



Effect of Integrated Nutrient Management on Growth and Yield of Tomato under Protected Cultivation

**Gunjan Gautam^a, Mahaveer Suman^{a*},
Manish Kumar^a and Gunnjeet Kaur^b**

^a *Department of Horticulture, School of Agricultural Sciences, Career Point University, Kota, Rajasthan, 320335, India.*

^b *Department of Molecular Biology and Biotechnology, School of Agricultural Sciences, Career Point University, Kota, Rajasthan, 320335, India.*

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

Tomato (*Solanum lycopersicum* L.), a self-pollinated Solanaceae crop originating from the Peru–Ecuador region, is a globally important and widely cultivated vegetable valued for its high productivity, profitability, and nutritional significance. The present study evaluated the effect of integrated nutrient management on growth, yield attributes and yield of tomato. The investigation was laid out in a Completely Randomised Design (CRD) to conduct the experiment. The experiment comprised different treatments involving combinations of recommended doses of fertilisers, farmyard manure (FYM), and vermicompost (VC). The results clearly indicated that integrated nutrient management significantly influenced plant growth and yield parameters. Among the evaluated treatments, T₈ (NPK 50% + FYM 25% + VC 25%) was the most effective, recording the highest plant height (25.03, 52.29 and 71.56 cm at 40, 80 DAT and harvest), plant spread

*Corresponding author: E-mail: mahaveersuman001@gmail.com;

(52.29, 89.16 and 140.23 cm), number of primary branches, number of leaves, and main shoot diameter. This treatment also resulted in the highest fruit yield per plot (21.64 kg) and total fruit yield (400.34 q), followed by T₅ (NPK 75% + VC 25%) and T₁ (100% NPK). In contrast, the control treatment (T₀) without application of fertilisers and manures recorded the lowest values for all growth and yield parameters. The improved performance observed under integrated nutrient management can be ascribed to enhanced nutrient availability and more favourable soil conditions arising from the combined application of organic and inorganic nutrient sources, which in turn facilitates superior crop growth and yield.

Keywords: Nitrogen; tomato; vermicompost; yield.

1. Introduction

Tomato (*Solanum lycopersicum* L.) is a member of the family *Solanaceae* and is predominantly a self-pollinated crop. The Peru–Ecuador region is widely recognised as the centre of origin. The crop was introduced into India by the Portuguese during the colonial period. At present, tomato is extensively cultivated across tropical and subtropical regions worldwide. Among vegetable crops, tomato is one of the most widely consumed and economically significant, ranking second in global production. In India, it constitutes an important cash crop and is grown throughout the year under both irrigated and rainfed conditions. A substantial proportion of fresh market tomatoes in the country is produced by smallholder farmers, whereas varieties intended for processing are generally cultivated on large-scale commercial farms. Tomato cultivation is particularly attractive to farmers due to its multiple harvests, relatively high economic returns, and considerable potential to enhance household income. In addition, its nutritional value contributes significantly to dietary improvement. Owing to its versatility in culinary applications and processing, tomato remains a crop of considerable agricultural and socio-economic importance (Mahajan et al., 2018; Purakayastha & Bhatnagar, 1997).

Solanaceous vegetable crops require substantial quantities of primary macronutrients, particularly nitrogen, phosphorus, and potassium, to support optimal vegetative growth, reproductive development, and yield formation. In addition to these, secondary nutrients such as calcium and sulphur are essential for ensuring proper physiological functioning, fruit set, and seed development, thereby contributing to improved overall productivity. Tomatoes are considered “heavy feeders” because of their rapid growth and long production season. Among nutrients, nitrogen is an important element as it plays a major role in the synthesis of chlorophyll, amino acids, and protein building blocks, which are ultimately responsible for a higher source to sink ratio.

The continuous use of high levels of chemical fertilisers leads to a decrease in the nutrient uptake efficiency of plants, resulting in a decrease in yield and also causing environmental pollution. Integrated sources of nutrients is a practice where all sources of nutrients, like organic, bio- fertilizer, green manures and inorganic fertilisers, can be used in combined form for improving soil health, getting good quality yield with enhanced soil fertility, soil productivity, and maintaining ecology and environment balance. The concept of integrated nutrient management (INM) emphasises the efficient and judicious utilisation of all major sources of plant nutrients in a coordinated and balanced manner. The primary objective is to achieve maximum economic yield while minimising adverse effects on the soil’s physiological and biochemical properties. This approach promotes the combined use of organic, inorganic, and biological nutrient sources to sustain soil fertility and enhance long-term agricultural productivity. Among the manures, animal manure is commonly used on higher value commodities such as potatoes, coffee and vegetables (Shapiro and Sanders 2002). Among the various organic manures, farmyard manure (FYM) and vermicompost are abundantly available at the local level and can be effectively utilised in vegetable production systems. These organic inputs supply essential macronutrients as well as micronutrients required for balanced plant nutrition. In addition, they contain growth-promoting substances such as indole-3-acetic acid (IAA) and gibberellic acid (GA₃), along with beneficial microorganisms that play a crucial role in enhancing nutrient availability and uptake. Consequently, the application of such organic sources supports proper plant growth and development while contributing to improved soil health (Sreenivasa et al., 2004). The application of organic nutrient sources to soil has been shown to enhance soil–water–plant relationships by favourably altering key physical properties, including bulk density, total porosity, and soil moisture dynamics. Such modifications improve the soil’s capacity to retain and transmit water, thereby facilitating more efficient root growth and nutrient uptake. Consequently, these improvements

contribute to enhanced plant growth and increased water use efficiency (Naresh et al., 2018). The combined use of different nutrient sources is one of the alternative ways of replenishing and maintaining soil fertility. In this regard, organic sources integrated with inorganic fertilisers are one of the promising techniques for improving soil fertility without any harmful effect and increasing tomato yield.

On the other hand, the combined application of organic manures and inorganic fertilisers has been reported to enhance economic returns while creating favourable conditions for achieving higher tomato yields. This integrated approach not only supports improved crop productivity but also contributes to superior fruit quality and enhanced nutrient status, thereby promoting more sustainable and efficient production systems (Solaiman and Rabbani, 2006). However, to date, very little data has been generated in the study area to substantiate the conviction that additional benefits can be obtained from the application of manures to the tomato crop, coupled with the application of inorganic fertilisers. More vegetative growth and fruit yield of tomato can be obtained by using integrated nutrient management practices (Dev et al. 2012, Kumaran et al., 1998). Similar suggestions were also given by various researchers, but further research is urgently needed to find out the best combination of organic and inorganic sources of nutrients to maximise tomato yield in particular areas.

2. Materials and Methods

2.1 Location

The experiment was conducted in the Kota district of Rajasthan (25.18° N to 75.83° E), located in the South Eastern plain (Agro-climatic zone V). The region receives an average rainfall of 660.6. mm. The maximum temperature range in the summer is 40 to 48°C, and the minimum is 1.0- 2.6°C during winter.

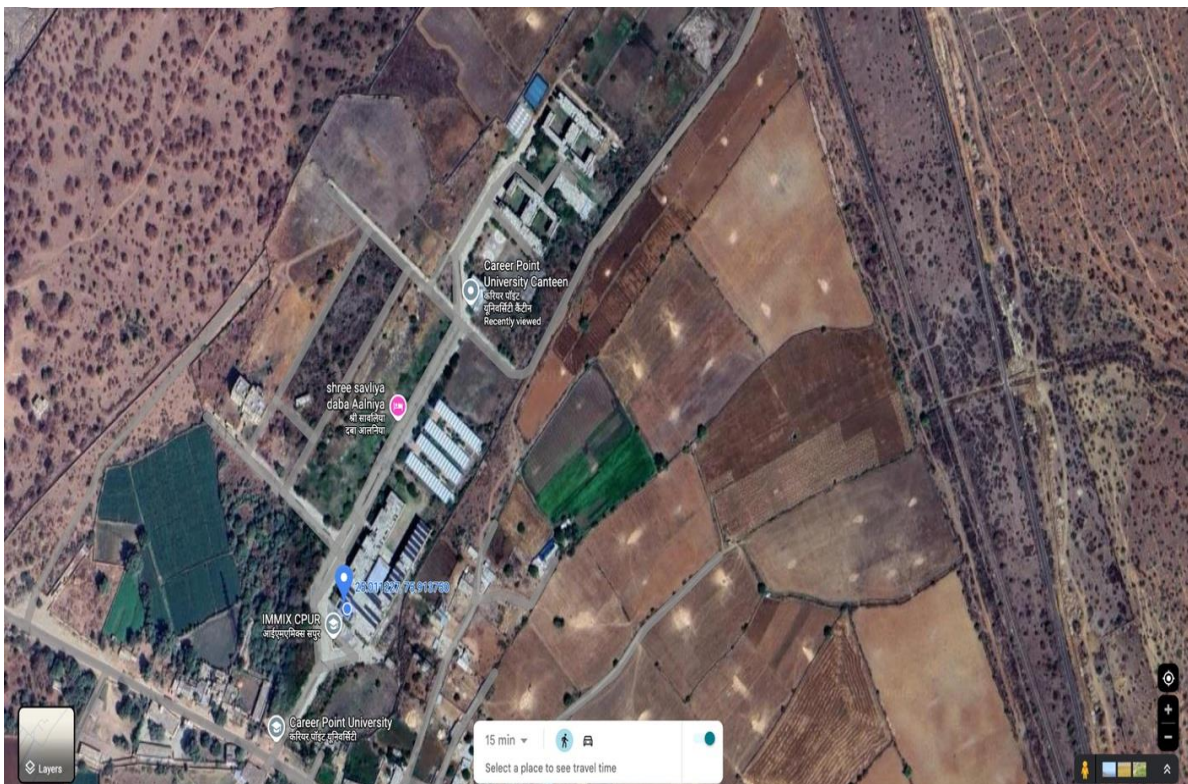


Fig. 1. Location of the experimental field

2.2 Protected Cultivation (Polyhouse)

The study was carried out in a naturally ventilated polyhouse covered with UV-stabilised polyethene film (200-micron thickness). The structure was oriented in a (north–south/east–west) direction. The temperature inside the

polyhouse ranged between (18–30°C) with relative humidity maintained at (60–70%). The crop was grown under a drip irrigation system coupled with fertigation, ensuring precise water and nutrient management. The soil inside the polyhouse was well-drained sandy loam and was properly sterilised before transplanting to minimise soil-borne pathogens.

2.3 Treatment Details

The experiment comprised nine treatments involving different combinations of organic and inorganic nutrient sources. Treatment T₁ consisted of 100% recommended dose of NPK (120:40:40 kg/ha), while T₂ 100% FYM (20 t/ha), T₃ 100% vermicompost (10 t/ha), T₄ with NPK 75% + FYM 25% (5 t/ha), T₅ with NPK 75% + VC 25% (2.5 t/ha), T₆ with NPK 50% + FYM 50% (10 t/ha) and T₇ with NPK 50% + VC 50% (5 t/ha). Treatment T₈ comprised a balanced combination of NPK 50% + FYM 25% (5 t/ha) + VC 25% (2.5 t/ha). Treatment T₉ served as a control, where no organic or inorganic fertilisers were applied.

2.4 Experimental Details

The present investigation was laid out in a Completely Randomised Design (CRD) to conduct the experiment. A total of nine treatments were applied in the field and replicated thrice. The experimental field was prepared by ploughing with a power tiller. Thereafter, a scientific layout plan was done properly with the help of rope, measuring tape, pegs, *etc.*, according to the statistical design of CRD. In each plot, ridges and furrows were made according to the planting distance. The growth and yield parameters of the crop were recorded using standard procedures. For growth characters, plant height (cm), plant spread (cm), number of primary branches, and number of leaves per plant were measured from five randomly selected plants at 40, 80, and the final harvesting stages, and the average values were calculated. Plant height was measured from the base to the top using a meter scale, plant spread with a measuring tape, while branches and leaves were counted manually. The diameter of the main shoot (cm) was measured at mid-season (70 days after transplanting) using a Vernier calliper and averaged. Fruit yield per plot (kg) was calculated by multiplying average fruit weight per plant by the total number of plants per plot, and total fruit yield (q/ha) was computed based on plant population per hectare.

3. Results

3.1 Effect of Integrated Nutrients Management on Growth Parameters

Data with respect to the effect of different organic and inorganic nutrient treatments on plant height are presented in Table 1. The maximum plant height (25.03, 52.29 and 71.56 cm) at the stages of 40, 80 DAT and at harvest were recorded under the treatment T₈- NPK 50% + FYM 25% (5 t ha⁻¹) + VC 25% (2.5 t ha⁻¹) followed by, (23.03, 49.89 and 68.03 cm) in the treatment T₅- NPK 75% + VC 25% (2.5 t ha⁻¹). However, the minimum height of the plant (18.63, 41.16 and 53.63 cm) was observed at the stages of 40, 80 DAT and at harvest under the treatment T₉-control (no organic and inorganic fertilisers).

The improvement in plant height at all growth stages with the application of NPK + FYM + VC may be attributed to the combined effect of readily available nitrogen from inorganic fertilisers and the gradual mineralisation of organic nitrogen from FYM and vermicompost. This integrated nutrient supply ensures both immediate and sustained availability of nitrogen, which is a key component of chlorophyll, proteins, and amino acids. Such balanced nutrition enhances cell division, protein synthesis, and metabolite translocation, thereby promoting better plant growth and development.

Table 1. Effect of integrated use of organic and inorganic sources of nutrients on plant height (cm) at different stages of tomato

Treatments	Plant height (cm) at various successive stages of growth		
	At 40 DAT	At 80 DAT	At Harvest
T ₁ -NPK 100% (120:40:40 kg ha ⁻¹)	22.76	49.43	67.09
T ₂ -FYM 100% (20 t ha ⁻¹)	21.36	46.69	57.63

Treatments	Plant height (cm) at various successive stages of growth		
	At 40 DAT	At 80 DAT	At Harvest
T ₃ -VC 100% (10 t ha ⁻¹)	21.36	44.09	57.09
T ₄ -NPK 75% + FYM 25% (5 t ha ⁻¹)	22.23	48.36	66.63
T ₅ - NPK 75% + VC 25% (2.5 t ha ⁻¹)	23.03	49.89	68.03
T ₆ - NPK 50% + FYM 50% (10 t ha ⁻¹)	22.09	47.89	66.43
T ₇ - NPK 50% + VC 50% (5 t ha ⁻¹)	21.56	47.63	66.23
T ₈ - NPK 50% + FYM 25% (5 t ha ⁻¹) + VC 25% (2.5 t ha ⁻¹)	25.03	52.29	71.56
T ₉ -Control (No organic and inorganic fertilisers)	18.63	41.16	53.63
SE (±)	0.80	1.09	0.70
C. D. at 5% of the level	2.40	3.18	2.21

Table 2. Effect of integrated use of organic and inorganic sources of nutrients on plant spread (cm) at different stages of tomato

Treatments	Plant spread (cm) at various successive stages of growth		
	At 40 DAT	At 80 DAT	At Harvest
T ₁ -NPK 100% (120:40:40 kg ha ⁻¹)	44.29	81.69	131.29
T ₂ -FYM 100% (20 t ha ⁻¹)	39.03	69.76	118.23
T ₃ -VC 100% (10 t ha ⁻¹)	38.49	68.83	112.96
T ₄ -NPK 75% + FYM 25% (5 t ha ⁻¹)	44.09	79.63	130.43
T ₅ - NPK 75% + VC 25% (2.5 t ha ⁻¹)	46.56	83.36	132.43
T ₆ - NPK 50% + FYM 50% (10 t ha ⁻¹)	43.43	79.36	128.89
T ₇ - NPK 50% + VC 50% (5 t ha ⁻¹)	43.06	76.76	128.23
T ₈ - NPK 50% + FYM 25% (5 t ha ⁻¹) + VC 25% (2.5 t ha ⁻¹)	52.29	89.16	140.23
T ₉ -Control (No organic and inorganic fertilisers)	34.03	48.89	109.03
SE (±)	1.20	3.80	2.60
C. D. at 5% of the level	3.61	11.56	7.80

Table 3. Effect of integrated use of organic and inorganic sources of nutrients on the number of primary branches at different stages of tomato

Treatments	Number of primary branches at various stages of growth		
	At 40 DAT	At 80 DAT	At Harvest
T ₁ -NPK 100% (120:40:40 kg ha ⁻¹)	8.83	15.63	12.76
T ₂ -FYM 100% (20 t ha ⁻¹)	8.23	14.89	9.96
T ₃ -VC 100% (10 t ha ⁻¹)	7.83	13.03	9.76
T ₄ -NPK 75% + FYM 25% (5 t ha ⁻¹)	8.69	15.56	12.69
T ₅ - NPK 75% + VC 25% (2.5 t ha ⁻¹)	8.89	15.89	12.83
T ₆ - NPK 50% + FYM 50% (10 t ha ⁻¹)	8.66	15.49	12.63
T ₇ - NPK 50% + VC 50% (5 t ha ⁻¹)	8.36	15.29	12.63
T ₈ - NPK 50% + FYM 25% (5 t ha ⁻¹) + VC 25% (2.5 t ha ⁻¹)	8.96	16.49	12.89
T ₉ -Control (No organic and inorganic fertilisers)	7.36	11.03	9.03
SE (±)	0.15	0.30	0.25
C. D. at 5% of the level	0.46	0.91	0.75

Table 4. Effect of integrated use of organic and inorganic sources of nutrients on the number of leaves at different stages of tomato

Treatments	Number of leaves per plant at various stages of growth		
	At 40 DAT	At 80 DAT	At Harvest
T ₁ -NPK 100% (120:40:40 kg ha ⁻¹)	45.09	203.09	229.23
T ₂ -FYM 100% (20 t ha ⁻¹)	42.49	191.09	198.83
T ₃ -VC 100% (10 t ha ⁻¹)	36.36	184.83	197.96
T ₄ -NPK 75% + FYM 25% (5 t ha ⁻¹)	44.69	202.89	229.03
T ₅ - NPK 75% + VC 25% (2.5 t ha ⁻¹)	46.03	206.29	229.96
T ₆ - NPK 50% + FYM 50% (10 t ha ⁻¹)	43.76	200.43	212.36
T ₇ - NPK 50% + VC 50% (5 t ha ⁻¹)	43.69	195.16	200.23
T ₈ - NPK 50% + FYM 25% (5 t ha ⁻¹) + VC 25% (2.5 t ha ⁻¹)	46.96	211.76	251.69
T ₉ -Control (No organic and inorganic fertilisers)	31.89	150.83	183.56
SE (±)	1.10	4.71	12.65
C. D. at 5% of the level	3.31	14.14	37.97

Table 5. Effect of integrated use of organic and inorganic sources of nutrients on the diameter of the main shoot (cm) in tomato

Treatments	Diameter of main shoot (cm)
T ₁ -NPK 100% (120:40:40 kg ha ⁻¹)	2.89
T ₂ -FYM 100% (20 t ha ⁻¹)	2.51
T ₃ -VC 100% (10 t ha ⁻¹)	2.47
T ₄ -NPK 75% + FYM 25% (5 t ha ⁻¹)	2.84
T ₅ - NPK 75% + VC 25% (2.5 t ha ⁻¹)	2.98
T ₆ - NPK 50% + FYM 50% (10 t ha ⁻¹)	2.82
T ₇ - NPK 50% + VC 50% (5 t ha ⁻¹)	2.72
T ₈ - NPK 50% + FYM 25% (5 t ha ⁻¹) + VC 25% (2.5 t ha ⁻¹)	3.05
T ₉ -Control (No organic and inorganic fertilisers)	2.15
SE (±)	0.10
C. D. at 5% of the level	0.30

The recorded data with respect to the effect of different organic and inorganic nutrient treatments on plant spread are presented in Table 2. The maximum plant spread (52.29, 89.16 and 140.23 cm) at the stages of 40, 80 DAT and at harvesting stage were recorded under the treatment T₈- NPK 50% + FYM 25% (5 t ha⁻¹) + VC 25% (2.5 t ha⁻¹) followed by, (46.56, 83.36 and 132.43 cm) in the treatment T₅-NPK 75% + VC 25% (2.5 t ha⁻¹) and (44.29, 81.69 and 131.29 cm) in the treatment T₁-NPK 100% (120:40:40 kg ha⁻¹) respectively. However, the minimum spread of the plant (34.03, 48.89 and 109.03 cm) was exhibited at the stages of 40, 80 DAT and at the harvesting stage under the treatment T₉-control (no organic and inorganic fertilisers).

Data with respect to the effect of different organic and inorganic nutrient treatments on the number of primary branches per plant are presented in Table 3. The maximum number of primary branches (8.96, 16.49 and 12.89) at the stages of 40, 80 DAT and at harvesting stage were recorded under the treatment T₈- NPK 50% + FYM 25% (5 t ha⁻¹) + VC 25% (2.5 t ha⁻¹) followed by, (8.89, 15.89 and 12.83) in the treatment T₅-NPK 75% + VC 25% (2.5 t ha⁻¹) and (8.83, 15.63 and 12.76) in the treatment T₁-NPK 100% (120:40:40 kg ha⁻¹) respectively, while minimum number of primary branches (7.36, 11.03 and 9.03) were observed at the stages of 40, 80 DAT and at harvesting stage under the treatment T₉-control (no organic and inorganic fertilizers).

The data recorded with respect to the effect of different organic and inorganic nutrient treatments on the number of leaves per plant have been presented in Table 4. The maximum number of leaves per plant (46.96, 211.76 and 251.69) at the stages of 40, 80 DAT and at harvesting stage were recorded under the treatment T₈-NPK 50% + FYM 25% (5 t ha⁻¹) + VC 25% (2.5 t ha⁻¹) followed by, (46.03, 206.29 and 229.96) in the treatment T₅-NPK 75% + VC 25% (2.5 t ha⁻¹) and (45.09, 203.09 and 229.23) under the treatment T₁-NPK 100% (120:40:40 kg ha⁻¹) respectively, whereas, minimum number of leaves per plant (31.89, 150.83 and 183.56) were observed under T₉-control at the stages of 40, 80 DAT and at harvesting stage.

The recorded data with respect to the effect of different organic and inorganic nutrient treatments on the diameter of the main shoot are presented in Table 5. The maximum diameter of shoot (3.05 cm) at 70 DAT was recorded under the treatment T₈- NPK 50% + FYM 25% (5 t ha⁻¹) + VC 25% (2.5 t ha⁻¹) followed by, (2.98 cm) in the treatment T₅-NPK 75% + VC 25% (2.5 t ha⁻¹) and (2.89 cm) in the treatment T₁-NPK 100% (120:40:40 kg ha⁻¹) respectively. However, treatment T₉-control (no organic and inorganic fertilisers) exhibited the minimum diameter of the main shoot (2.15 cm).

3.2 Effect of Integrated Nutrients Management on Yield Parameters

Data with respect to the effect of different organic and inorganic nutrient treatments on fruit yield per plot of all picking are presented in Table 6. The maximum fruit yield per plot of all picking (21.64 kg) was recorded in treatment T₈- NPK 50% + FYM 25% (5 t ha⁻¹) + VC 25% (2.5 t ha⁻¹) followed by, (20.10 kg) in the treatment T₅-NPK 75% + VC 25% (2.5 t ha⁻¹) and (18.60 kg) under the treatment T₁-NPK 100% (120:40:40 kg ha⁻¹) respectively, while the plant treated without manures and fertilizers under treatment T₉-control (no organic and inorganic fertilizers) exhibited minimum value (11.80 kg) for the same. The data with respect to the effect of different organic and inorganic nutrient treatments on total fruit yield are presented in Table 6. The plants treated with T₈- NPK 50% + FYM 25% (5 t ha⁻¹) + VC 25% (2.5 t ha⁻¹) produced maximum fruit yield (400.34 q) followed by, (371.85 q) in the treatment T₅-NPK 75% + VC 25% (2.5 t ha⁻¹) and (344.10 q) under the treatment T₁-NPK 100% (120:40:40 kg ha⁻¹) respectively, while, minimum total fruit yield (218.30 q) produced by T₉-control (no organic and inorganic fertilizers).

Table 6. Effect of integrated use of organic and inorganic sources of nutrients on the yield attributes of tomato

Treatments	Fruit yield	
	Fruit yield (kg)	Total fruit yield (q ha ⁻¹)
T ₁ -NPK 100% (120:40:40 kg ha ⁻¹)	18.60	344.10
T ₂ -FYM 100% (20 t ha ⁻¹)	15.16	280.46
T ₃ -VC 100% (10 t ha ⁻¹)	14.88	275.28
T ₄ -NPK 75% + FYM 25% (5 t ha ⁻¹)	18.28	338.18
T ₅ - NPK 75% + VC 25% (2.5 t ha ⁻¹)	20.10	371.85
T ₆ - NPK 50% + FYM 50% (10 t ha ⁻¹)	16.84	311.54
T ₇ - NPK 50% + VC 50% (5 t ha ⁻¹)	16.54	305.99
T ₈ - NPK 50% + FYM 25% (5 t ha ⁻¹) + VC 25% (2.5 t ha ⁻¹)	21.64	400.34
T ₉ -Control (No organic and inorganic fertilisers)	11.80	218.30
SE (±)	0.56	11.80

4. Discussion

4.1 Effect of Integrated Nutrients Management on Growth Parameters

The observed enhancement in plant spread across all growth stages following the application of NPK in combination with farmyard manure (FYM) and vermicompost (VC) may be attributed to improved uptake and efficient translocation of nitrogen to the actively growing tissues, facilitated by its increased availability under this treatment regime. The beneficial effect of organic sources on plant spread due to the fact that after proper decomposition and mineralization of organic and inorganic fertilizer such as vermicompost, micro and macro nutrients were made easily available to plants and also helped in solubilising the fix form of nutrient in the available soil. Similar results were also reported by Adekiya et al. (2022) in tomato, Naresh et al. (2018) and Islam et al. (2017) in tomato and Hegde (1997).

The number of primary branches per plant increased, which may be due to the application of organic manure like FYM and vermicompost, which could improve the physical and biological properties of soil and provide a better environment for growth, resulting in an increased number of primary branches. Consequently, these nodes increased the number of dormant buds from where the primary branches may have originated (Krishna and Ughreja, 2002). It might be attributed to the stimulatory effect of the integrated use of inorganic and organic sources, which increased the number of branches. The present results were also supported by Shashidhara (2000) and Yephtho et al. (2012) in tomato.

The increased number of leaves under the combined application of organic and inorganic nutrient sources may be associated with improved nutrient availability and enhanced plant growth processes, which could promote leaf initiation and development. This response may also be attributed to the synergistic effects of zinc, which plays a key role in the synthesis of auxin, a growth-promoting phytohormone directly involved in cell division and elongation (Gosavi et al., 2010; Yu et al., 2024) in tomato. The improvement in the diameter of the main shoot at 70 DAT with the application of NPK + FYM + VC might be due to an increase in the number of leaves and leaf area that produced more photosynthates, which in turn might have increased the shoot diameter of the flower. Similar results were also reported by Anburani and Manivannan (2002), Suthar et al. (2005), and Swain et al. (2015) in chilli.

4.2 Effect of Integrated Nutrients Management on Yield Parameters

The increase in total fruit yield may be attributed to improved nutrient uptake, as reflected in the enhanced vegetative growth and reproductive performance of tomato plants (Zhao et al., 2024). Organic manures ensure a sustained and more efficient release of nutrients throughout the crop growth period. Several studies have likewise reported significant improvements in fruit yield following the combined application of organic manures and inorganic fertilisers. The present results are in close conformity with the results by Wu et al. (2023), Fan et al. (2023), Mudasir et al. (2012), Sathyajeet et al. (2014), Makinde et al. (2016), and Boraiah et al. (2017) in tomato.

5. Conclusion

The study concludes that integrated nutrient management significantly improves the growth and yield of tomato. The treatment T₈ (NPK 50% + FYM 25% + VC 25%) was found to be the most effective, recording the highest values for all growth and yield parameters. Therefore, the combined use of organic and inorganic fertilisers is recommended as a sustainable approach for higher productivity in tomato cultivation.

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 writing or editing of this manuscript.

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Competing Interests

Authors have declared that no competing interests exist.

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