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Effect of INM on Growth and Yield of Capsicum (*Capsicum annuum* l.) under Protected Cultivation

Shubham Sharma [a++], Vinay Joseph Silas [b#*], Jitendra Kumar [b#], Raghvendra Singh [b#], Ravikesh Kumar Pal [b#], Anushka Tripathi [a++] and Dilip Kumar [a++]

[a] RAMA University, Mandhana, Kanpur (Uttar Pradesh), India.
[b] Faculty of Agricultural Sciences and Allied Industries, RAMA University, Mandhana, Kanpur (Uttar Pradesh), 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

The present investigation entitled "Effect of INM on Growth and Yield of Capsicum (Capsicum annuum L.) Under Protected Cultivation" was conducted at the Horticulture Research Farm, Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur (U.P.) during 2024–2025. The experiment comprised nine treatments, replicated thrice in a randomized block design (RBD).

[++] M.Sc. Scholar;
[#] Assistant Professor;
**Corresponding author: Email: vinay.fas@ramauniversity.ac.in;*

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It was concluded that the application of integrated nutrient management (INM) had a significant effect on almost all the growth, yield, and quality parameters of capsicum. The results revealed that the maximum plant height (79.84 cm), number of branches per plant (18.13), number of leaves per plant (94.65), leaf area (164.34 cm^2), days to 50% flowering (35.38), number of flowers per plant (18.37), number of fruits per plant (15.37), fruit length (8.07 cm), fruit diameter (7.09 cm), fruit weight (72.61 g), pericarp thickness (9.17 mm), fruit yield per plant (1.116 kg), fruit yield per plot (16.74 kg), fruit yield per hectare (34.87 t ha^{-1}), total soluble solids (6.83 °Brix), and ascorbic acid content in fruit juice (150.93 mg/100g) were recorded with treatment T7 (50% FYM + 25% NPK + 25% Vermicompost). In terms of economics, treatment T7 (50% FYM + 25% NPK + 25% Vermicompost) also recorded the highest gross return (Rs. 15,69,033.3 ha^{-1}), net return (Rs. 13,43,532.9 ha^{-1}), and benefit-cost ratio (1:5.96).

Keywords: Capsicum; growth; yield; quality.

1. INTRODUCTION

India is characterized by a rich diversity of flora, fauna, and various soil and agro-climatic conditions (Apu et al., 2020). This diversity enables the cultivation of the highest number of vegetable crops globally, earning it the title of a horticultural paradise. Sweet pepper was introduced to India by British colonists in the 19th century, with the first successful large-scale cultivation occurring in the Shimla hills, which is why it is commonly referred to as 'Shimla Mirch.' It ranks as the second most consumed vegetable crop worldwide. In India, sweet pepper is cultivated over an area of 37 thousand hectares, yielding a production of 586 thousand metric tonnes (Anonymous, 2022). In Himachal Pradesh, sweet pepper is grown as a cash crop in sub-temperate regions, covering an area of 2.85 thousand hectares and producing 48.86 metric tonnes (Anonymous, 2022). The annual, day-neutral sweet pepper (Capsicum annuum L. var. Grossum), belonging to the Solanaceae family, is recognized for its significant nutritional value, flavour, and vibrant color, making it one of the most crucial vegetable crops cultivated globally, including in India (Tiwari et al., 2013). It is also considered one of the primary commercial crops worldwide. India stands as one of the largest producers, consumers, and exporters of chili, attributed to the favourable soil and climatic conditions conducive to chili cultivation (Anonymous, 2021). In terms of area, India ranks first, while it holds the second position in production, following China. The country encompasses an area of 7.43 lakh hectares and achieves a production of 19.14 lakh metric tons, with a productivity rate of 2576 kg per hectare (National Horticulture Board, 2022). This crop is an excellent source of vitamins A and C. The spiciness of chili is attributed to the alkaloid capsaicin ($C_9H_{14}O_2$), which acts as a digestive stimulant. It boasts a high nutritional profile, containing 1.29 mg of protein, 11 mg of calcium, 870 I.U. of vitamin A, 175 mg of ascorbic acid, 0.06 mg of thiamine, riboflavin, 0.55 mg of niacin per 100 g of edible fruit, and 321 mg of vitamin C per 100 g (Agarwal et al., 2007). The yield per unit area can be enhanced alongside quality improvement through the judicious use of both organic and inorganic fertilizers in appropriate combinations. Sweet pepper shows a favourable response to the application of organic manures and inorganic fertilizers. The incorporation of organic manures in integrated nutrient management (INM) aids in alleviating various nutrient deficiencies (Jamir et al., 2017). Organic manures consist of decomposed plant and animal waste. Farmyard manure (FYM) is a mixture of decomposed dung and urine from livestock, along with litter and other materials derived from roughages or fodder provided to cattle. Typically, well-decomposed farmyard manure contains 0.5% nitrogen (N), 0.3% phosphorus pentoxide (P2O5), and 0.5% potassium oxide (K2O). It can supply nearly all essential soil fertility elements required by crops, although not always in sufficient quantities or correct proportions (Jamir et al., 2017).

2. MATERIALS AND METHODS

The present investigation was conducted to study the effect of integrated nutrient management (INM) on the growth and yield of capsicum (Capsicum annuum L.) under protected cultivation at the Horticulture Research Farm, Rama University, Kanpur, during the Rabi season from October 2024 to February 2025. Geographically, the region falls under a sub-tropical climate, situated at 26°47′ N latitude and 82°12′ E longitude, located in the Indo-Gangetic alluvial plains of eastern Uttar Pradesh, India. The area receives an average annual rainfall of approximately 1100 mm, of which 85% occurs during the monsoon season (mid-June to end of September). The winter months are cold and dry, with occasional frost occurrences. Temperatures begin to rise from February onwards, continuing to increase up to June. The experimental site, located approximately 25 km from the district headquarters of Kanpur (Pin Code: 208024), lies at 20°16′ N latitude and 80°08′ E longitude, at an altitude of 180 meters above sea level, and falls under the southwestern plains of Uttar Pradesh, within the subtropical agro-climatic zone. The field was well-leveled and equipped with adequate irrigation and drainage facilities. Prior to the experiment, any stubble and weeds from the previous crop were manually removed. The soil of the experimental site was sandy loam in texture, with a pH of 7.9, electrical conductivity (EC) of 0.3 dS/m, and organic carbon content of 4.5%. The available nitrogen, phosphorus, and potassium contents before experimentation were 210, 12.8, and 198 kg/ha, respectively. The experiment was laid out in a Randomized Block Design (RBD) with three replications, comprising nine treatment combinations, as follows: T1: Control, T2: 100% FYM, T3: 50% FYM + 50% Vermicompost, T4: 75% FYM + 25% Vermicompost, T5: 50% FYM + 50% NPK, T6: 75% FYM + 25% NPK, T7: 50% FYM + 25% NPK + 25% Vermicompost, T8: 75% FYM + 12.5% NPK + 12.5% Vermicompost, T9: 50% Vermicompost + 50% NPK. Thirty-day-old seedlings were transplanted at a spacing of 60 cm × 40 cm. During the investigation, various growth, yield, and quality parameters were recorded, including: Plant height (cm), Number of branches per plant, Number of leaves per plant, Leaf area (cm²), Days to 50% flowering, Number of flowers per plant, Number of fruits per plant, Fruit length (cm), Fruit diameter (cm), Fruit weight (g), Pericarp thickness (mm), Fruit yield per plant (kg), Fruit yield per plot (kg), Fruit yield per hectare (t/ha), Total soluble solids (°Brix), Ascorbic acid content (mg/100g) of fruit juice. The data recorded during the course of the investigation were subjected to statistical analysis as per the analysis of variance (ANOVA) method. The significance or non-significance of treatment effects was determined using the 'F' variance ratio test (Arancon et al. 2005).

3. RESULTS AND DISCUSSION

The data regarding the integrated nutrient management (INM) studies in capsicum are presented in Tables 1 and 2. The results showed that INM had a significant effect on various growth, yield, and quality parameters, such as plant height (cm), number of branches per plant, number of leaves per plant, leaf area (cm²), days to 50% flowering, number of flowers per plant, number of fruits per plant, fruit length (cm), fruit diameter (cm), fruit weight (g), pericarp thickness (mm), fruit yield per plant (kg), fruit yield per plot (kg), fruit yield (t/ha), total soluble solids (°Brix), and ascorbic acid content (mg/100g) of fruit juice.

3.1 Growth Parameters

Observations for plant height, number of branches per plant, and leaf area are presented in Table 1. A perusal of this table reveals a progressive increase in plant height and number of branches per plant at 30, 60, and 90 days after transplanting (DAT), significantly influenced by different treatments. The maximum plant height at 30, 60, and 90 DAT (30.27 cm, 48.85 cm, and 79.84 cm respectively) was recorded under T7 (50% FYM + 25% NPK + 25% Vermicompost), which was statistically at par with T8 (75% FYM + 12.5% NPK + 12.5% Vermicompost) and T9 (50% Vermicompost + 50% NPK). The lowest plant height (21.49, 33.40, and 56.34 cm at respective intervals) was observed in T1 (Control). Similarly, the maximum number of leaves per plant at 30, 60, and 90 DAT (35.87, 77.01, and 94.65) was also observed in T7, followed by T8 and T9, whereas the minimum (24.35, 47.68, and 64.66) was recorded in T1. Leaf area followed the same trend, with T7 showing the maximum value (164.34 cm²), and T1 the minimum (114.93 cm²). These results align with previous findings by Joshi and Pal Vig (2010), Ramesh et al. (2015), and Huerta et al. (2010), who reported significant improvements in vegetative growth through INM. The increase may be attributed to better nitrogen availability in the root zone, improving plant metabolism. Similar results were also observed by Fawzy et al. (2010), Malik et al. (2011), Lal and Kanaujia (2013), Jamir et al. (2017), and Shilpa et al. (2017).

At 90 DAT, the maximum number of branches per plant (2.58, 9.41, and 18.13 at respective intervals) was again found in T7, followed by T8 and T9, with the lowest (1.22, 3.99, and 6.30) in T1. The increase in branching may be due to higher nitrogen levels enhancing protein synthesis and chlorophyll content, leading to improved photosynthesis. These findings corroborate the reports of Kumar and Dhar (2010), Malik et al. (2016), and Shilpa et al. (2017).

Table 1. Effect of integrated nutrient management on growth, yield and yield of capsicum (*Capsicum annuum* L.) under protected cultivation

S.N.	No. of Treatments	Plant height (cm)			Number of branches per plant			Number of leaves per plant			Leaf area (cm2) at 90 DAT
		30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	
1	T_1	21.49	33.40	56.34	1.22	3.96	6.30	24.35	47.68	64.66	114.93
2	T_2	24.43	39.85	65.07	2.07	7.40	9.97	29.94	67.97	87.81	144.05
3	T_3	24.12	40.72	66.28	2.14	7.33	9.47	33.17	67.86	84.00	143.50
4	T_4	24.69	38.27	67.67	1.86	6.41	11.39	27.08	49.82	85.06	145.99
5	T_5	24.94	41.67	71.58	1.33	7.09	12.35	26.62	65.40	76.23	141.85
6	T_6	24.26	39.24	71.35	1.32	7.31	12.30	24.82	62.08	75.57	144.20
7	T_7	30.24	48.85	79.84	2.58	9.41	18.13	35.87	77.01	94.65	164.34
8	T_8	28.78	46.47	77.50	2.27	9.13	15.95	33.30	75.03	93.17	159.93
9	T_9	26.98	45.20	75.85	2.22	8.19	14.10	30.75	72.27	93.68	153.26
	F-Test	S	S	S	S	S	S	S	S	S	S
	C.D.at 5%	1.28	1.94	4.75	0.22	0.87	1.56	2.70	6.20	3.47	8.17
	S.Ed. (±)	0.60	0.91	2.24	0.10	0.41	0.74	1.28	2.93	1.64	3.85
	S.Em.	0.43	0.65	1.58	0.07	0.29	0.52	0.90	2.07	1.16	2.73
	CV	2.89	2.70	3.91	6.71	6.87	7.40	5.29	5.32	2.39	3.24

Table 1. Effect of integrated nutrient management on growth, yield and yield of capsicum (*Capsicum annuum* L.) under protected cultivation (contd….)

S.N.	No. of Treatments	Days to 50% flowering	Number of flower per plant	Number of fruit per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Pericarp thickness (mm)	Fruit yield per plant (kg-1)	Fruit yield per plot (kg-1)	Fruit yield (t ha-1)	Total soluble solid (0Brix)	Ascorbic acid (mg/ 100g) of fruit juice
1	T_1	48.49	9.87	6.33	5.66	5.05	35.05	5.27	0.222	3.32	6.92	4.79	139.83
2	T_2	38.89	14.65	10.37	7.27	5.51	59.04	6.95	0.612	9.18	19.12	3.95	144.88
3	T_3	40.93	13.47	11.73	6.66	6.07	59.10	7.15	0.693	10.40	21.66	5.53	145.40
4	T_4	41.53	14.76	11.59	7.07	5.75	64.07	6.51	0.742	11.14	23.20	5.75	147.27
5	T_5	41.16	13.30	9.57	7.48	6.09	61.30	7.36	0.587	8.80	18.34	5.91	144.21
6	T_6	41.93	13.62	9.41	6.42	5.62	65.72	7.41	0.618	9.26	19.30	5.41	141.49
7	T_7	35.38	18.37	15.37	8.07	7.09	72.61	9.17	1.116	16.74	34.87	6.83	150.93
8	T_8	36.73	16.75	13.39	7.51	6.83	70.64	8.47	0.946	14.19	29.57	6.40	149.39
9	T_9	37.38	15.72	7.97	7.21	6.34	43.63	8.09	0.348	5.22	10.87	6.12	148.34
	F-Test	S	S	S	S	S	S	S	S	S	S	S	S
	C.D.at 5%	0.88	0.52	0.86	0.25	0.17	4.78	0.48	0.06	0.91	1.98	0.24	2.11
	S.Ed. (±)	0.41	0.24	0.41	0.12	0.08	2.26	0.23	0.03	0.43	0.94	0.11	0.99
	S.Em.	0.29	0.17	0.29	0.08	0.06	1.60	0.16	0.02	0.30	0.66	0.08	0.70
	CV	1.26	2.06	4.66	2.07	1.60	4.68	3.77	5.61	5.37	5.61	2.36	0.84

3.2 Yield and Quality Parameters

Data presented in Tables 1 and 2 also reflect the influence of INM on fruit yield and quality:

Days to 50% flowering: Minimum in T7 (35.38), significantly superior to others, while maximum (48.49) was noted in T1. This may be due to earlier nutrient availability facilitating rapid growth and flower initiation, as supported by Naidu et al. (2002), Prativa & Bhattarai (2011) and Sultana et al., 2020).

Number of flowers per plant: Highest in T7 (18.37), followed by T8, T9, and T4. The lowest (9.7) was observed in T1. The increase may be due to better nutrient uptake and hormonal stimulation from vermicompost, as noted by Shiva et al. (2015), Bhattarai et al. (2011), and Chetri et al. (2012). Number of fruits per plant: Highest in T7 (15.37), followed by T8; lowest (6.33) in T1. The enhanced fruit set is attributed to improved nutrient supply, C:N balance, and biological activity, in agreement with Malik et al. (2011), Lal and Kanaujia (2013), and Ngupok (2018). Fruit length and diameter: Maximum fruit length (8.07 cm) and diameter (7.09 cm) in T7; minimum (5.66 cm and 5.05 cm) in T1. Sufficient potassium and phosphorus likely contributed to better cell elongation and fruit development, as also observed by Dubey et al. (2017) and Chetri et al. (2012). Fruit weight: Highest (72.61 g) in T7, minimum (35.05 g) in T1. Conjoint application of organics and inorganics improves assimilate partitioning, promoting heavier fruits (Suthar, 2009; Raturi et al., 2019). Pericarp thickness: Maximum (9.17 mm) in T7, minimum (5.27 mm) in T1. This could be due to improved soil structure and nutrient availability. Similar findings were reported by Malik et al. (2011) and Lal and Kanaujia (2013). Fruit yield per plant, per plot, and per hectare, whereas Per plant: Highest in T7 (1.116 kg), lowest in T1 (0.222 kg), Per plot: Highest in T7 (16.74 kg), lowest in T1 (3.32 kg), Per hectare: Highest in T7 (34.87 t/ha), lowest in T1 (6.92 t/ha) Enhanced fruit yield is directly related to higher vegetative growth, flower, and fruit set, as shown in studies by Bhattarai et al. (2011), Dubey et al. (2017), and Sharma et al. (2020, Bharathi et al. 2011).

Total Soluble Solids (°Brix): Maximum in T7 (6.83), minimum in T1 (4.79). Organic-inorganic integration improves sugar accumulation, a trait supported by similar studies. Ascorbic acid content: Highest in T7 (150.93 mg/100g), lowest in T1 (139.83 mg/100g). Enhanced micronutrient uptake, especially under vermicompost, may contribute to better vitamin C content, aligning with findings of Chetri et al. (2012) and Howlader et al., 2019).

4. CONCLUSION

From the present investigation it is concluded that treatment T_7 50% FYM + 25% NPK + 25% Vermicompost performed best in terms of Growth parameters, yield and quality viz., plant height (79.84), number of branches per plant (18.13), number of leaves per plant (94.65), leaf area (164.34 cm2), days to 50% flowering (35.38), number of flower per plant (18.37), number of fruit per plant (15.37), fruit lengrth (cm) (8.07), fruit diameter (cm) (7.09), fruit weight (g) (72.61), pericarp thickness (mm) (9.17), fruit yield per plant (kg^{-1}) (1.116), fruit yield per plot (kg^{-1}) (16.74), fruit yield (t ha-1) (34.87), total soluble solid (^{0}Brix) (6.83) and ascorbic acid (mg/ 100g) of fruit juice (150.93) of capsicum.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of this manuscript. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. ChatGPT

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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