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Impact of Nutrient Management Practices on Growth Parameters, Yield Attributes and Yield of Tomato (*Solanum lycopersicum* L.)

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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

With increasing global concerns about environmental sustainability, nutrient management for tomato production must balance productivity with ecological integrity. Integrated Nutrient Management **(**INM) approaches help to reduce dependency on synthetic fertilizers, limit nutrient leaching into groundwater, and build soil organic carbon, thereby promoting long-term soil fertility and environmental health. The present study explores the Impact of nutrient management under natural farming on growth, yield and quality of tomato (*Solanum lycopersicum* L.) in Madhya Pradesh, India. The investigation was conducted during the Rabi seasons of 2023–24 and 2024–25 at the research farm of the Department of Horticulture, Faculty of Agriculture, Rabindranath Tagore University, Raisen (M.P.), India. The experiment comprised twelve treatments T_1 - Control, T_2 -100% nutrition by RDF, T_3 -50% nutrition by recommended dose of FYM+50% nutrition by fertilizer, T_4 -50% nutrition by recommended dose of VC+50%nutrition by fertilizer, T_5 -50% nutrition by recommended dose of poultry manure+50%nutrition by fertilizer, T_6 -75% nutrition by recommended dose of FYM+25% nutrition by fertilizer, T_7 -75% nutrition by recommended dose of VC+25% nutrition by fertilizer, T_8 -75% nutrition by recommended dose of poultry manure+25% nutrition by fertilizer, T_9 -25% nutrition by recommended dose of FYM+75% nutrition by fertilizer, T_{10} -25% nutrition by recommended dose of VC+75% nutrition by fertilizer, T_{11} -25% nutrition by recommended dose of poultry manure+75% nutrition by fertilizer, T_{12} -Jeevamrit involving various combinations of vermicompost, farmyard manure (FYM), vermiwash, panchgavya, and jeevamrit, arranged in a Randomized Block Design with three replications. Plant protection measures were adopted as per standard recommendations to manage pests and diseases. Five plants were selected randomly from each plot and tagged to record the observations. The growth parameters recorded were plant height (cm) at 30, 60, and 90 DAT, number of branches per plant, days to first flowering, number of flowers per cluster, and number of flower clusters per plant. Among all treatments, T_{12} (vermicompost + vermiwash + panchgavya + jeevamrit) emerged as the most effective in enhancing growth attributes and yield of tomato. This treatment recorded the maximum plant height (97.13 cm) and number of branches per plant (15.48) at 90 days after transplanting. It also yielded the highest number of fruits per plant (41.65) and fruit diameter (5.93 cm), resulting in a fruit yield of 427.32 q/ha. The results suggest that the integrated use of vermicompost, vermiwash, panchgavya, and jeevamrit under natural farming significantly enhances tomato productivity and profitability, making it a sustainable and eco-friendly alternative to conventional practices.

Keywords: Panchgavya; jeevamrit; vermiwash; vermicompost; integrated nutrient management; phosphate solubilizing bacteria.

1. Introduction

Tomato (*Solanum lycopersicum L.*) is one of the most widely cultivated and economically important vegetable crops worldwide, recognised for its high nutritive value, including vitamins, minerals, antioxidants, and dietary fibers. However, tomato is also classified as a heavy feeder it demands substantial quantities of essential nutrients to sustain vigorous growth, optimal yield attributes, and high marketable yields. Despite its importance, tomato production is constrained by several challenges, including pest and disease incidence, fluctuating market prices, and nutrient-related constraints. Declining soil fertility, unbalanced fertilizer use, and overreliance on chemical fertilizers have led to soil degradation, reduced microbial activity, and environmental concerns. Nutrient imbalances, resulting from excessive nitrogen or insufficient phosphorus and potassium, directly affect plant growth, fruit set, and yield quality. These challenges necessitate the adoption of sustainable nutrient management strategies to enhance productivity while maintaining soil health (Kumar et al., 2024; Sahu et al., 2025). Inadequate or imbalanced nutrient supply can result in poor vegetative development, delayed flowering, reduced fruit set, and ultimately lower productivity. Therefore, nutrient management practices play a pivotal role in tomato cultivation, influencing plant physiological processes and determining overall crop performance. Recent studies have shown that both inorganic fertilisers and integrated or organic nutrient strategies dramatically affect growth parameters, yield components, and final tomato yield (Sharma et al., 2025). Integrated Nutrient Management (INM) has emerged as a sustainable approach, combining inorganic fertilizers with organic amendments (farmyard manure, vermicompost) and biofertilizers (Azotobacter, phosphate - solubilising bacteria). INM aims to improve nutrient use efficiency, maintain soil fertility, and enhance crop productivity while reducing environmental risks (Verma et al., 2025). Integrated soil-tomato system strategies are required to enhance productivity and meet consumer demands. Additionally, this review uniquely integrates multidisciplinary approaches to highlight synergistic strategies for optimizing both yield and quality. Breeders and researchers are dedicated to developing tomato varieties that exhibit superior flavor and quality, with the goal of meeting market demands and enhancing the overall economic efficiency of the tomato industry (Li et al., 2025). Vegetative growth characteristics such as plant height, leaf area, number of branches, and dry matter accumulation directly influence photosynthetic capacity and set the foundation for reproductive success. Balanced nutrients enable optimal leaf development and vigorous root systems, which enhance nutrient uptake and support rapid early growth. Recent research demonstrates significant improvements in vegetative growth under integrated nutrient regimes compared to conventional fertilizer use. For instance, a study combining 50% RDF, organic manures, and biofertilizers recorded superior plant height, number of leaves per plant, and branches compared to sole RDF treatments, indicating strong synergistic effects between nutrient sources (Singh et al., 2023). Tomato yield measured as fruit weight per unit area reflects the cumulative effects of growth parameters and yield attributes impacted by nutrient supply. Yield responses vary based on nutrient sources, application methods, and their interactions with soil conditions and crop genetics. Several recent experiments revealed that INM practices often outperform traditional fertilization in achieving higher fruit yields. For example, integrated treatments including 75% RDF combined with organic manures and biofertilizers recorded significantly higher yields than standard RDF alone, indicating enhanced nutrient uptake and utilisation efficiency (Dhawai et al., 2025). With increasing global concerns about environmental sustainability, nutrient management for tomato production must balance productivity with ecological integrity. INM approaches help to reduce dependency on synthetic fertilizers, limit nutrient leaching into groundwater, and build soil organic carbon, thereby promoting long-term soil fertility and environmental health (Manta et al., 2024). As tomato is a crop, not much work has been done on its natural farming cultivation technology in the present condition of Madhya Pradesh; information is lacking in respect of the facts as discussed above. Keeping in view the above facts the present study explores the Impact of nutrient management under natural farming on growth, yield and quality of tomato (*Solanum lycopersicum* L.).

2. Materials and Method

The experiment was conducted in field of the Department of Horticulture, Agriculture Research Centre, Faculty of Agriculture Science, Rabindranath Tagore University, Raisen, Madhya Pradesh during Rabi season 2022-23. Raisen is a district of Madhya Pradesh state of India. Which is part of Bhopal Division. Raisen district is situated between the latitude 22 47' and 23 33' north and the longitude 7721' and 78 49' east. It covers an area of 8,395 square kilometres (3,241 sq mi). Raisen district has ten tehsils Raisen, Goharganj, Begamganj, Gairatganj, Silwani, Bareli, Udaipura, Deori, Sultanpur and Badi. The normal annual rainfall of Raisen district is 1207.3 mm. It receives maximum rainfall during southwest monsoon period. About 92.2% of the annual rainfall is received during the monsoon seasons July to September. The field experiment was conducted in a Randomized Block Design (RBD) with three replications having twelve different integrated nutrient management treatments, i.e., T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11} and Control T_{12}. The soil was brought to a fine tilth by continuous cultivation followed by planking. After thorough ploughing, weeds, stubbles, stones and other unwanted materials were completely removed from the field. The recommended dose of fertilizers (NPK) was applied at the rate of 150:100:50 kg/ha. The fertilizers were applied in split doses, wherein half of the nitrogen, along with the full dose of phosphorus and potassium, was applied as basal at the time of transplanting. The remaining half of the nitrogen was supplied in two split doses at 30 and 45 DAT as top dressing. Frequent irrigations were provided during the spring-summer season due to high temperatures and evapotranspiration. The first irrigation was given immediately after transplanting to ensure proper establishment of seedlings, followed by irrigations at regular intervals of 4-5 days to maintain adequate soil moisture for optimum growth and fruit setting. Organic nutrient sources such as FYM and vermicompost were applied as per treatment requirements and thoroughly incorporated into the soil 15-20 days prior to transplanting. Healthy and uniform 30-35 days old seedlings of tomato cv. ‘PKM-1 (TNAU)’ were selected and transplanted at a spacing of 60 × 45 cm. Gap filling was done within a week to maintain the recommended plant population. Regular intercultural operations such as weeding, hoeing, and earthing-up were carried out to keep the crop free from weeds and to promote better aeration. Plant protection measures were adopted as per standard recommendations to manage pests and diseases. Five plants were selected randomly from each plot and tagged to record the observations. The growth parameters recorded were plant height (cm) at 30, 60, and 90 DAT, number of branches per plant, days to first flowering, number of flowers per cluster, and number of flower clusters per plant. The yield attributes included the number of fruits per plant, average fruit weight (g), fruit diameter (cm), fruit yield per plant (kg), and fruit yield per plot (kg). All observations were recorded carefully at regular intervals using standard procedures to ensure accuracy and reliability of the experimental data.

3. Results and Discussion

3.1 Plant Height (cm)

Table 1 clearly indicates that the application of different nutrient management practices significantly influenced plant height of tomato at 30, 60 and 90 days after transplanting (DAT) during both the years as well as on pooled basis. At all growth stages, plant height increased progressively with crop age, and the magnitude of increase varied significantly among the treatments. At 30 DAT, the pooled data revealed that the maximum plant height (20.13 cm) was recorded under T_{12} (Vermicompost + Vermiwash + Panchgavya + Jeevamrit), which was statistically superior to most of the treatments. This was closely followed by T11 (19.75 cm) and T_{10} (19.26 cm). The minimum plant height (13.62 cm) was observed in the control treatment (T_1). A similar trend was observed at 60 DAT, where T_{12} again recorded the highest pooled plant height (97.31 cm), followed by T_{11} (91.13 cm) and T_{10} (88.45 cm). The control treatment recorded significantly lower plant height (56.34 cm). At 90 DAT, the pooled plant height was maximum under T_{12} (97.13 cm), which remained significantly superior over all other treatments, indicating better vegetative growth due to the combined application of organic inputs. Treatments involving vermicompost, vermiwash, panchgavya and jeevamrit in combination consistently performed better than single or two-component treatments. Overall, the results demonstrate that integrated use of multiple natural farming organic nutrient sources markedly enhanced plant height of tomato compared to control, likely due to improved nutrient availability and microbial activity in the soil. These findings strongly justify the use of integrated organic formulations for promoting robust plant development. The enhancement in plant height across all stages indicates better nutrient uptake and hormonal stimulation, key to vegetative vigour. Thus, the study substantiates that the inclusion of diverse organic inputs, particularly in synergistic combinations, significantly enhances plant growth performance in tomato cultivation under sustainable farming systems. Federic ***et al.*** (2007) and Joshi and Vig (2010) reported significant increases in tomato plant height with vermicompost application compared to control, confirming its positive effect on vegetative growth.

3.2 Number of Branches Per Plant

The pooled data on the number of branches per tomato plant at 30, 60 and 90 days after transplanting (DAT) under natural farming conditions showed significant variation among treatments. Treatment T_{12} (vermicompost + vermiwash + panchgavya + jeevamrit) consistently recorded the highest number of branches at all stages, followed by T_{11} and T_{10}, while the control (T_1) showed the lowest values. T_{12} exhibited marked increases over the control at each growth stage, indicating improved vegetative growth. The results clearly demonstrate that integrated application of multiple organic inputs enhances branching, plant architecture and overall vegetative performance of tomato under natural farming systems. The synergistic effects of vermicompost, vermiwash, Panchgavya, and Jeevamrit appear to improve nutrient availability and hormonal balance, resulting in better plant architecture and overall vegetative performance in tomato under natural farming practices. Alam (2011) and Chanda *et al.* (2011) reported that vermicompost and integrated nutrient treatments significantly increased the number of branches per plant, enhancing overall growth and yield of tomato under field conditions.

3.3 Days to First Flowering and Days to 50% Flowering

The pooled results on days to first flowering and 50% flowering in tomato under natural farming conditions revealed significant variation among treatments. Integrated organic nutrient applications markedly hastened flowering compared to the control. Treatment T_{12} (vermicompost + vermiwash + panchgavya + jeevamrit) recorded the earliest first flowering at 32.13 days after transplanting (DAT) and 50% flowering at 40.96 days, advancing flowering by 14.92 days (31.73%) and 19.98 days (32.80%), respectively, over the control. Treatments T_{11} (FYM + vermiwash + panchgavya + jeevamrit) and T_{10} (vermicompost + panchgavya) also significantly reduced the time to flowering. In contrast, the control exhibited the most delayed flowering. The early floral induction under integrated organic treatments may be attributed to the synergistic supply of nutrients, beneficial microorganisms, and growth-promoting substances. Early flowering is advantageous for shortening crop duration, enabling early harvest, and improving market opportunities under natural farming systems. In summary, the results emphasise the effectiveness of integrated organic formulations in fostering early reproductive development under natural farming, thereby improving both agronomic performance and economic returns. Zodape *et al.* (2011) and Prativa *et al.* (2012) reported that foliar application of seaweed sap and integrated use of FYM and vermicompost with NPK significantly hastened first and 50% flowering in tomato plants.

3.4 Yield Parameters

3.4.1 Number of Trusses Per Plant

The pooled analysis of truss and fruit development in tomato (Table 1) revealed notable differences among treatments under natural farming. Treatment T_{12} (vermicompost + vermiwash + panchgavya + jeevamrit) recorded the highest number of trusses per plant (7.02), followed closely by T_{11} (FYM + vermiwash + panchgavya + jeevamrit) with 6.01, and T_{10} (vermicompost + panchgavya) with 5.52. In contrast, the lowest truss number was observed in the control (T1), which recorded only 2.68 trusses per plant. This implies that T_{12} produced 162.31% more trusses than the control, while T_{11} and T_{10} showed increases of 124.25% and 105.97%, respectively.

3.4.2 Number of Fruits Per Truss

The pooled data on truss and fruit development in tomato under natural farming conditions showed significant superiority of integrated organic nutrient management. Treatment T_{12} (vermicompost + vermiwash + Panchgavya + Jeevamrit) produced the highest number of trusses per plant (7.02) and fruits per truss (11.06), registering increases of 162.31% and 150.23%, respectively, over the control. Treatments T_{11} and T_{10} also markedly improved these traits, though to a lesser extent. The enhanced reproductive performance under T_{12} may be attributed to improved nutrient availability, microbial activity, and hormonal stimulation, resulting in greater yield potential and sustainable tomato production.

3.4.3 Number of Fruits Per Plant

The pooled data on the number of fruits per plant and fruit diameter (Table 2) in tomato under natural farming clearly demonstrated that integrated organic nutrient treatments significantly outperformed the control. Among all treatments, T_{12} (vermicompost + vermiwash + panchgavya + jeevamrit) recorded the highest number of fruits per plant (41.65), followed by T_{11} (FYM + vermiwash + panchgavya + jeevamrit) with 38.46, and T_{10} (vermicompost + panchgavya) with 36.93. In contrast, the control treatment T1 yielded only 14.17 fruits per plant. This represents a substantial increase of 193.91% in T_{12} over the control, 171.37% in T11, and 160.52% in T10, highlighting the positive impact of diverse organic inputs on fruit productivity.

3.4.4 Fruit Diameter

The pooled data on number of fruits per plant and fruit diameter in tomato under natural farming revealed significant enhancement in yield-related traits with integrated organic nutrient treatments. Among all treatments, T_{12} (vermicompost + vermiwash + Panchgavya + Jeevamrit) recorded the highest fruit count (41.65), nearly tripling the output of the control (T1), which produced only 14.17 fruits per plant—an increase of 193.91%. T11 and T10 also performed well, with increases of 171.37% and 160.52% over the control, respectively. This sharp rise in fruit number underscores the superior efficacy of diverse organic amendments in stimulating reproductive success and fruit retention. Similarly, fruit diameter was significantly enhanced, with T12 achieving the largest average (5.93 cm), a 31.19% improvement over T1 (4.52 cm). T11 and T10 closely followed, demonstrating increases of 28.32% and 27.43%, respectively. These improvements in both fruit number and size reflect enhanced nutrient availability, hormonal stimulation, and overall plant vigour facilitated by the organic inputs. Overall, the results affirm that the integrated use of vermicompost, vermiwash, Panchgavya, and Jeevamrit under natural farming not only boosts fruit quantity but also improves quality, making it a highly effective and sustainable strategy for maximizing tomato yield and market value. Chaitanya *et al.* (2013) and Kashem *et al.* (2015) reported that integrating vermicompost with chemical fertilizers significantly increased the number of fruits per plant and fruit diameter compared to control and sole fertilizer treatments.

3.5 Number of Locules Per Fruit

The pooled data on number of locules per fruit and number of seeds per fruit (Table 2) in tomato under natural farming clearly demonstrated that integrated organic nutrient treatments significantly outperformed the control.

The pooled data for number of locules and number of seeds per fruit in tomato under natural farming clearly indicated that organic nutrient management treatments significantly influenced fruit development traits. Among the treatments, the highest number of locules per fruit was recorded in T1 (control) with 4.01, followed by T2 (FYM+ Jeevamrit) with 3.46 and T3 (Vermicompost + Jeevamrit) with 3.28. However, these treatments did not correspond to higher seed numbers, which are more indicative of reproductive success.

3.6 Number of Seeds Per Fruit

The pooled data on the number of locules and seeds per fruit in tomato under natural farming revealed that integrated organic nutrient treatments significantly influenced reproductive traits. Interestingly, the control (T1) recorded the highest number of locules per fruit (4.01), followed by T2 (3.46) and T3 (3.28), yet this did not translate into superior seed production—an essential indicator of reproductive success. In contrast, the highest number of seeds per fruit was observed in T12 (vermicompost + vermiwash + Panchgavya + Jeevamrit), with a remarkable count of 194.75 seeds, far surpassing the control (34.94 seeds). T11 and T10 also showed significantly higher seed counts of 192.02 and 158.54, respectively. These values represent dramatic increases over the control—457.47% in T12, 449.57% in T11, and 353.83% in T10—underscoring the potent role of combined organic inputs in enhancing seed development. The superior seed set in T12, despite fewer locules, indicates improved ovule fertilization and nutrient partitioning under enriched organic conditions. Motallebi (2015) and Singh *et al.* (2015) reported that vermicompost and integrated nutrient use substantially improved physiological traits and fruit yield, suggesting enhanced seed count and locule formation under nutrient-rich organic conditions.

3.7 Fruit Yield

The pooled data on fruit yield per plant and fruit yield per hectare (Table 3) in tomato under natural farming clearly demonstrated that integrated organic nutrient treatments significantly outperformed the control. Among the various combinations, the treatment T12 (vermicompost + vermiwash + panchgavya + jeevamrit) recorded the highest fruit yield of 9.23 kg per plant and 427.32 q/ha, clearly demonstrating its superiority in enhancing productivity. This was followed by T11 (FYM + vermiwash + panchgavya + jeevamrit), which yielded 8.25 kg per plant and 408.25 q/ha, and T10 (vermicompost + panchgavya) with 6.45 kg per plant and 371.02 q/ha. In contrast, the control (T1) recorded the lowest yield of 0.54 kg per plant and 126.30 q/ha. Compared to the control, T12 showed an impressive yield increase of 1609.26% on a per plant basis and 238.21% per hectare. Similarly, T11 recorded a 1427.78% increase in per plant yield and 223.27% in yield per hectare, while T10 showed an 1094.44% increase in yield per plant and 193.70% per hectare over the control. These results highlight the substantial positive impact of integrated organic nutrient application, particularly the synergistic effect of combining vermiwash, panchgavya, and jeevamrit, in significantly boosting tomato fruit yield under natural farming conditions.

The pooled data on fruit yield per plant and per hectare in tomato under natural farming unequivocally demonstrated the superior impact of integrated organic nutrient treatments over the control. Treatment T_{12} (vermicompost + vermiwash + Panchgavya + Jeevamrit) emerged as the most effective, producing the highest yield of 9.23 kg per plant and 427.32 q/ha. This represented a remarkable increase of 1609.26% and 238.21%, respectively, compared to the control (T1), which recorded only 0.54 kg per plant and 126.30 q/ha. T11 and T10 also performed significantly better, with T11 yielding 8.25 kg per plant (1427.78%) and 408.25 q/ha (223.27%), while T10 achieved 6.45 kg per plant (1094.44%) and 371.02 q/ha (193.70%). These results clearly highlight the synergistic benefits of using multiple organic inputs. The combination of vermicompost, vermiwash, Panchgavya, and Jeevamrit appears to optimise nutrient availability, enhance microbial activity, and stimulate plant metabolic processes, leading to robust growth and improved yield. The dramatic improvement in productivity underscores the potential of natural farming, when supported with scientifically integrated organic amendments, to meet both sustainability and yield goals in tomato cultivation. Laxmi *et al.* (2015), Singh *et al.* (2015), Chaitanya *et al.* (2013) and Kashem *et al.* (2015) consistently reported that integrated nutrient management involving vermicompost, FYM, and poultry manure significantly enhanced tomato fruit yield compared to inorganic fertilizer alone.

Table 1. Effect of application of natural farming organic nutrient sources on the performance of tomato for plant height

Treatment Details		Plant height (cm)								
		30 DAT			60 DAT			90 DAT		
		1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled
T_1	Control	13.65	13.90	13.62	58.87	54.80	56.34	60.77	56.70	58.21
T_2	FYM + Jeevamrit	14.63	14.64	14.67	59.65	57.65	58.32	62.05	60.22	61.12
T_3	Vermicompost + Jeevamrit	16.18	15.97	16.24	73.40	76.25	74.78	74.75	78.02	76.23
T_4	Panchgavya + Jeevamrit	18.25	18.12	18.12	79.77	77.77	78.24	80.47	79.13	79.43
T_5	Vermiwash + Jeevamrit	16.99	17.22	17.07	77.42	76.80	77.23	78.32	78.37	78.41
T_6	FYM + Vermiwash	15.80	15.65	15.82	68.43	68.48	68.33	72.37	73.90	73.15
T_7	Vermicompost + Vermiwash	18.39	18.59	18.45	82.20	78.93	80.45	82.45	81.60	82.12
T_8	Panchgavya + Vermiwash	17.05	17.84	17.55	79.33	77.67	78.52	79.53	78.65	79.03
T_9	FYM + Panchgavya	15.24	15.22	15.45	66.02	58.87	62.42	69.83	69.38	69.56
T_{10}	Vermicompost + Panchgavya	19.69	18.70	19.26	84.67	92.37	88.45	85.92	83.90	84.78
T_{11}	FYM + Vermiwash + Panchgavya + Jeevamrit	19.93	19.94	19.75	85.45	96.65	91.13	91.93	93.62	92.76
T_{12}	Vermicompost + Vermiwash + Panchgavya + Jeevamrit	20.04	20.26	20.13	92.58	102.05	97.31	96.10	97.90	97.13
CD @ 5%		1.47	3.58		10.11	12.05		19.10	12.05	
SE m (±)		0.50	1.22		3.63	4.11		6.51	4.11	

Table 2. Effect of application of natural farming organic nutrient sources on the performance of tomato for number of branches per plant

Treatment Details		Number of branches per plant								
		30 DAT			60 DAT			90 DAT		
		1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled
T_1	Control	4.57	4.38	4.34	7.82	7.63	7.72	9.45	8.59	9.01
T_2	FYM + Jeevamrit	4.63	4.50	4.52	7.93	7.80	7.82	9.63	9.26	9.38
T_3	Vermicompost + Jeevamrit	5.93	6.27	6.21	9.23	9.57	9.43	11.27	11.98	11.59
T_4	Panchgavya + Jeevamrit	7.36	7.20	7.21	10.91	10.70	10.82	12.47	12.06	12.28
T_5	Vermiwash + Jeevamrit	6.42	6.62	6.32	9.82	10.27	10.02	11.65	12.03	11.78
T_6	FYM + Vermiwash	5.81	5.92	5.46	9.16	9.37	9.24	10.98	10.68	10.81
T_7	Vermicompost + Vermiwash	7.69	7.30	7.65	11.24	11.00	11.17	12.58	12.16	12.33
T_8	Panchgavya + Vermiwash	6.91	6.99	6.78	10.36	10.34	10.32	11.77	12.05	11.96
T_9	FYM + Panchgavya	4.90	5.82	5.33	8.25	9.17	8.70	10.02	10.57	10.26
T_{10}	Vermicompost + Panchgavya	7.72	7.58	7.45	11.37	11.13	11.21	13.07	13.08	13.03
T_{11}	FYM + Vermiwash + Panchgavya + Jeevamrit	8.02	8.28	8.12	11.82	11.83	11.78	13.90	13.20	13.51
T_{12}	Vermicompost + Vermiwash + Panchgavya + Jeevamrit	8.15	9.07	8.35	13.25	14.17	13.68	15.17	15.83	15.48
CD @ 5%		1.49	1.23		1.49	1.23		1.23	1.20	
SE m (±)		0.51	0.42		0.51	0.42		0.42	0.40	

Table 3. Effect of application of natural farming organic nutrient sources on the performance of tomato for number of leaves per plant

Treatment Details		Number of leaves per plant								
		30 DAT			60 DAT			90 DAT		
		1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled
T_1	Control	14.38	12.27	13.31	32.42	31.00	31.68	49.70	45.42	47.52
T_2	FYM + Jeevamrit	15.00	13.90	14.46	33.63	32.90	33.24	50.00	46.87	48.41
T_3	Vermicompost + Jeevamrit	16.57	17.17	16.82	38.50	38.57	38.51	57.63	53.75	55.67
T_4	Panchgavya + Jeevamrit	20.75	20.02	20.33	42.95	45.75	44.34	59.23	61.07	60.14
T_5	Vermiwash + Jeevamrit	18.93	18.70	18.79	39.73	39.27	39.47	57.87	53.87	55.83
T_6	FYM + Vermiwash	16.48	17.03	16.74	36.40	38.12	37.24	53.40	52.10	52.73
T_7	Vermicompost + Vermiwash	21.00	20.57	20.71	44.93	47.52	46.21	59.47	63.17	61.32
T_8	Panchgavya + Vermiwash	19.93	19.12	19.57	40.43	39.32	39.87	58.60	57.40	58.05
T_9	FYM + Panchgavya	15.77	17.02	16.34	35.82	35.77	35.76	51.78	50.57	51.13
T_{10}	Vermicompost + Panchgavya	22.92	21.07	21.95	45.85	48.17	47.04	59.62	64.67	62.14
T_{11}	FYM + Vermiwash + Panchgavya + Jeevamrit	23.80	23.98	23.84	47.43	48.80	48.14	60.50	65.57	63.01
T_{12}	Vermicompost + Vermiwash + Panchgavya + Jeevamrit	25.57	26.83	26.16	52.10	55.20	53.63	62.17	67.67	64.87
CD @ 5%		3.86	3.58		5.33	4.71		13.35	4.50	
SE m (±)		1.32	1.22		1.82	1.61		4.55	1.50	

Table 4. Effect of application of natural farming organic nutrient sources on the performance of tomato for days to first flowering and days to 50% flowering

Treatment Details		Days to first flowering			Days to 50% flowering		
		1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled
T_1	Control	45.70	48.33	47.05	59.47	62.45	60.94
T_2	FYM + Jeevamrit	44.33	47.47	45.86	56.25	61.40	58.85
T_3	Vermicompost + Jeevamrit	43.53	43.70	43.60	54.00	51.87	52.92
T_4	Panchgavya + Jeevamrit	39.10	40.33	39.68	51.80	47.98	49.84
T_5	Vermiwash + Jeevamrit	43.07	42.13	42.56	52.35	51.43	51.82
T_6	FYM + Vermiwash	44.07	44.20	44.11	54.07	57.93	55.89
T_7	Vermicompost + Vermiwash	37.13	38.13	37.61	50.68	47.32	48.96
T_8	Panchgavya + Vermiwash	39.23	41.30	40.24	51.95	49.75	50.82
T_9	FYM + Panchgavya	44.10	45.37	44.72	54.83	58.47	56.62
T_{10}	Vermicompost + Panchgavya	34.50	33.70	34.06	47.17	47.32	47.21
T_{11}	FYM + Vermiwash + Panchgavya + Jeevamrit	32.95	32.98	32.97	45.28	45.80	45.53
T_{12}	Vermicompost + Vermiwash + Panchgavya + Jeevamrit	32.53	31.80	32.13	44.57	37.45	40.96
CD @ 5%		5.33	4.86		13.35	12.84	
SE m (±)		1.82	1.62		4.55	4.28	

Table 5. Effect of application of natural farming organic nutrient sources on the performance of tomato for Number of trusses per plant and Number of fruits per truss

Treatment Details		Number of trusses per plant			Number of fruits per truss		
		1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled
T1	Control	2.89	2.57	2.68	4.85	4.01	4.42
T2	FYM + Jeevamrit	3.31	2.80	3.04	4.98	4.61	4.76
T3	Vermicompost + Jeevamrit	4.28	3.88	4.02	6.72	7.09	6.87
T4	Panchgavya + Jeevamrit	4.60	5.13	4.84	8.07	7.95	7.97
T5	Vermiwash + Jeevamrit	4.38	4.38	4.33	7.15	7.48	7.27
T6	FYM + Vermiwash	3.70	3.86	3.72	6.38	6.01	6.16
T7	Vermicompost + Vermiwash	5.39	5.14	5.26	8.33	8.19	8.24
T8	Panchgavya + Vermiwash	4.43	4.92	4.64	7.32	7.87	7.53
T9	FYM + Panchgavya	3.34	3.31	3.32	5.42	5.92	5.65
T10	Vermicompost + Panchgavya	5.68	5.41	5.52	8.97	9.10	9.02
T11	FYM + Vermiwash + Panchgavya + Jeevamrit	6.40	5.66	6.01	9.85	9.15	9.47
T12	Vermicompost + Vermiwash + Panchgavya + Jeevamrit	6.77	7.30	7.02	10.82	11.41	11.06
CD @ 5%		1.23	1.05		1.23	1.49	
SE m (±)		0.42	0.36		0.42	0.51	

Table 6. Effect of application of natural farming organic nutrient sources on the performance of tomato for Number of fruits per plant and Fruit diameter

Treatment Details		Number of fruits per plant			Fruit diameter (cm)		
		1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled
T1	Control	13.03	15.37	14.17	4.72	4.45	4.52
T2	FYM + Jeevamrit	18.73	15.67	17.13	4.92	4.86	4.84
T3	Vermicompost + Jeevamrit	26.67	18.43	22.52	5.26	5.37	5.30
T4	Panchgavya + Jeevamrit	33.17	33.07	33.05	5.42	5.54	5.46
T5	Vermiwash + Jeevamrit	29.20	23.50	26.23	5.27	5.38	5.30
T6	FYM + Vermiwash	25.40	18.40	21.85	5.00	5.15	5.03
T7	Vermicompost + Vermiwash	35.15	34.57	34.82	5.43	6.11	5.75
T8	Panchgavya + Vermiwash	29.70	29.47	29.53	5.28	5.53	5.36
T9	FYM + Panchgavya	18.80	18.03	18.35	4.95	4.93	4.91
T10	Vermicompost + Panchgavya	36.10	37.83	36.93	5.44	6.13	5.75
T11	FYM + Vermiwash + Panchgavya + Jeevamrit	37.80	39.49	38.46	5.45	6.21	5.80
T12	Vermicompost + Vermiwash + Panchgavya + Jeevamrit	37.80	45.80	41.65	5.70	6.28	5.93
CD @ 5%		8.69	3.74		1.05	1.03	
SE m (±)		2.96	1.28		0.36	0.35	

Table 7. Effect of application of natural farming organic nutrient sources on the performance of tomato for Fruit yield per plant and Fruit yield per hectare

Treatment Details		Fruit yield per plant (kg)			Fruit yield per hectare (q/ha)		
		1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled
T_1	Control	0.62	0.51	0.54	145.08	119.34	126.30
T_2	FYM + Jeevamrit	2.47	2.22	2.25	278.67	247.00	262.43
T_3	Vermicompost + Jeevamrit	3.68	3.41	3.35	296.50	320.00	308.14
T_4	Panchgavya + Jeevamrit	6.42	6.27	6.26	313.17	360.17	336.45
T_5	Vermiwash + Jeevamrit	3.98	3.96	3.76	303.33	331.17	317.16
T_6	FYM + Vermiwash	3.03	2.78	2.68	291.00	282.33	286.48
T_7	Vermicompost + Vermiwash	6.77	6.36	6.42	352.83	375.33	364.02
T_8	Panchgavya + Vermiwash	5.29	5.76	5.43	307.17	345.33	326.17
T_9	FYM + Panchgavya	2.63	2.76	2.67	288.17	249.17	268.49
T_{10}	Vermicompost + Panchgavya	7.20	6.67	6.45	363.67	378.50	371.02
T_{11}	FYM + Vermiwash + Panchgavya + Jeevamrit	8.51	9.07	8.25	367.13	450.13	408.25
T_{12}	Vermicompost + Vermiwash + Panchgavya + Jeevamrit	9.78	9.50	9.23	391.67	463.67	427.32
CD @ 5%		1.14	1.10		18.06	18.36	
SE m (±)		0.39	0.38		6.02	6.12	

4. Conclusion

Based on the comprehensive evaluation of various organic nutrient management treatments under natural farming, it was concluded that the integrated application of vermicompost + vermiwash + panchgavya + jeevamrit (T_{12}) consistently outperformed all other treatments across critical growth and yield. At 90 days after transplanting (DAT), T_{12} recorded the maximum plant height of 97.13 cm, indicating robust vegetative growth. This treatment also exhibited the highest number of branches per plant (15.48), reflecting enhanced structural development and potential for higher fruit-bearing sites. In terms of reproductive performance, T_{12} produced the maximum number of fruits per plant (41.65) and achieved the greatest fruit diameter of 5.93 cm, signifying superior fruit set and development. These favourable growth and yield traits translated into the highest fruit yield of 427.32 quintals per hectare, demonstrating the remarkable productivity potential of this integrated organic approach.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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