International Journal of Environment, Agriculture and Biotechnology
Vol-10, Issue-5; Sep-Oct, 2025
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Effect of integrated nutrient management on growth and yield of green chilli (*Capsicum annuum* L.)

Har Lal Meena[1], Hari Singh Meena[2], Pooja Sharma[3], Ramesh Kumar Meena[4], B. D. Yadav[5]

[1,4]Department of Horticulture, School of Agriculture, University of Technology, Jaipur, 303903
[2]Department of Plant Physiology, Rajasthan College of Agriculture, MPUAT, Udaipur, 303001
[3]Department of Statistics, Rajasthan College of Agriculture, MPUAT, Udaipur, 303001
[4]Department of Horticulture, Rajasthan Agriculture Research Institute, Durgapura, Jaipur, 302018

Received: 13 Sep 2025; Received in revised form: 15 Oct 2025; Accepted: 21 Oct 2025; Available online: 30 Oct 2025

Abstract— *This study investigates the impact of integrated nutrient management (INM) on the growth and yield attributes of chilli (Capsicum annuum L.), a major spice and vegetable crop with significant economic and culinary value in tropical regions. Chilli is nutritionally rich, containing capsaicinoids, vitamins A and C, carotenoids and essential minerals, contributing to its flavor and health benefits. Excessive use of synthetic fertilizers has degraded soil health, necessitating sustainable alternatives. INM, which combines organic (vermicompost, Farm Yard Manure (FYM)) and inorganic fertilizers (NPK), offers a balanced nutrient supply, promoting soil fertility and crop productivity. Among the treatments, T7 (NPK + 50% vermicompost) significantly enhanced growth parameters such as plant height, branch number and fruit attributes, outperforming other treatments. T7 also shortened the time to first fruit harvest, confirming the positive influence of consistent nutrient availability through INM. The study recorded substantial improvements in fruit length, girth, weight and yield per plant in T7, with T8 (NPK + 50% FYM) following closely. Results indicate that combining organic and inorganic sources enhances nutrient use efficiency, promoting root proliferation, canopy growth and enhanced production of growth regulators. These findings align with previous studies on nutrient management in various crops (e.g., tomatoes and fennel) and support INM's role in sustainable agriculture. Overall, INM demonstrated clear advantages over single organic and inorganic manure applications, confirming its effectiveness in boosting chilli crop yield and quality while maintaining soil health and sustainability.*

Keywords— ***Integrated Nutrient Management, Chilli.***

I. INTRODUCTION

Chilli (*Capsicum annuum* L.) is a widely cultivated vegetable and spice crop, particularly in tropical and subtropical regions like India, where it holds significant culinary and economic value. Known for its unique nutritional and sensory profile, chilli contains various bioactive compounds such as steam volatile oils, fatty oils, capsaicinoids, carotenoids, vitamins, proteins, fibers and essential minerals, which contribute to its distinctive flavor, aroma and colour (Gomez-Garca and Ochoa-Alejo, 2013). Fresh green chilli peppers, for instance, have higher vitamin C levels than citrus fruits (Orobiyi et al., 2015; Sottosanti, 2023), while fresh red peppers surpass the vitamin A content of carrots, highlighting their potential as both a food ingredient and natural bactericidal agent (Votava et al., 2002).

India has significantly advanced in fertilizer usage to boost crop productivity. However, prolonged, unbalanced use of chemical fertilizers has caused severe environmental issues and degraded soil health, affecting its physical, chemical and biological properties (Dwivedi, A.K. and Dwivedi, 2015). Overreliance on synthetic fertilizers threatens long-term agricultural sustainability by reducing soil quality and contributing to pollution (Verma et al., 2020). Hence, a balanced approach that integrates organic inputs is crucial for maintaining soil and crop quality (Dwivedi and Dwivedi, 2015). Organic amendments like manure improve soil structure, microbial biomass and crop

quality, though alone they may not yield optimal results due to lower nutrient content (Timsina, 2018). An integrated strategy, combining organic and inorganic fertilizers, enhances crop productivity, soil health and nutrient efficiency, while reducing the dependency on costly synthetic fertilizers (Laxminarayana, 2006; Jat et al., 2015).

INM provides a sustainable solution by harmonizing nutrient supply from organic, inorganic and biological sources (Rehman et al., 2019). INM fosters soil fertility and crop health, boosting both yield and quality, especially in crops like chilli (Chandana et al., 2023). The combination of FYM, vermicompost and NPK fertilizers enhances productivity sustainably, with vermicompost providing readily available nutrients that improve soil aeration, drainage and microbial vitality (Arancon et al., 2005). Through INM, chilli cultivation aligns with sustainable agriculture, balancing productivity and soil health.

II. MATERIAL AND METHODS

The present study evaluated the effect of integrated nutrient management on the growth and yield of the green chilli cultivar 'Kashi Anmol,' developed through recurrent selection from an Indian chilli introduction. The field experiment was conducted in 2022 at the Research Farm, Department of Horticulture, School of Agriculture, University of Technology, Jaipur. The trial included eight treatments combining organic and inorganic nutrient sources as follows: T0 (Control), T1 (FYM @ 25 t/ha), T2 (Vermicompost @ 5 t/ha), T3 (Recommended NPK at 70:42:32 kg/ha), T4 (50% FYM + 50% NPK), T5 (50% Vermicompost + 50% NPK), T6 (50% FYM + 50% NPK + 50% Vermicompost), T7 (Recommended NPK + 50% Vermicompost) and T8 (Recommended NPK + 50% FYM).

Data collection focused on key growth and yield parameters viz., plant height (measured at 60, 90 days after sowing and at harvest), primary branch number, days to 50% flowering, days to first fruit harvest, fruit length (cm), fruit girth (cm), number of fruits per plant, average fruit weight (g), yield per plot (kg) and crop duration. Fruit girth measurements were taken by digital vernier calipers and observations were recorded from three biological replicates per treatment. The study aimed to determine the optimal nutrient management strategy to enhance chilli crop productivity and quality through balanced and sustainable nutrient applications.

III. EXPERIMENTAL RESULTS

The effect of INM on the plant height. Plant height measurements were recorded at 60 and 90 days after sowing, as well as at the harvest stage. All treatments showed a significant increase in plant height compared to the control (T0). Among the treatments, T2 (Vermicompost @ 5 t/ha) consistently achieved the highest plant height across all growth stages, reaching 52.00 cm, 61.47 cm and 84.07 cm, respectively. This was closely followed by T8 (Recommended NPK + 50% FYM), with plant heights of 52 cm, 61.00 cm and 81.67 cm and by T4 (50% FYM + 50% NPK), which recorded plant heights of 49.00 cm, 57.67 cm and 77.33 cm at each stage. In contrast, the control treatment (T0) consistently recorded the shortest plant height, measuring 41.10 cm, 46.43 cm and 64.57 cm at 60 days, 90 days and harvest stage, respectively.

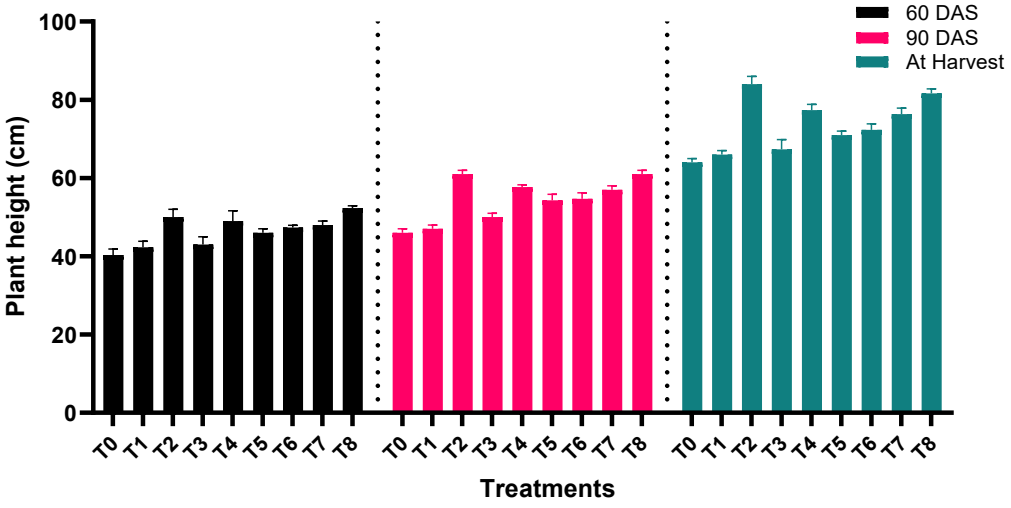

Fig. 1. The effect of INM on the plant height (cm) at 60, 90 days after sowing and at harvest stage on green chilli. The error bars represent ± standard error over mean.

Effect of INM on the number of primary branches per plant. The number of primary branches per plant was significantly impacted by different nutritional treatments. All treatments, except T5, resulted in a marked increase in primary branch count compared to the control. Treatment T7 (Recommended NPK + 50% Vermicompost) yielded the highest number of primary branches per plant 14.0, followed closely by treatment T8 (Recommended NPK + 50% FYM) with 12.33 branches and treatment T3 (Recommended NPK (70: 42: 32) kg/ha) with 9.0 branches per plant. In contrast, the control plant (T0) exhibited the lowest number of primary branches, with an average of 1.67 branches per plant.

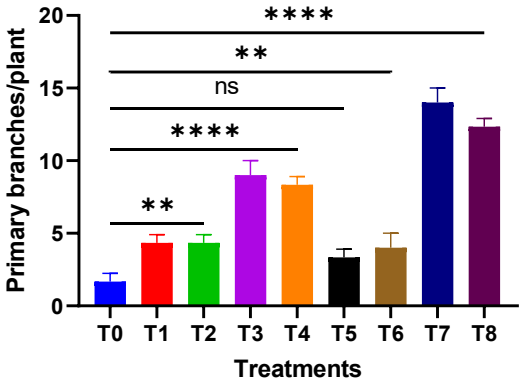

*Fig. 2. Effect of INM on the number of primary branches per plant in green chilli. The error bars represent ± standard error over mean. Bars with asterisk represent significance at **P<0.01 and ****P<0.0001. ns indicate non-significant.*

Effect of INM on days to 50 % flowering. The influence of INM treatments on the number of days to reach 50% flowering was assessed, revealing that all treatments, except T1, significantly affected this parameter. The shortest time to 50% flowering was observed with treatment T7 (Recommended NPK + 50% Vermicompost) at 37 days, followed by T8 (Recommended NPK + 50% FYM) at 39.67 days and treatment T3 (Recommended NPK (70: 42: 32) kg/ha) at 43 days. In contrast, the longest duration to 50% flowering was recorded in the control treatment (T0), taking 62 days.

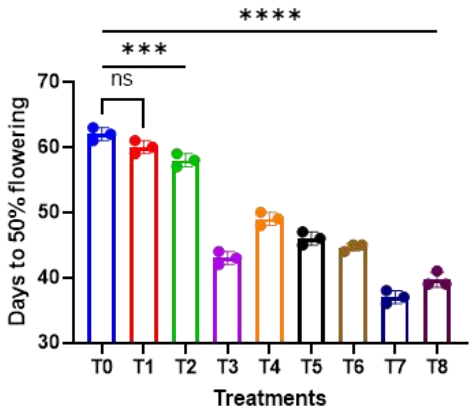

*Fig. 3. Effect of INM on days to 50 % flowering in green chilli. The error bars represent ± standard error over mean. Bars with asterisk represent significance at ***P<0.001 and ****P<0.0001. ns indicate non-significant.*

Effect of INM on days to Ist fruit harvest. The data on days required to reach the first fruit harvest revealed significant effects of different nutrient combinations compared to the control plant. The shortest duration to first fruit harvest was observed under treatment T7 (Recommended NPK + 50% Vermicompost), with 45.33 days, followed by treatment T6 (50 % FYM + 50 % NPK + 50 % Vermicompost) at 45.67 days and treatment T8 (Recommended NPK + 50 % FYM) at 47.67 days. In contrast, the longest period to first fruit harvest was recorded in the control treatment (T0), requiring 68 days.

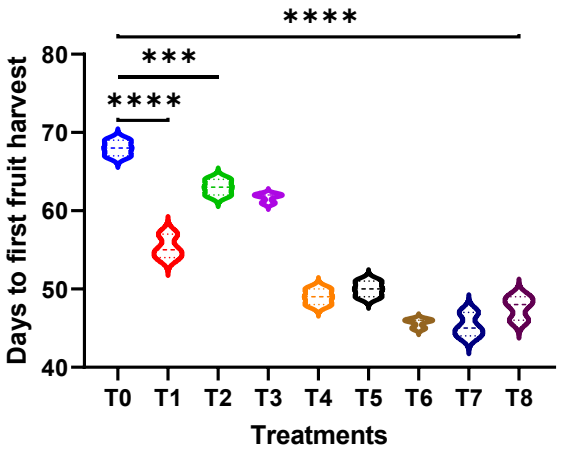

*Fig. 4. Effect of INM on days to Ist fruit harvest in green chilli. The error bars represent ± standard error over mean. Bars with asterisk represent significance at ***P<0.001 and ****P<0.0001.*

Effect of INM on fruit length (cm). Fruit length was significantly affected by various combinations of organic

and inorganic manures in all treatments except T2, compared to the control plant. The highest fruit length, approximately 11 cm, was recorded with treatment T7 (Recommended NPK + 50% Vermicompost), followed closely by treatment T6 (50% FYM + 50% NPK + 50% Vermicompost) at 10.37 cm and treatment T4 (50% FYM + 50 % NPK) at 8.07 cm. In contrast, the control treatment (T0) exhibited the shortest fruit length, measuring only 4.9 cm.

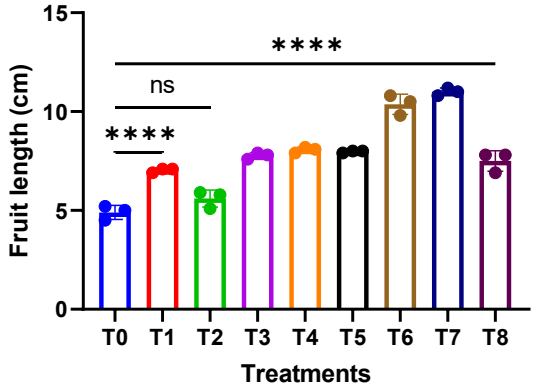

*Fig. 5. Effect of INM on fruit length (cm) in green chilli. The error bars represent ± standard error over mean. Bars with asterisk represent significance at ****P<0.0001. ns indicate non-significant.*

Effect of INM on fruit girth (cm). Data on fruit girth indicated that the highest measurement was recorded under treatment T7 (Recommended NPK + 50% Vermicompost) at 2.9 cm, followed by treatment T8 (Recommended NPK + 50% FYM) at 2.7 cm and treatment T6 (50% FYM + 50% NPK + 50% Vermicompost) at 2.57 cm. In contrast, the control treatment T0 resulted in the lowest fruit girth, measuring 1.2 cm.

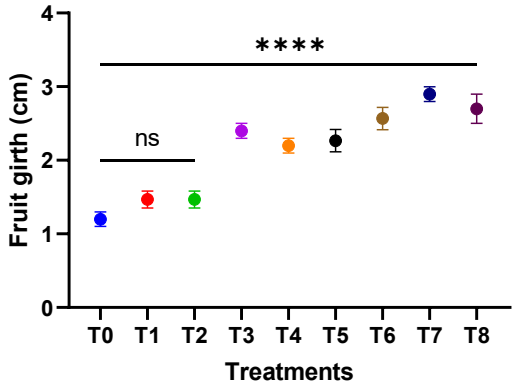

*Fig. 6. Effect of INM on fruit girth (cm) in green chilli. The error bars represent ± standard error over mean. Bars with asterisk represent significance at ****P<0.0001. ns indicate non-significant.*

Effect of INM on the number of fruits per plant. In all treatments except T1, the number of fruits per plant was significantly influenced by various combinations of organic and inorganic manures. The highest fruit count per plant (49.33) was observed with treatment T7 (Recommended NPK + 50% Vermicompost), followed by treatment T8 (Recommended NPK + 50% FYM) with 45.33 fruits and treatment T6 (50% FYM + 50% NPK + 50% Vermicompost) with 43.33 fruits per plant. In contrast, the control treatment (T0) yielded the lowest fruit count, with only 8.67 fruits per plant.

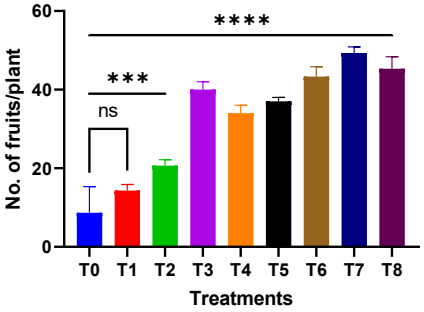

*Fig. 7. Effect of INM on the number of fruits per plant in chilli. The error bars represent ± standard error over mean. Bars with asterisk represent significance at ***P<0.001 and ****P<0.0001. ns indicate non-significant.*

Effect of INM on average fruit weight (g). The average fruit weight was significantly affected by various manure combinations compared to the control treatment. Treatment T8 (Recommended NPK + 50% FYM) produced the highest average fruit weight at 2.14g, followed closely by T7 (Recommended NPK + 50% Vermicompost) at 2.10g and T6 (50% FYM + 50% NPK + 50% Vermicompost) at 1.93g. In contrast, the lowest average fruit weight of 0.47g was recorded in the control treatment (T0).

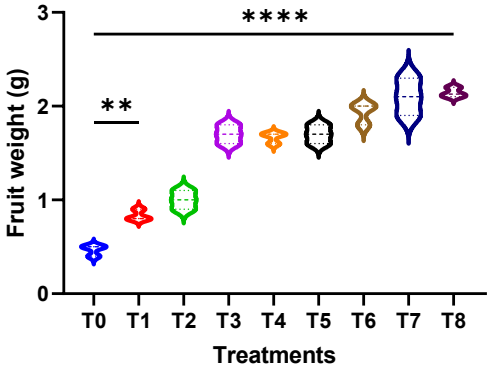

*Fig. 8. Effect of INM on average fruit weight (g) in green chilli. The error bars represent ± standard error over mean. Bars with asterisk represent significance at **P<0.01 and ****P<0.0001.*

Effect of INM on yield per plot (kg). The application of various INM practices significantly enhanced fruit yield per plot compared to the control plant. The highest yield per plot 16.9 kg was achieved with treatment T7 (Recommended NPK + 50% Vermicompost), followed by T8 (Recommended NPK + 50% FYM) at 15.22 kg and T6 (50% FYM + 50% NPK + 50% Vermicompost) at 14.77 kg. In contrast, the lowest yield per plot 1.73 kg was recorded under the control treatment (T0).

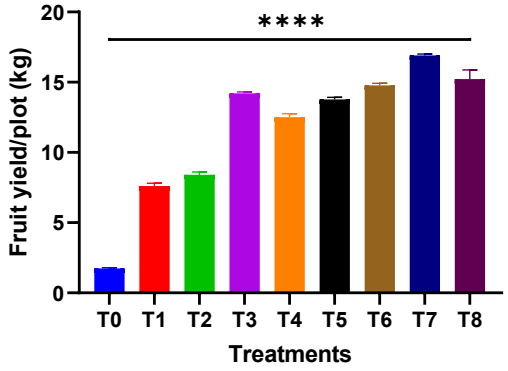

*Fig. 9. Effect of INM on yield per plot (kg) in green chilli. The error bars represent ± standard error over mean. Bars with asterisk represent significance at ****P<0.0001.*

Effect of INM on crop duration (days). The crop duration was notably influenced by various combinations of organic and inorganic manures. Treatment T7, which included a combined nutrient approach, resulted in the longest crop duration of 152 days, followed by T6 at 148.33 days and T5 at 139.3 days. In contrast, the control treatment (T0) exhibited the shortest crop duration, at 83.33 days.

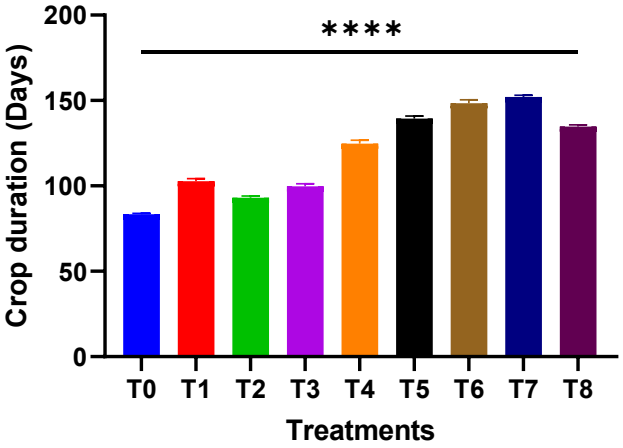

*Fig. 10. Effect of INM on crop duration (days) in green chilli. The error bars represent ± standard error over mean. Bars with asterisk represent significance at ****P<0.0001.*

IV. DISCUSSION

In the present study, significant variation in plant height was observed across treatments. Data analysis revealed that plant height increased progressively at distinct crop stages, 60 days, 90 days after sowing and at harvest. Notably, the maximum plant height at harvest was recorded under treatment T8, which outperformed the control treatment. This enhancement in plant height is likely attributed to a sustained nutrient supply via the recommended dose of NPK and FYM, providing continuous nutrient availability. Similar findings on height increase were reported by Dutta et al. (2011) and Narkhede et al., (2011) in chilli crops with the application of vermicompost and biofertilizers.

A significantly higher number of primary branches per plant was recorded in treatment T7 compared to other treatments. The use of inorganic fertilizers in combination with organic manure appears to facilitate efficient nutrient absorption and root proliferation, promoting rapid canopy development. This enhanced growth likely accelerated the production of growth regulators, stimulating cell elongation and division, resulting in increased plant growth and branch numbers. This outcome aligns with the work of Pariari and Khan (2013) and Rao et al., (2015) on chilli. The INM approach also had a notable effect on flowering, crop duration and timing to first fruit harvest due to improved nutrient availability.

In treatment T7, the time to first fruit harvest was the shortest among all treatments. These findings confirm those of Rahman et al., (2012) and Shiva et al., (2015), who examined INM's influence on chilli crop growth, including the timing of 50% flowering and first fruit harvest. Consistent nutrient supply through INM positively affected these growth parameters, demonstrating the benefits of prolonged nutrient availability. Regarding yield attributes such as fruit length, girth and average fruit weight this study showed a significant positive effect from different combinations of organic and inorganic nutrient sources. The combined application of vermicompost and FYM notably increased fruit length, girth, average weight and fruit count per plant. This cumulative improvement in yield attributes can be traced to enhanced growth driven by these nutrient combinations. These observations align with previous studies by Singh et al., (2010) on tomato, Ranjitha (2016) on chilli and Jamir et al., (2017) on sweet pepper, reinforcing the positive impact of diverse organic and inorganic nutrient inputs on fruit quality across crops.

Similarly, the effect of INM on fruit yield per plant was positive, with different nutrient combinations yielding a higher fruit count per plant. Treatment T7 recorded the most substantial increase in fruit count, suggesting that

balanced nutrient availability through various organic and inorganic sources enhanced growth and yield in chilli plants. This enhancement aligns with prior research by Chumyani et al., (2012) on tomatoes and Khandaker et al., (2017), whose results closely correspond with this investigation's findings.

INM significantly improved all growth parameters by providing a gradual, steady nitrogen supply through organic fertilizers alongside inorganic ones. This gradual nitrogen release ensures sustained nutrient uptake throughout the plant's growth cycle. Improved growth characteristics were reflected in enhanced yield attributes, leading to higher crop yield overall. Among all treatments, T7 achieved the highest yield, aligning closely with the findings of Deepika et al., (2010) in chilli, Kumar et al., (2016) in chilli.

V. CONCLUSIONS

Our study suggested that the combined application of organic and inorganic fertilizers demonstrated superior efficacy compared to the use of either type alone. The treatment with Recommended NPK + 50% Vermicompost (T7) achieved the highest values across all growth parameters, followed closely by Recommended NPK + 50% FYM (T8). Control treatments (T0) exhibited significantly lower values in all growth metrics. Fruit attributes, such as fruit length and girth, were also maximized with T7, followed by T8. Overall, integrating organic and inorganic nutrient sources provided enhanced growth and yield benefits compared to individual treatments or control.

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