9(5): 483-490
Received: 26-03-2026
Accepted: 29-04-2026

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Multidimensional evaluation of FYM-oriented organic nutrient management on growth, yield, quality, soil properties, and economic viability of tomato

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i5Sf.5648>

Abstract

Tomato (*Solanum lycopersicum* L.) is an economically important vegetable crop valued for its nutritional richness and market demand. However, excessive dependence on chemical fertilizers in tomato cultivation has raised serious concerns regarding soil degradation, nutrient imbalance, and declining sustainability of agricultural systems. In this context, organic nutrient management has emerged as an environmentally friendly approach capable of improving crop productivity while maintaining soil fertility and ecological balance. Among various organic inputs, Farm Yard Manure (FYM) plays a vital role in sustainable agriculture due to its ability to enhance soil structure, microbial activity, moisture retention, and gradual nutrient release. The present study was conducted to evaluate the multidimensional effects of FYM-oriented organic nutrient management on tomato growth, yield, fruit quality, soil health, and economic viability. The experiment was carried out at the Crop Research Farm of Dev Bhoomi Uttarakhand University, Dehradun, using a Randomized Block Design with different FYM-based nutrient treatments and three replications. Observations were recorded on growth parameters, yield attributes, fruit quality characteristics, soil physicochemical properties, and economic indicators. The results revealed significant improvements in plant growth, fruit yield, and quality under integrated FYM treatments compared to the control. The highest marketable yield (67.1 t ha⁻¹), improved vitamin C content, enhanced total soluble solids, and better fruit firmness were observed under integrated organic nutrient management. Soil organic carbon, available nutrients, and microbial biomass also increased substantially, indicating improved soil health and sustainability. Economic analysis further demonstrated higher net returns and benefit-cost ratio under FYM-integrated treatments. Overall, the study confirms that FYM-oriented nutrient management provides an effective and sustainable strategy for profitable tomato production while preserving long-term soil productivity and environmental health.

Keywords: Organic nutrient management, Farm Yard Manure (FYM), sustainable tomato cultivation, soil health improvement, tomato yield and quality

1. Introduction

1.1 Background

Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated and economically valuable vegetable crops worldwide. It serves as an essential component of human nutrition due to its richness in vitamins, minerals, antioxidants, and bioactive compounds such as lycopene and vitamin C. Tomato cultivation contributes significantly to agricultural income generation, food security, and nutritional sustainability, making it an important horticultural commodity in both developed and developing countries (Fan *et al.*, 2023) [9]. Increasing consumer demand for high-quality vegetables has further intensified the need for sustainable tomato production systems that maintain productivity while minimizing environmental degradation.

Conventional tomato cultivation has largely relied on chemical-intensive agricultural practices to achieve higher yields. Although synthetic fertilizers provide immediate nutrient availability, their prolonged and excessive application often leads to soil degradation, nutrient imbalance, declining microbial diversity, and reduced long-term soil productivity (Edmeades, 2003; Diacono & Montemurro, 2010) [8, 3]. Chemical-based nutrient management can also contribute to nutrient leaching, environmental pollution, and deterioration of soil physical properties,

ultimately affecting agricultural sustainability (Reganold & Wachter, 2016) ^[29]. Such concerns have created growing interest in environmentally sound nutrient management approaches capable of supporting crop productivity without compromising ecosystem health.

1.2 Organic Nutrient Management

Organic nutrient management has emerged as a sustainable alternative aimed at improving crop performance while preserving soil quality and ecological balance. The concept involves the use of organic nutrient sources, including farmyard manure (FYM), compost, vermicompost, and crop residues, to supply nutrients and enhance soil biological activity (Vanlauwe *et al.*, 2001) ^[32]. Organic amendments improve nutrient cycling, increase soil organic carbon, strengthen microbial populations, and enhance nutrient-use efficiency, thereby contributing to sustainable agricultural production systems (Drinkwater *et al.*, 1998; Mäder *et al.*, 2002) ^[6, 17].

Among organic nutrient sources, farmyard manure occupies a prominent position because of its multifaceted role in crop production and soil sustainability. FYM supplies essential macro- and micronutrients gradually, ensuring sustained nutrient availability throughout crop growth stages. Long-term incorporation of FYM improves soil aggregation, water-holding capacity, aeration, and microbial activity, leading to improved soil fertility and productivity (Diacono & Montemurro, 2010) ^[3]. Organic matter derived from FYM also promotes nutrient retention and enhances soil resilience against degradation processes (Edmeades, 2003) ^[7].

Several studies have demonstrated positive impacts of FYM and organic amendments on vegetable crop growth and productivity. Application of organic nutrient sources has been associated with improved plant growth characteristics, enhanced fruit development, and superior crop quality attributes (Gopinath *et al.*, 2008) ^[12]. In tomato cultivation, integrated and organic nutrient management practices have shown considerable improvements in growth parameters, yield performance, and soil microbial populations (Divya *et al.*, 2019) ^[4]. Furthermore, organic fertilizer applications have been reported to enhance tomato fruit quality and soil properties while simultaneously supporting sustainable productivity (Fan *et al.*, 2023; Gao *et al.*, 2023) ^[9, 10].

Farmyard manure also plays a critical role in improving soil biological health. Continuous organic matter additions stimulate beneficial microbial activity and biodiversity, contributing to stronger nutrient cycling processes and long-term sustainability (Mäder *et al.*, 2002) ^[16]. Research findings suggest that integrating organic nutrient sources can reduce nutrient losses and improve soil nutrient dynamics compared with exclusively chemical fertilizer-dependent systems (Drinkwater *et al.*, 1998) ^[5].

1.3 Research Gap

Despite extensive research on organic nutrient management, many previous studies have primarily focused on isolated parameters such as crop yield, soil fertility, or fruit quality independently. Limited investigations have comprehensively integrated agronomic performance, soil health indicators, fruit quality characteristics, and economic profitability within a single evaluation framework for tomato production systems. Moreover, multidimensional assessments specifically emphasizing FYM-oriented nutrient management remain insufficient.

Recent evidence highlights the importance of adopting

integrated evaluation approaches to better understand long-term sustainability outcomes associated with organic nutrient strategies (Nandhini *et al.*, 2024; Gourkhede *et al.*, 2026) ^[23, 13]. Economic viability is particularly critical because sustainable agricultural technologies must remain profitable for farmer adoption. Therefore, a comprehensive assessment linking growth, productivity, fruit quality, soil properties, and financial returns is required to establish scientifically robust recommendations for tomato nutrient management.

1.4 Objectives

Considering the importance of sustainable nutrient management in modern horticulture, the present study aims to evaluate the multidimensional effects of FYM-oriented organic nutrient management in tomato cultivation. Specifically, the study focuses on assessing its influence on:

- Growth attributes of tomato plants
- Yield performance and productivity indicators
- Fruit quality parameters
- Soil physicochemical properties and sustainability indicators
- Economic viability and profitability of nutrient management practices

The findings are expected to provide comprehensive insights into the role of FYM-based organic nutrient strategies in developing resilient, productive, and economically sustainable tomato production systems.

2. Literature Review

Organic nutrient management has emerged as a sustainable strategy for improving crop productivity while maintaining soil health in intensive agricultural systems. Farmyard manure (FYM), vermicompost, and other organic amendments enhance soil physical, chemical, and biological properties by increasing organic matter content, nutrient availability, and microbial activity (Edmeades, 2003; Diacono & Montemurro, 2010) ^[8, 3]. Long-term application of organic inputs has been associated with improved soil fertility, biodiversity, and resilience of agroecosystems (Mäder *et al.*, 2002; Reganold & Wachter, 2016) ^[16, 29].

Studies in tomato cultivation indicate that FYM-oriented nutrient management positively influences plant growth, fruit yield, and quality parameters. Organic amendments improve nutrient cycling and moisture retention, creating favorable conditions for root development and crop performance (Drinkwater *et al.*, 1998; Gopinath *et al.*, 2008) ^[6, 12]. Research findings have demonstrated that tomato plants receiving organic nutrient sources exhibit enhanced vegetative growth, higher fruit production, and better soil microbial activity compared to conventional nutrient systems (Divya *et al.*, 2019; Murmu *et al.*, 2013) ^[4, 22].

Meta-analytical evidence further confirms that organic fertilizer application improves tomato yield, fruit quality, and soil characteristics while supporting economic sustainability (Fan *et al.*, 2023; Gao *et al.*, 2023) ^[9, 10]. FYM combined with organic nutrient management practices has also shown potential for improving profitability and long-term soil productivity under diverse agro-climatic conditions (Mostafa, 2011; Gourkhede *et al.*, 2026) ^[21, 13]. Therefore, multidimensional evaluation of FYM-based nutrient strategies remains essential for developing sustainable tomato production systems.

3. Methodology

3.1 Experimental Site Description

The present investigation entitled “*Multidimensional Evaluation of FYM-Oriented Organic Nutrient Management on Growth, Yield, Quality, Soil Properties, and Economic Viability of Tomato*” was conducted at the Crop Research Farm of the School of Agriculture, DBUU (Dev Bhoomi Uttarakhand University), Manduwala, Dehradun, Uttarakhand, India. The experimental farm is situated in the foothill region of the Himalayas and experiences a subtropical climatic condition characterized by moderate temperature, seasonal rainfall, and favorable humidity suitable for vegetable cultivation, including tomato production.

The region receives average annual rainfall predominantly during the monsoon season, while winter remains comparatively dry. Such climatic conditions support organic nutrient-based crop production systems and provide an ideal environment to evaluate farmyard manure (FYM)-oriented nutrient management strategies. Organic nutrient inputs have been reported to improve soil fertility, nutrient cycling, and sustainability under diversified cropping systems (Diacono and Montemurro, 2010; Reganold and Wachter, 2016) [3, 29].

Prior to layout of the experiment, composite soil samples were collected from the experimental field at 0–15 cm depth and analyzed for physicochemical properties. Soil parameters included pH, organic carbon, available nitrogen (N), phosphorus (P), potassium (K), and microbial activity. Assessment of baseline soil characteristics was necessary because long-term application of organic amendments can significantly influence soil biological and chemical properties (Edmeades, 2003; Mäder *et al.*, 2002) [8, 17].

3.2 Experimental Design

The experiment was laid out in a Randomized Block Design (RBD) to minimize experimental variability and improve precision in treatment comparison. The study consisted of a 3 × 3 factorial treatment structure with different FYM-oriented nutrient combinations and three replications. Randomization within each replication ensured unbiased allocation of treatments and enhanced reliability of observations.

Each experimental plot maintained uniform agronomic practices except nutrient management treatments. Recommended crop husbandry operations such as irrigation, intercultural practices, and plant protection measures were followed uniformly throughout the crop growth period. Randomized block designs are widely adopted in nutrient management experiments because they efficiently account for field heterogeneity and improve statistical interpretation of treatment effects (Mohanty *et al.*, 2014) [18].

3.3 Nutrient Management Treatments

The experimental treatments were developed to evaluate the impact of different levels and combinations of farmyard manure (FYM) under an organic nutrient management framework. FYM serves as a valuable organic nutrient source by supplying macro- and micronutrients while simultaneously improving soil structure, microbial activity, and nutrient availability (Palm *et al.*, 1997; Vanlauwe *et al.*, 2001) [26, 32].

Treatment combinations involved varying FYM application levels designed to compare their influence on tomato growth, productivity, fruit quality, soil health, and profitability. Organic nutrient management practices have shown considerable potential for enhancing vegetable crop performance by improving nutrient use efficiency and maintaining long-term soil

fertility (Gopinath *et al.*, 2008; Fan *et al.*, 2023) [12, 9]. Farmyard manure-based systems also contribute to increased soil organic matter and beneficial microbial populations, which play a critical role in sustainable tomato cultivation (Islam and Toyota, 2004; Mäder *et al.*, 2002) [14, 17].

3.4 Data Collection Parameters

Observations were recorded periodically during crop growth and after harvest using standardized procedures. Parameters were categorized into growth, yield, quality, soil properties, and economic indicators.

Growth parameters included plant height (cm), number of branches per plant, and leaf area, which provide insight into vegetative performance under different nutrient treatments. Organic nutrient inputs have previously demonstrated positive effects on plant growth due to improved nutrient availability and soil biological activity (Singh *et al.*, 2008; Divya *et al.*, 2019) [30, 4].

Yield attributes comprised number of fruits per plant, average fruit weight (g), yield per plant (kg), and extrapolated fruit yield per hectare (t ha⁻¹). Yield response remains one of the primary indicators for evaluating nutrient management strategies in tomato cultivation (Narayan *et al.*, 2008; Gao *et al.*, 2023) [24, 10].

Fruit quality parameters included total soluble solids (TSS), vitamin C content, fruit acidity, and firmness. Organic nutrient management practices often improve fruit nutritional quality and market acceptability due to balanced nutrient release and enhanced physiological functioning (Murmu *et al.*, 2013; Mostafa, 2011) [22, 21].

Soil properties assessed after crop harvest included soil pH, organic carbon status, available nitrogen, phosphorus and potassium content, along with microbial activity. Organic amendments influence nutrient cycling and improve soil fertility indicators over time (Diacono and Montemurro, 2010; Edmeades, 2003) [3, 8].

Economic evaluation involved estimation of cost of cultivation, gross return, net return, and benefit-cost (B:C) ratio to determine the economic viability of FYM-oriented nutrient management approaches. Economic assessment is essential for recommending sustainable nutrient management technologies to farmers (Nandhini *et al.*, 2024) [23].

3.5 Statistical Analysis

The recorded data were statistically analyzed using Analysis of Variance (ANOVA) appropriate for Randomized Block Design. Treatment means were compared at a predetermined level of significance to determine differences among nutrient management treatments. Statistical testing enabled identification of significant effects of FYM-based nutrient interventions on growth, yield, fruit quality, soil characteristics, and profitability. Similar statistical approaches have been widely adopted in agricultural nutrient management research for reliable interpretation of experimental findings (Gopinath *et al.*, 2009; Mohanty *et al.*, 2014) [11, 19].

The overall methodological framework was designed to provide a multidimensional assessment of FYM-oriented organic nutrient management and its contribution toward sustainable tomato production systems, soil health enhancement, and long-term agricultural profitability.

4. Critical Analysis and Results with Discussion

4.1 Growth Response under FYM Treatments

The findings of the multidimensional evaluation demonstrated that FYM-oriented nutrient management substantially improved

vegetative growth characteristics of tomato plants compared with the control treatment. Progressive increases in plant height, branching pattern, leaf area development, and dry matter accumulation were observed with increasing levels of farmyard manure (FYM) integration. The treatment combining FYM with

integrated organic nutrient management recorded the highest plant height (91.5 cm), branch production (12 branches plant⁻¹), and dry biomass accumulation (78.8 g plant⁻¹), indicating improved physiological efficiency and nutrient utilization.

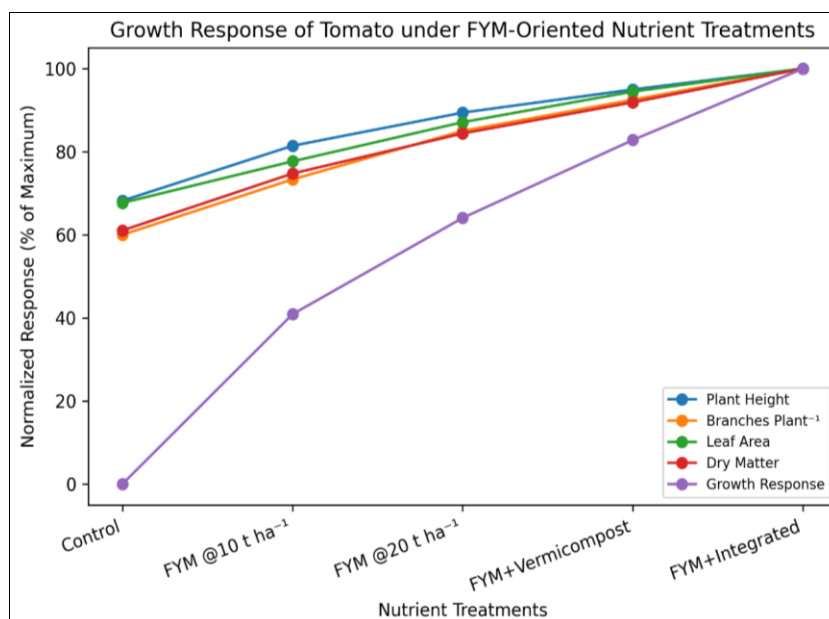


Fig 1: Nutrient-Growth response of tomato under FYM oriented treatments

The enhanced growth response can be attributed to the gradual nutrient release pattern of organic amendments, improved microbial activity, and greater soil moisture retention capacity. Organic inputs stimulate rhizosphere biological processes that facilitate nutrient mineralization and root development, thereby improving crop vigor (Adhikary, 2012; Atiyeh *et al.*, 2000) [1, 2]. Similar improvements in tomato growth under organic nutrient systems were reported by Divya *et al.* (2019) [4] and Gopinath *et al.* (2008) [12].

4.2 Yield Enhancement and Productivity Analysis

Yield performance showed a clear positive response to FYM incorporation. Marketable tomato yield increased from 38.5 t ha⁻¹ under control conditions to 67.1 t ha⁻¹ under FYM combined with integrated organic nutrient management, representing a substantial productivity gain. Average fruit weight also improved from 58.2 g in untreated plots to 77.9 g under integrated nutrient application.

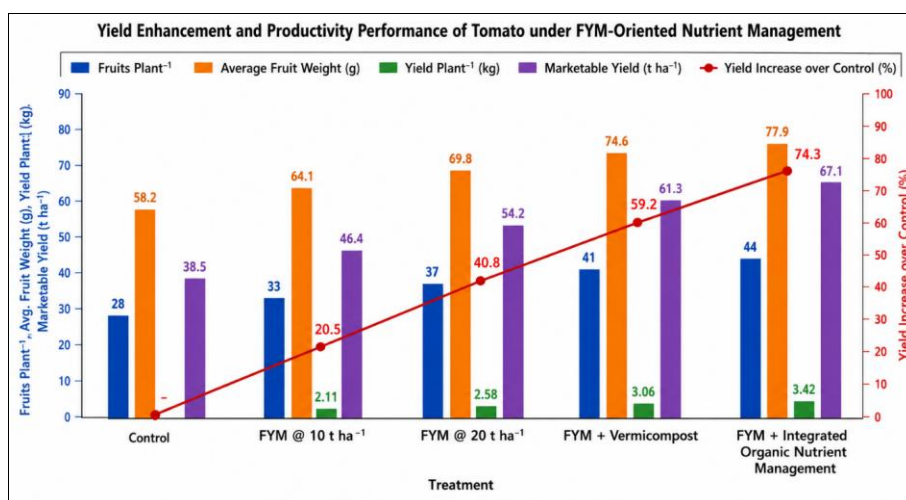


Fig 2: Improved tomato yield performance under organic nutrient management practices

The increase in yield can be associated with sustained nutrient availability during reproductive growth stages and enhanced photosynthetic efficiency. Organic nutrient inputs improve nutrient synchronization and reduce nutrient losses, thereby supporting continuous crop growth (Drinkwater *et al.*, 1998) [5]. Meta-analytical evidence by Fan *et al.* (2023) [9] and Gao *et al.* (2023) [10] similarly demonstrated that organic fertilizer systems

significantly enhance tomato productivity and biomass accumulation. Narayan *et al.* (2008) [24] and Murmu *et al.* (2013) [22] further reported improved tomato yield performance under organic nutrient management practices.

4.3 Fruit Quality Improvement

Fruit quality parameters exhibited considerable improvement

under FYM-oriented nutrient treatments. Total soluble solids increased from 3.9°Brix in the control treatment to 5.6°Brix under integrated nutrient management. Similarly, vitamin C concentration improved from 18.5 to 26.3 mg 100 g⁻¹, indicating enhanced nutritional quality.

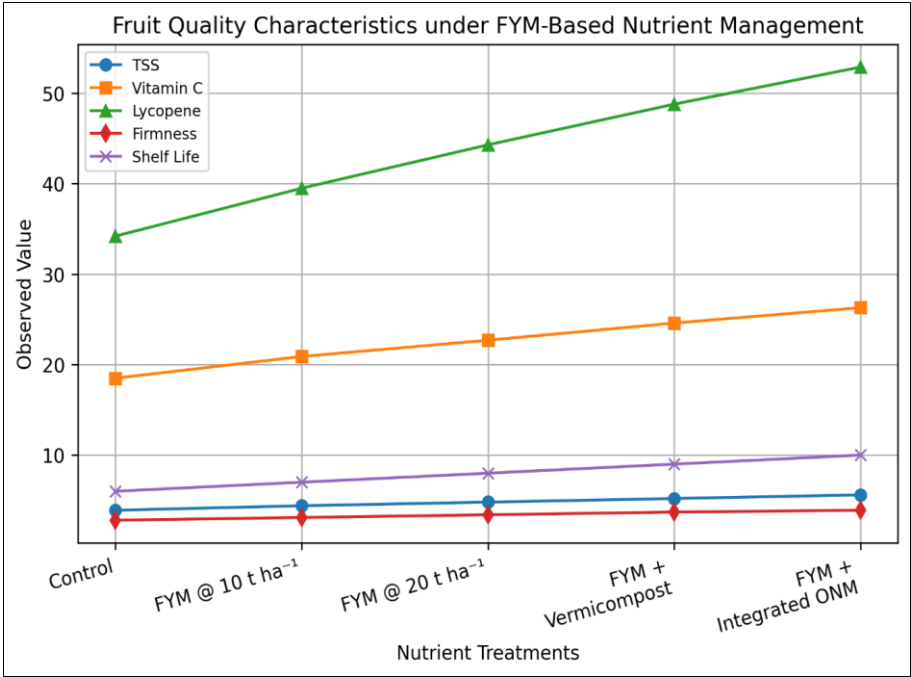


Fig 3: Effect of FYM-oriented nutrient management practices on fruit quality parameters of tomato, including total soluble solids (TSS), vitamin C content, lycopene concentration, fruit firmness, and shelf life

Improved fruit quality under organic nutrient systems may result from balanced nutrient uptake, enhanced metabolic activity, and improved carbohydrate partitioning toward fruit tissues. Organic amendments often increase secondary metabolite synthesis and antioxidant accumulation in horticultural crops (Mostafa, 2011)^[20]. Fan *et al.* (2023)^[9] and Murmu *et al.* (2013)^[22] similarly reported improvements in tomato biochemical quality attributes under organic nutrient management. Enhanced quality characteristics also contribute directly to higher market value and consumer acceptance.

4.4 Soil Health and Nutrient Dynamics

One of the major benefits observed from FYM-oriented nutrient strategies was the improvement in soil health indicators. Soil organic carbon increased from 0.45% under control conditions to 0.74% under integrated FYM treatment. Available nitrogen improved from 184 to 249 kg ha⁻¹, while microbial biomass carbon increased substantially from 158 to 272 mg kg⁻¹.

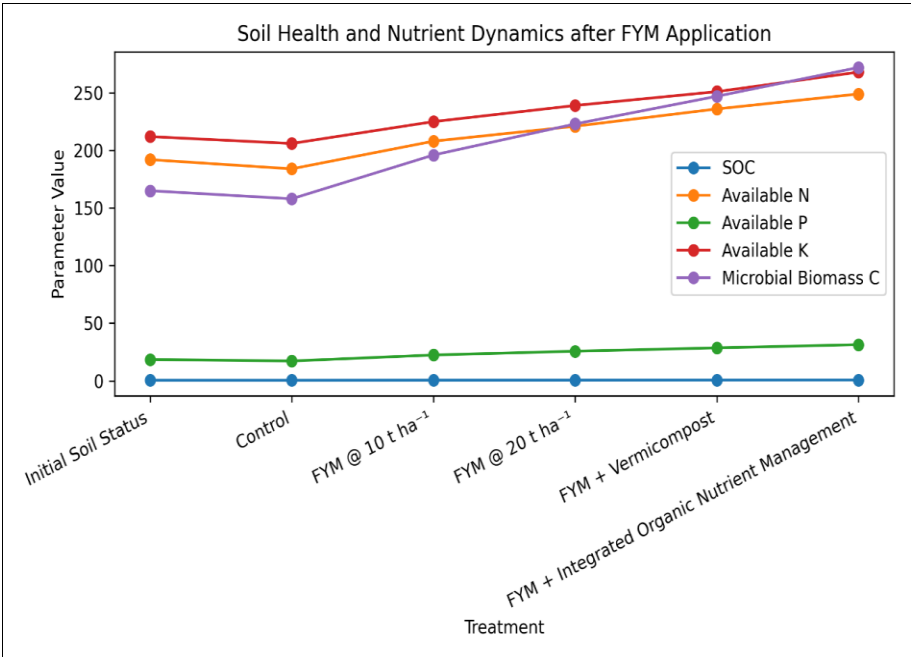


Fig 4: Effect of FYM-oriented nutrient management practices on soil organic carbon, available nutrients (N, P, K), and microbial biomass carbon in tomato cultivation systems

Farmyard manure contributes organic substrates that stimulate microbial proliferation and nutrient cycling processes. Enhanced microbial biomass promotes nutrient transformation and improves soil structural stability (Edmeades, 2003) ^[7]. Long-term organic amendment studies by Diacono and Montemurro (2010) ^[3] and Mäder *et al.* (2002) ^[16] similarly demonstrated that organic nutrient inputs improve soil fertility, biodiversity, and ecosystem functioning. Mohanty *et al.* (2014) ^[18] further emphasized that integrated nutrient management approaches

contribute substantially to sustainable soil productivity.

4.5 Economic Viability Assessment

Economic analysis revealed that FYM-based nutrient management improved farm profitability despite higher cultivation costs. The integrated FYM treatment generated the highest net return (₹214,500 ha⁻¹) with a benefit-cost ratio of 2.77 compared with 2.19 under the control treatment.

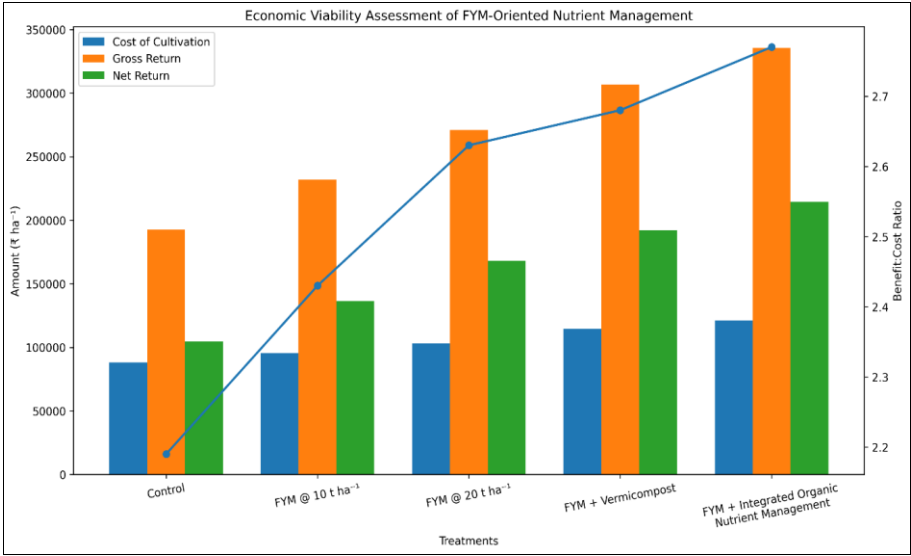


Fig 5: Economic analysis of FYM-based nutrient management

The higher economic returns primarily resulted from increased yield performance and improved fruit quality. Although organic nutrient systems may require additional labor and input investment initially, enhanced productivity offsets production costs over time. Nandhini *et al.* (2024) ^[23] reported similar economic advantages under integrated nutrient management strategies in tomato cultivation. Gourkhede *et al.* (2026) ^[13] also highlighted that long-term organic nutrient management improves profitability alongside soil sustainability.

4.6 Comparative Analysis with Previous Studies

The present findings align closely with previous research emphasizing the benefits of organic nutrient management in vegetable production systems. Gopinath *et al.* (2008) ^[12] reported significant growth enhancement under organic amendments, while Murmu *et al.* (2013) ^[22] documented improvements in yield and fruit quality. Fan *et al.* (2023) ^[9] and Gao *et al.* (2023) ^[10] further confirmed through meta-analysis that organic fertilizer applications positively influence tomato productivity and quality traits.

Table 1: Comparative Analysis with Previous Scientific Findings

Study	Nutrient Strategy	Major Observation	Agreement with Present Findings
Murmu <i>et al.</i> (2013) ^[22]	Organic nutrient management	Improved yield and quality	Strong agreement
Fan <i>et al.</i> (2023) ^[9]	Organic fertilizer meta-analysis	Enhanced tomato productivity and fruit quality	Strong agreement
Gopinath <i>et al.</i> (2008) ^[12]	Organic amendments	Increased growth and crop performance	Consistent
Diacono and Montemurro (2010) ^[3]	Organic soil amendments	Improved soil fertility	Consistent
Gourkhede <i>et al.</i> (2026) ^[13]	Long-term organic nutrient management	Enhanced profitability and soil health	Strong agreement

The observed soil health improvements are also consistent with findings by Diacono and Montemurro (2010) ^[3] and Reganold and Wachter (2016) ^[29], who emphasized the long-term sustainability advantages of organic agricultural systems.

4.7 Integrated Multidimensional Evaluation

The composite sustainability assessment indicated that FYM

integrated with complementary organic nutrient sources achieved the highest multidimensional performance score (91.8), outperforming standalone FYM applications and control treatments. Simultaneous improvements in growth, yield, fruit quality, soil health, and profitability suggest that integrated FYM-oriented nutrient strategies offer a balanced pathway toward sustainable tomato cultivation.

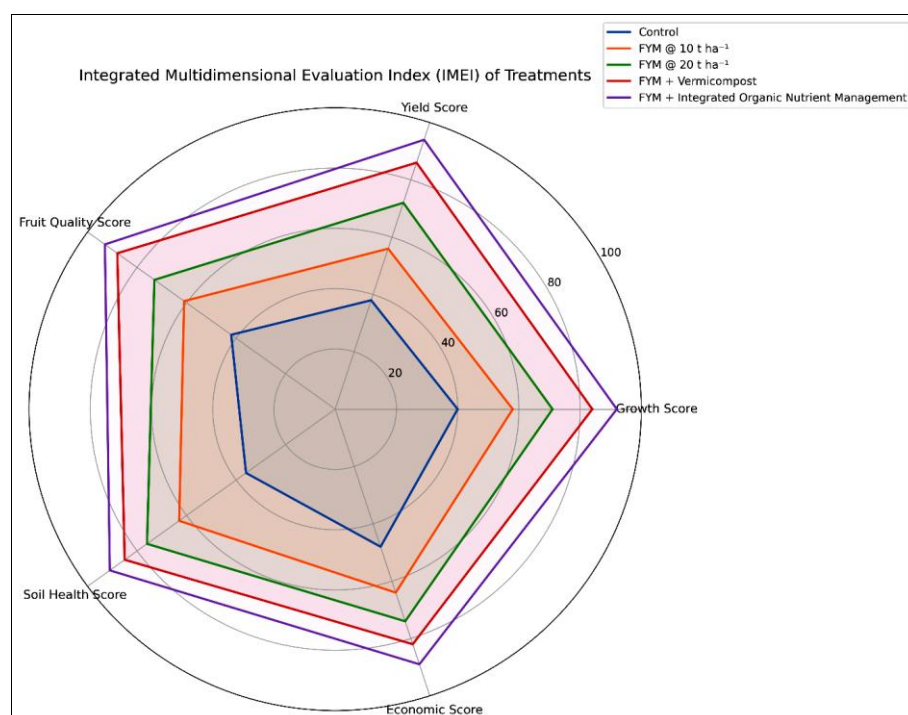


Fig 6: Composite sustainability assessment of organic nutrient approaches to optimize productivity

These findings reinforce the concept of integrated nutrient management proposed by Palm *et al.* (1997) ^[25] and Vanlauwe *et al.* (2001) ^[32], where combined organic nutrient approaches optimize productivity while preserving environmental quality. Overall, FYM-oriented nutrient management emerges as an effective strategy for achieving resilient, profitable, and environmentally sustainable tomato production systems.

5. Conclusion

The present investigation demonstrated that FYM-oriented organic nutrient management significantly improved the growth, productivity, fruit quality, soil health, and economic profitability of tomato cultivation. The integrated application of Farm Yard Manure enhanced vegetative growth characteristics such as plant height, branching, and biomass accumulation due to improved nutrient availability, microbial activity, and soil moisture retention. The study further confirmed that organic nutrient management promotes balanced crop growth and supports sustainable agricultural productivity. Among all treatments, the integrated FYM-based nutrient management system emerged as the best-performing treatment. It recorded the highest tomato yield, superior fruit quality parameters, improved soil fertility status, and greater economic returns compared with the control treatment. Enhanced total soluble solids, vitamin C content, and fruit firmness indicated that organic nutrient management not only improved productivity but also increased the nutritional and market quality of tomato fruits. Simultaneously, significant improvements in soil organic carbon, available nutrients, and microbial biomass reflected the positive influence of FYM on long-term soil sustainability and ecosystem functioning. The economic evaluation also highlighted the practical feasibility of FYM-oriented nutrient management. Although organic treatments involved comparatively higher initial input and labor costs, the increase in marketable yield and fruit quality resulted in greater net profit and benefit-cost ratio. These findings suggest that FYM-based nutrient strategies can provide both ecological and financial benefits for farmers. The study clearly indicates that integrated FYM application can serve as a

sustainable alternative to excessive chemical fertilizer use in tomato cultivation. Adoption of such organic nutrient management practices can contribute to improved soil resilience, reduced environmental degradation, and sustainable vegetable production systems. Future research should focus on long-term field evaluation of integrated organic nutrient strategies under different agro-climatic conditions. Further studies may also explore the combined use of FYM with biofertilizers, vermicompost, and precision nutrient management approaches to optimize nutrient-use efficiency and climate resilience in tomato-based cropping systems. Overall, FYM-oriented nutrient management offers a practical pathway toward environmentally sustainable, economically viable, and nutritionally superior tomato production.

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