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Effect of micronutrients on growth, fruit yield and quality parameters of capsicum (*Capsicum annuum* L.) under protected cultivation

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Abstract

The present investigation entitled “Effect of Micronutrients on Growth, Fruit Yield and Quality Parameters of Capsicum (*Capsicum annuum* L.) under Protected Cultivation” was conducted during 2025–26 at the Vegetable Research Farm, Department of Vegetable Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India. The experiment was laid out in a Randomized Block Design (RBD) with 08 treatments in three replications to evaluate the effect of foliar application of zinc (Zn), iron (Fe), and boron (B), applied singly and in combinations, on the growth, yield, quality, and economics of capsicum cultivation under protected conditions. The treatments comprised T₁: Zn @ 3 g L⁻¹, T₂: Fe @ 5 g L⁻¹, T₃: B @ 2 g L⁻¹, T₄: Zn + Fe @ 3 + 5 g L⁻¹, T₅: Zn + B @ 3 + 2 g L⁻¹, T₆: Fe + B @ 5 + 2 g L⁻¹, T₇: Zn + Fe + B @ 3 + 5 + 2 g L⁻¹, and T₈: Control (no micronutrient application). Observations were recorded on growth, flowering, fruiting, yield, quality attributes, and economic parameters.

The results revealed that the combined foliar application of Zn + Fe + B @ 3 + 5 + 2 g L⁻¹ (T₇) significantly improved all growth parameters. The maximum plant height was recorded at 45 DAT (34.45 cm) and 90 DAT (104.45 cm), while the highest number of branches per plant was observed at 45 DAT (5.33) and 90 DAT (9.46). Treatment T₇ also recorded the minimum days to flowering initiation (33.89 days) and fruit initiation (56.39 days). Among yield attributes, T₇ produced the minimum first fruit harvest (84.62 days), last fruit harvest (111.26 days). The maximum in T₇ fruit circumference (8.99 cm), number of fruits per plant (18.44), and average fruit weight (188.10 g). Consequently, the highest fruit yield per plant (3.51 kg), fruit yield per plot (10.50 kg), and fruit yield (102.66 q per 1000 m²) were obtained under T₇. In contrast, the control treatment (T₈) recorded the lowest values for most growth and yield parameters.

Quality parameters were also significantly influenced by micronutrient application. Treatment T₇ recorded the maximum shelf life (10.75 days), pericarp thickness (8.78 mm), and dry matter content (22.89%), indicating superior fruit quality under combined micronutrient application. The control treatment recorded the lowest shelf life (6.50 days), pericarp thickness (6.53 mm), and dry matter content (14.33%). Economic analysis revealed that the highest Benefit cost ratio (2.83) was achieved with T₇ (Zn + Fe + B @ 3 + 5 + 2 g L⁻¹), followed by T₄ (2.73) and T₅ (2.63), demonstrating the economic viability of combined micronutrient application. The control treatment recorded the lowest B:C ratio (1.94).

Based on the findings of the study, it can be concluded that foliar application of Zn + Fe + B @ 3 + 5 + 2 g L⁻¹ (T₇) is the most effective treatment for enhancing growth, yield, fruit quality, profitability and shelf life of capsicum under protected cultivation and can be recommended for commercial production.

Keywords: Capsicum growth, fruit yield, quality parameters and economics

Introduction

Chilli (*Capsicum annuum* L.) is an important vegetable and spice crop in the family of Solanaceae. It has diploid chromosome number i.e. 2n=24, originated in Mexico, Southern Peru and Bolivia. It is herbaceous, profusely branching and bushy in nature. It was introduced in India by the Britishers in the 19th century in Shimla hills. It was introduced by Portuguese from Brazil to India during 1584 and in the North-eastern regions by Christian missionaries. It is mainly grown in Africa, USA, Japan, Mexico, India, Turkey, etc. It is commercially cultivated as a cash crop in India. India is the leading country in production, consumption and export of Chilli in the world. It is third important vegetable crop after tomato and potato.

Capsicum is also known as bell pepper, sweet pepper, or Shimla Mirch. It has a good amount of vitamin A, vitamin C, and minerals such as calcium (13.4 mg), magnesium (14.9 mg), phosphorus (28.3 mg), and potassium (263.7 mg) for every 100 g of fresh weight. It contains a lot of rutin, which is crucial for the pharmaceutical industry. Capsicum can also be used in salads and pickles. The pungency and red hue are caused by the compound's capsaicin and capsanthin, respectively. Despite being a cool-season crop, capsicum may be grown all year round under a covered structure. Because they provide nutrient-dense components that are essential for a balanced diet, vegetables make a substantial contribution to human diets. Sweet pepper has a higher vitamin content than tomatoes, particularly in A and C. Sweet peppers are rich in calcium, carotene, and vitamin C.

According to the latest FAO-based statistics, global production of chilies and peppers (*Capsicum* spp.) was estimated at approximately 38 million tonnes in 2024. China remained the largest producer with about 17.3 million tons, followed by India (5.32 million tonnes), Türkiye (3.43 million tonnes), and Mexico (3.22 million tonnes). Despite a marginal decline from the record production level of 2023, global output remained historically high, reflecting the continued importance of *Capsicum* crops in world vegetable production. India's production of green chillies and peppers reached approximately 5.318 million tonnes in 2024, representing a 3.1% increase over the previous year. In addition, production of dry chillies and peppers was estimated at 2.91 million tonnes in 2024, the highest level recorded for the country. Food and Agriculture Organization. (2024-25).

Vegetables are the most inexpensive and naturally occurring food source. Western Uttar Pradesh Himachal Pradesh, Karnataka, Tamil Nadu, Maharashtra, Andhra Pradesh, Uttaranchal, Madhya Pradesh, West Bengal, Rajasthan, Punjab, Orissa, northeastern states, and Bihar are India's top growing states. In 2021–22, 556 Mt of capsicum were produced on 38 million hectares of land in India, and 9.70 Mt were produced on 5.40 million hectares in Rajasthan (Pariari and Khan 2013).

The production of solanaceous crops is constrained by several biotic, abiotic, and socio-economic factors that adversely affect crop growth, yield, and quality. Major constraints include the incidence of insect pests and diseases, unfavorable environmental conditions, poor soil fertility, water stress, high input costs, and post-harvest losses. Climate variability, including temperature extremes, irregular rainfall, and drought, further limits productivity. In addition, inadequate availability of quality planting material, limited adoption of improved production technologies, and market price fluctuations pose significant challenges to profitable cultivation of solanaceous vegetables.

Protected cultivation offers significant advantages over open-field cultivation in capsicum production. Under open-field conditions in India, capsicum yields generally range from 20–40 t ha⁻¹, depending on climate, variety, and management practices. In contrast, protected cultivation systems such as polyhouses and greenhouses can achieve yields of 80–120 t ha⁻¹ under commercial conditions and up to 120–150 t ha⁻¹ in well-managed high-tech structures. The higher productivity under protected cultivation is attributed to favorable microclimatic conditions, efficient fertigation, reduced biotic and abiotic stresses, improved fruit quality, and an extended harvesting period. Protected cultivation also enables off-season production and more efficient use of water and nutrients compared with open-field systems.

Materials and Methods

The experiment was conducted at the Vegetable Research Farm,

C. S. Azad University of Agriculture & Technology, Kanpur (U.P). Physio-chemical character Soil Coarse sand 3.49%, Fine sand 43.60%, Silt 29.56% and Clay 23.50%. Variety Indra (Hybrids), The present investigation entitled “Effect of Micronutrients on Growth, Yield and Quality Parameters of Capsicum under Protected Cultivation” was conducted during 2025–26 at the Vegetable Research Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India. The experiment was laid out in a Randomized Block Design (RBD) with eight treatments and three replications to evaluate the effect of foliar application of zinc (Zn), iron (Fe), and boron (B), applied singly and in combinations, on the growth, yield, quality, and economics of capsicum cultivation under protected conditions. The treatments comprised T₁: Zn @ 3 g L⁻¹, T₂: Fe @ 5 g L⁻¹, T₃: B @ 2 g L⁻¹, T₄: Zn + Fe @ 3 + 5 g L⁻¹, T₅: Zn + B @ 3 + 2 g L⁻¹, T₆: Fe + B @ 5 + 2 g L⁻¹, T₇: Zn + Fe + B @ 3 + 5 + 2 g L⁻¹, and T₈: Control (no micronutrient application). Observations were recorded on growth, flowering, fruiting, yield, quality attributes, and economic parameters.

Observations

Observations were recorded on growth parameters plant height, no. of branches/ plant, days of flowering initiation, days of fruit initiation, first fruit harvest, last fruit harvest). Fruit characters fruit circumference (cm), number of fruits/plants, average fruit weight (g), fruit yield/plant (kg), fruit yield/plot (kg), fruit yield (q/1000 m²), and quality attributes shelf life of the fruit (Days), pericarp thickness (mm), dry matter of the fruits and economics Benefit: Cost ratio was calculated.

Data were statistically analyzed using ANOVA for RBD at 5% level of significance and treatments means were compared using Critical Difference (CD).

Results and Discussion

The results revealed that the combined foliar application of Zn + Fe + B @ 3 + 5 + 2 g L⁻¹ (T₇) significantly improved all growth parameters. The maximum plant height was recorded at 45 DAT (34.45 cm) and 90 DAT (104.45 cm), while the highest number of branches per plant was observed at 45 DAT (5.33) and 90 DAT (9.46). Treatment T₇ also recorded the minimum days to flowering initiation (33.89 days) and fruit initiation (56.39 days). Among yield attributes, T₇ produced the minimum first fruit harvest (84.62 days), last fruit harvest (111.26 days). The maximum in T₇ fruit circumference (8.99 cm), number of fruits per plant (18.44), and average fruit weight (188.10 g). Consequently, the highest fruit yield per plant (3.51 kg), fruit yield per plot (10.50 kg), and fruit yield (102.66 q per 1000 m²) were obtained under T₇. In contrast, the control treatment (T₈) recorded the lowest values for most growth and yield parameters. Quality parameters were also significantly influenced by micronutrient application. Treatment T₇ recorded the maximum shelf life (10.75 days), pericarp thickness (8.78 mm), and dry matter content (22.89%), indicating superior fruit quality under combined micronutrient application. The control treatment recorded the lowest shelf life (6.50 days), pericarp thickness (6.53 mm), and dry matter content (14.33%). Economic analysis revealed that the highest Benefit cost ratio (2.83) was achieved with T₇ (Zn + Fe + B @ 3 + 5 + 2 g L⁻¹), followed by T₄ (2.73) and T₅ (2.63), demonstrating the economic viability of combined micronutrient application. The control treatment recorded the lowest B:C ratio (1.94).

Table 1: Effect of foliar application of micronutrients on growth parameter of capsicum under protected cultivation

Treatments	Plant height (cm)	Branches	Days of flowering initiation	Days of fruit initiation	1 st fruit harvest (Days)
T ₁	96.44	6.21	35.98	58.98	87.28
T ₂	94.65	6.17	36.26	59.56	88.14
T ₃	91.36	5.96	36.58	59.65	89.45
T ₄	102.83	8.88	34.48	57.37	85.24
T ₅	102.21	8.12	34.61	58.49	85.97
T ₆	100.11	7.66	35.79	58.88	86.45
T ₇	104.45	9.46	33.89	56.39	84.62
T ₈	87.35	5.45	37.68	60.19	90.12
SEm±	1.72	0.10	0.50	0.88	0.61
C.D.	5.28	0.32	1.53	2.64	1.89

Table 2: Effect of foliar application of micronutrients on yield parameter of capsicum under protected cultivation

Treatments	Last fruit harvest (Days)	Fruit circumference (cm)	No. of fruits plant ⁻¹	Av. fruit weight (g)	Fruit yield plant ⁻¹ (kg)
T ₁	116.03	7.96	17.66	178.78	3.22
T ₂	117.63	7.88	17.54	178.04	3.13
T ₃	118.16	7.79	17.21	177.17	2.89
T ₄	112.60	8.74	18.33	182.49	3.27
T ₅	114.06	8.53	18.07	180.40	3.24
T ₆	115.26	8.38	17.97	181.02	3.15
T ₇	111.26	8.99	18.44	188.10	3.51
T ₈	120.00	6.68	10.97	170.44	1.89
S.E.m±	0.88	0.14	0.34	2.45	0.08
C.D. (P=0.05)	2.72	0.45	1.03	7.43	0.24

Table 3: Effect of foliar application of micronutrients on quality and economics parameter of capsicum under protected cultivation

Treatments	Fruit yield/plot (Kg)	Fruit yield (q/1000 m ⁻²)	Shelf-life of the fruit (Days)	Pericarp thickness (mm)	Dry matter of the fruit (%)	B:C ratio (%)
T ₁	7.27	79.78	8.16	7.87	20.88	2.19
T ₂	7.17	77.33	7.79	7.83	21.33	2.12
T ₃	7.12	72.35	7.67	7.66	19.40	1.98
T ₄	8.64	99.28	9.38	8.75	19.58	2.73
T ₅	8.14	95.58	9.22	8.69	22.66	2.63
T ₆	7.67	87.17	8.79	8.57	21.48	2.40
T ₇	10.50	102.66	10.75	8.78	22.89	2.83
T ₈	6.70	70.33	6.50	6.53	14.33	1.94
SEm±	0.16	1.39	0.05	0.14	0.34	
C.D. (P=0.05)	0.49	4.27	0.16	0.43	1.05	

Conclusion

The growth, productivity, and quality of capsicum were greatly impacted by the foliar administration of micronutrients. When compared to individual and dual nutrient applications, the combination application of Zn + Fe + B (T₇) at 3 + 5 + 2 g/L showed to be the most successful treatment, leading to greater plant growth, higher fruit output, and enhanced quality parameters.

Zinc, iron, and boron each play significant roles in plant physiological processes, as demonstrated by the favorable benefits of single nutrient treatments (T₁, T₂, and T₃) over the control. Nevertheless, their combined application had a synergistic impact, improving fruit development, blooming, photosynthesis, and nutrient uptake more effectively.

The triple combination (T₇) was more successful than the dual combinations (T₄, T₅, and T₆), indicating that a balanced supply of micronutrients is essential for the best possible crop performance.

Micronutrient supplementation is crucial for capsicum production, particularly in micronutrient-deficient environments, since the control treatment (T₈) showed the lowest growth and yield.

In conclusion, foliar application of Zn + Fe + B at recommended concentrations can be recommended as an effective nutrient management strategy for maximizing capsicum productivity and

quality.

The study clearly indicates that foliar application of micronutrients enhanced economic profitability compared with the control treatment. The combined application of Zn + Fe + B @ 3 + 5 + 2 g L⁻¹ (T₇) proved to be the most economically effective treatment, recording the highest Benefit cost ratio of 2.83. Therefore, integrated foliar application of zinc, iron, and boron can be recommended as a profitable nutrient management practice for maximizing crop productivity and economic returns. The inclusion of zinc in combination treatments appears particularly beneficial in improving overall profitability.

Based on the findings of the study, it can be concluded that foliar application of Zn + Fe + B @ 3 + 5 + 2 g L⁻¹ (T₇) is the most effective treatment for enhancing growth, yield, fruit quality, and profitability hence can be recommended for commercial production capsicum under protected cultivation.

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