



Influence of Organic and Inorganic Sources of Nutrients on Soil Properties, Yield, Economics and Energetics of Tomato in Open Ventilated Polyhouse

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ABSTRACT

Background: An experiment was performed during the summer season of 2023 and 2024 at School of Agricultural Sciences, Shri Guru Ram Rai University, Pathribagh, Dehradun, Uttarakhand under low hills of northern Himalaya, to study the influence of vermicompost and fertilizers on soil properties, fruit yield, economics, energetics of tomato (*Solanum lycopersicum* L.).

Methods: The experimental trial was executed inside an 1800 m² open ventilated polyhouse. The transplanting of tomato was done in the first week of March in both years. The experiment was carried out in split-plot design with 3 levels of each vermicompost (0, 2.5 and 5 tonnes/ha) in the main plots and inorganic fertilizers (50, 75 and 100 % of recommended dose) in subplots, having 3 replications.

Result: Application of vermicompost at the highest rate (5 t ha⁻¹) produced a markedly greater fruit yield (34.8 t ha⁻¹) compared to both the lower dose (2.5 t ha⁻¹) and the control treatment without vermicompost, consistently across both years of study. Similarly, the full recommended dose of chemical fertilizers (100:25.8:52.1 kg N, P and K ha⁻¹) resulted in significantly superior yield performance relative to the 50% and 75% application levels. Both organic and inorganic nutrient sources exerted a statistically significant influence on key growth and yield parameters including plant height, number of fruits per plant, fruit size (length and diameter) and average fruit weight. Economic evaluation indicated that the highest net monetary returns were obtained with the application of 5 t ha⁻¹ vermicompost (₹ 2,15,600 ha⁻¹) and the full recommended NPK dose (₹ 2,22,200 ha⁻¹). In addition, energy based indices such as net energy output, energy use efficiency and energy productivity were also maximized under these treatment combinations. Soil fertility status, particularly the availability of nitrogen, phosphorus and potassium, showed a significant improvement under the highest level of vermicompost and the complete recommended fertilizer dose when compared to other treatments.

Key words: Economics, Inorganic nutrients, Open ventilated polyhouse, Soil properties, Tomato, Vermicompost.

INTRODUCTION

Vegetable are recognized for their great yield potential which leads to substantial removal of nutrients from the soil, thereby necessitating adequate nutrient replenishment through fertilization. However, the escalating cost of chemical fertilizers and concerns related to energy consumption have prompted the need to minimize reliance on these external inputs. In this context, integrated nutrient management offers a balanced approach by mingling organic and inorganic nutrient sources to prolong crop yield while maintaining soil fertility (Sheetal *et al.*, 2022). Organic amendments also contribute essential micronutrients that are often not adequately supplied through chemical fertilizers alone (Gnanamani and Vijayalakshmi, 2023). Recent research findings further indicate that INM enhances nutrient use efficiency, improves soil health and supports higher productivity, particularly under intensive cropping systems (Dhatt *et al.*, 2023; Ghosh *et al.*, 2023 and Choudhary *et al.*, 2023). The adoption of protected cultivation techniques has significantly improved the efficiency and quality of vegetable crops especially high value horticultural produce. This system not only facilitates off-season production but also ensures consistent supply throughout the year. However, maintaining a controlled

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environment within structures such as polyhouses requires considerable energy input, making it a resource intensive production system. Despite this, economic returns per unit area under protected cultivation are substantially higher often many times greater than those obtained under open field conditions (Dhillon *et al.*, 2020). Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated vegetable crop in Uttarakhand, particularly during the summer and rainy seasons (Kavitha *et al.*, 2019). Protected cultivation, also referred to as off-season production or vegetable forcing, enables the creation of optimal environmental conditions that support enhanced plant growth and yield. In such high input systems, the application of INM becomes increasingly important to optimize resource use efficiency and sustain productivity (Mini and Suja, 2025). Several studies have demonstrated that integrating organic and inorganic nutrient sources under polyhouse conditions leads to improvements in yield, fruit quality and economic returns (Kavitha *et al.*, 2019 and Singh *et al.*, 2023). Additionally, recent investigations highlight the need to assess energy efficiency alongside crop performance to ensure long term sustainability of protected cultivation practices (Kumar *et al.*, 2023). In the hilly regions of North India, tomato cultivation under polyhouse conditions has gained prominence due to the limitations of open field production where low winter temperatures adversely affect both yield and fruit quality (Meena and Yadav, 2015). Similar advantages of protected cultivation including enhanced productivity, improved water and nutrient use efficiency and superior fruit quality have been reported by Elayaraja and Sathiyamurthi (2020). Despite these advancements, there is remain a need of inclusive studies addressing the combined evaluation of organic and inorganic nutrient sources on productivity, economic viability as well as energy dynamics of tomato production under polyhouse conditions in the low hill regions of Uttarakhand. Therefore, the present investigation was undertaken to fill this research gap and generate relevant scientific information.

MATERIALS AND METHODS

A two-year field investigation was undertaken during 2023 and 2024 at the School of Agricultural Sciences of Shri Guru Ram Rai University, Pathribagh campus, Dehradun, Uttarakhand, India which is situated in the low hill zone of the northern Himalayas at 30°31'N latitude and 78°03'E longitude. The study area experiences a subtropical weather with cold winters, hot and arid summers and a moderately distributed monsoon season. The experimental soil within the polyhouse ranged from sandy loam to loam in texture. Key physico-chemical properties included a bulk density of 1.40 Mg m⁻³, available water capacity of 2.68 cm per 15 cm soil depth, porosity of 46.6%, organic carbon content of 0.48% and available nitrogen, phosphorus and potassium levels of 338, 14.2 and 112.4 kg ha⁻¹, respectively. The trial was conducted in an open ventilated polyhouse covering 1800 m² and all recorded observations

were subsequently standardized on a hectare basis. The experimental layout followed a split-plot design and replicate thrice. Vermicompost was applied to the main research plots at three rates (0, 2.5 and 5 t ha⁻¹), while subplots received varying levels of inorganic fertilizers corresponding to 50%, 75% and 100% of the recommended dose. The standard fertilizer recommendation for tomato was 150 kg N, 24 kg P and 45.8 kg K per hectare. Seedlings of the tomato cultivar 'Pusa Ruby' were transplanted during the first week of March in both cropping seasons, maintaining a spacing of 60 cm × 50 cm. Identical crop establishment schedules were followed in each year to ensure uniformity. At transplanting, the full quantity of vermicompost along with the entire dose of phosphorus and potassium and one-third dose of nitrogen were incorporated into the soil as per treatment specifications. The remaining nitrogen was supplied as top dressed in two equal applications at 30 day intervals after transplanting. Standard intercultural practices, including weed management were performed at 30, 45 and 60 days after transplanting. Growth and yield observations encompassed plant height, fruit number per plant, fruit length, fruit diameter, mean fruit weight, pericarp thickness and total yield. Yield related parameters were documented at the time of harvest. Total soluble solids content of fruits was measured using a digital refractometer. For energy analysis, all inputs utilized throughout the crop cycle such as labour, seed, vermicompost, chemical fertilizers, herbicides and pesticides were quantified and converted into energy equivalents using established conversion coefficients. Output energy was computed based on the mean fruit yield of two years and expressed in mega joules (MJ). Derived indices included total input energy, output energy, net energy gain, energy use efficiency (output/input ratio), energy productivity (yield per unit of energy input) and energy profitability (net energy return per unit of input energy) (Table 1). Following the 2023 crop harvest, soil samples were obtained from 0-15 cm depth using an auger for postharvest analysis. The samples were evaluated for soil pH, organic carbon (by Walkley-Black method), available nitrogen (by Kjeldahl method), available phosphorus (by Olsen method) and available potassium (ammonium acetate extraction). Economic analysis was performed using prevailing market prices for both inputs and outputs. Total cost of cultivation was estimated by considering all field operations and input expenses including fertilizers, organic manures, plant protection measures and labour (₹ 350 per man-day). Additional costs such as staking and intercultural operations were also included. Input prices used were ₹ 22 per kg of nitrogen, ₹ 45 per kg of phosphorus and ₹ 18 per kg of potassium, while seed and agrochemical costs were based on existing market prices. The selling price of tomato fruits was supposed to be ₹ 10 per kg for economic calculations. The data collected were subjected to statistical assessment using analysis of variance (ANOVA). Treatment differences

were tested for significance at the 5% probability level ($P \leq 0.05$) and treatment means were compared using the least significant difference (LSD) test.

RESULTS AND DISCUSSION

Effect on growth and yield attributes

Vermicompost and inorganic fertilizers significantly influenced growth and yield attributes of tomato (Table 2). The maximum plant height, number of fruits per plant and average fruit weight were recorded under 5 t ha⁻¹ vermicompost and 100% recommended NPK. The improvement in growth parameters might be due to improved nutrient accessibility, improved soil physical properties and better microbial activity associated with vermicompost application. Vermicompost acts as a reservoir of macro and micronutrients and improves soil enzymatic activities, leading to better nutrient uptake and plant growth. Analogous results have been reported by Arebu (2022) and Singh *et al.* (2023), who viewed significant improvements in vegetative parameters of tomato under integrated nutrient management practices. The higher response to NPK levels may be due to the essential role of nitrogen in vegetative growth, phosphorus in root expansion

and energy transport and potassium in enzyme activation and translocation of assimilates (Kaur *et al.*, 2023) and (Helaly, 2021).

Effect on fruit yield

Fruit yield improved significantly with rising levels of vermicompost and NPK. Application of 5 t ha⁻¹ vermicompost resulted in 74% higher yield compared to control, while 100% recommended NPK increased yield by 46% over 50% NPK. The increase in yield is primarily attributed to higher number of fruits per plant and improved fruit size. The synergistic effect of organic and inorganic nutrient component enhances nutrient accessibility during the entire crop growth phase, resulting in improved flowering, fruit setting and fruit development. Similar synergistic effects of INM on tomato yield under protected cultivation have been reported by Kumar *et al.* (2024) and Shilpa *et al.* (2025). Positive influence of organic manures on tomato yield and its contributing traits may be explained by their decomposition and subsequent mineralization which release nutrients in plant available forms. In addition to direct nutrient supply, these organic inputs can enhance the mobilization of otherwise unavailable nutrients in the soil, thereby improving overall nutrient accessibility

Table 1: Energy conversion coefficients for different inputs and outputs in tomato cultivation.

Power source	Units	Equivalent energy (MJ)
Human labour		
Adult man	Man-hour	1.96
Woman	Woman-hour	1.57
Farm machinery	kg	64.8
Inorganic fertilizers		
N	kg	60.65
P ₂ O ₅	kg	11.18
K ₂ O	kg	6.78
Vermicompost	kg (Dry mass)	0.28
Plant protection substances	kg	122
Crop produce (Tomato)	kg	0.86

Table 2: Effect of organic and inorganic nutrient sources on growth and yield parameters of tomato under open ventilated polyhouse condition (Pooled data of two years).

Treatment	Plant height (cm)	Fruits/plant	Avg. fruit weight (g)	Fresh fruit yield (t/ha)	Fruit length (mm)	Fruit diameter (mm)	TSS (°brix)	Pericarp thickness (mm)
Vermicompost (t/ha)								
0	64.2	6.6	48	18.9	35.9	18.9	3.8	1.2
2.5	74.8	8.4	78	26.1	68.0	78.8	4.6	2.2
5.0	82.6	12.4	93	32.4	89.6	87.2	5.4	3.2
CD ($P \leq 0.05$)	4.4	2.4	8.4	2.8	10.2	10.5	0.2	NS
NPK								
50%	66.4	7.2	49	19.6	38.0	19.6	3.9	1.3
75%	78.8	8.8	79	28.5	70.2	79.8	4.8	2.5
100%	84.7	13.6	98	36.2	90.0	92.4	5.6	3.8
CD ($P \leq 0.05$)	3.9	1.26	8.3	2.53	12.1	8.2	0.4	NS

(Azuka and Idu, 2022). Furthermore, the observed enhancement in yield may be linked to the combined effect of improved vegetative development and superior yield attributes resulting from the application of vermicompost. The present findings are in concurrence with individuals reported by Keteku *et al.* (2019), who observed the greatest fruit yield of tomato with elevated levels of NPK fertilization, specifically 125:48:65 kg/ha and 180:68:85 kg/ha of N, P and K, respectively. The increase in yield and its associated components with higher nutrient application can also be certified to the fundamental roles of nitrogen, phosphorus and potassium in plant physiology (Adhikary *et al.*, 2021). These elements are integral to the synthesis of essential biomolecules such as proteins, nucleic acids, chlorophyll and enzymes, thereby regulating key metabolic activities that directly influence both vegetative growth and reproductive performance of the crop (Kalika-Singh *et al.*, 2022).

Effect on fruit quality

Total soluble solids were significantly improved with higher levels of vermicompost and NPK. The increase in TSS may be attributed to enhanced carbohydrate metabolism and better translocation of sugars into fruits under improved nutrient availability. These findings are in agreement with earlier reports indicating improved fruit quality under integrated nutrient management by Sharma *et al.* (2022) and Kavitha *et al.* (2019).

Economics

Economic analysis revealed that higher levels of vermicompost and NPK significantly improved net returns and benefit-cost ratio (Table 3). The maximum net returns ($\text{₹ } 2.22 \text{ lakh ha}^{-1}$) and B:C ratio (3.16) were recorded under 100% recommended NPK, followed by 5 t ha⁻¹ vermicompost. Although the cost of cultivation increased with higher input levels, the substantial increase in yield compensated for the additional cost, resulting in higher profitability. This might be due to that integrated nutrient management enhances economic returns by improving nutrient use efficiency and reducing dependence on costly chemical fertilizers (Kumar *et al.*, 2025). Similar economic advantages of INM in tomato cultivation have been reported by Choudhary *et al.* (2023) and Shilpa *et al.* (2025).

Energetics

Energy analysis indicated that the use of vermicompost and NPK significantly influenced energy input and output (Table 4). The maximum energy output, energy ratio and energy productivity were recorded under 5 t ha⁻¹ vermicompost. Among fertilizer levels, 100% NPK recorded higher energy efficiency compared to lower levels. The increased energy efficiency under higher nutrient levels is mainly due to increased yield, which contributes to higher energy output. Although energy input increased due to high

Table 3: Effect of organic and inorganic nutrient sources on economics of tomato production under open ventilated polyhouse.

Treatment	Cost of cultivation ($\times 10^3 \text{ ₹/ha}$)	Net returns ($\times 10^3 \text{ ₹/ha}$)	Benefit: Cost ratio
Vermicompost (t/ha)			
0	72.6	95.4	1.31
2.5	78.4	148.5	1.89
5.0	84.5	215.6	2.55
NPK			
50%	65.4	130.8	2.00
75%	67.2	174.1	2.60
100%	70.4	222.2	3.16
CD ($P=0.05$)	2.06	4.18	3.12

Table 4: Effect of organic and inorganic nutrient sources on energetics of tomato production under open ventilated polyhouse condition (Pooled data of two years).

Treatment	Total energy input ($\times 10^3 \text{ MJ}$)	Total energy output ($\times 10^3 \text{ MJ}$)	Net energy return ($\times 10^3 \text{ MJ}$)	Energy ratio	Energy profitability	Energy productivity (kg/MJ)	Energy consumption (MJ/kg)
Vermicompost (t/ha)							
0	11.0	12.7	1.7	1.15	0.15	1.71	0.58
2.5	14.0	16.8	2.8	1.20	0.20	1.86	0.54
5	17.0	22.7	5.7	1.33	0.33	1.90	0.52
NPK							
50%	16.4	14.6	-1.8	0.89	-0.11	1.19	0.84
75%	17.8	18.8	1.0	1.05	0.06	1.60	0.62
100%	21.6	22.8	1.2	1.06	0.05	1.67	0.60
CD ($P=0.05$)	2.03	1.06	0.2	1.03	0.10	0.41	0.11

Table 5: Effect of different organic and inorganic nutrient sources on soil properties after two years of tomato production under open ventilated polyhouse condition.

Treatment	pH	Organic C (%)	Available nutrient (kg/ha)		
			N	P	K
Vermicompost (t/ha)					
0	6.80	0.87	306.7	13.6	196.8
2.5	6.86	0.88	325.8	14.8	222.4
5	6.70	0.90	338.6	15.5	238.7
CD _(P=0.05)	NS	NS	18.38	1.42	24.7
NPK					
50%	6.78	0.88	286.1	12.9	186.6
75%	6.74	0.89	306.3	13.8	197.8
100%	6.68	0.89	332.4	14.9	224.0
CD _(P=0.05)	NS	NS	12.2	1.6	11.0

use of inputs, the proportional increase in output energy resulted in improved energy indices. These findings are consistent with Kumar *et al.* (2023), who reported improved energy productivity with use of integrated nutrient management in protected cultivation system. Similarly, Dhillon *et al.* (2020) also stated that fertilizer and vermicompost has a major contribute to total energy input use in polyhouse for tomato production.

Soil properties

Application of vermicompost and NPK significantly enhanced soil available N, P and K, while soil pH and organic carbon remained statistically non-significant (Table 5). The increase in available nutrients under vermicompost treatments may be attributed to mineralization of organic substance and improved microbial activity, which enhance nutrient cycling and availability. Integrated nutrient management improves soil fertility by maintaining a balance between nutrient addition and removal. The absence of significant change in organic carbon may be due to the short duration of the study, as changes in soil organic matter generally require longer-term interventions. Similar improvements in soil nutrient status under INM have been supported by Rana *et al.* (2024); Verma *et al.* (2024) and Ghosh *et al.* (2023).

CONCLUSION

The study revealed that integrated application of vermicompost and recommended NPK significantly improved growth, yield, fruit quality, profitability and energy efficiency of tomato. Application of 5 t ha⁻¹ vermicompost along with 100% recommended NPK recorded the best overall performance. Integrated nutrient management also enhanced soil available N, P and K through improved nutrient availability and microbial activity. Higher net returns and energy productivity indicated better economic and resource use efficiency. Thus, combined use of organic and inorganic fertilizers can be recommended as a

sustainable and profitable nutrient management strategy for tomato cultivation under protected condition.

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Disclaimer

The results presented here are the independent work of the authors and may not align with the views of the institutions they are associated with. Every work has been made to ensure the accuracy and trustworthiness of the data. However, the authors accept no responsibility for any errors or concerns arising from its use. As the study was conducted under specific agro-climatic and management conditions, the results may not be universally applicable and should be adopted with appropriate validation under local conditions.

Conflict of interest

The authors affirm that no competing interests be present in connection with this work.

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