



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(6): 894-898
Received: 11-03-2026
Accepted: 15-04-2026

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Effect of micronutrients and plant growth regulators on growth, yield and quality of Parthenocarpic Cucumber (*Cucumis sativus* L.) under Protected Cultivation

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i6l.5800>

Abstract

The field experiment was conducted on cucumber crops during the autumn-winter season 2025-26 at Department of Vegetable Science Kalyanpur of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, (UP). The experiment was laid out in RBD with eight treatments and three replications and cucumber variety Pant Parthenocarpic Cucumber-2 was used in experiment. Observations were recorded for different characteristics related to vegetative, yield and yield attributing and quality traits & economics of treatments. T₁ (Control), T₂ (Boric acid 0.1%), T₃ (ZnSO₄ 0.5%), T₄ (Micronutrient mixture (ZnSO₄ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1%), T₅ GA₃ (50 ppm, foliar spray), T₆ (CPPU (Forchlorfuron (5 ppm, foliar spray), T₇ (Micronutrient mixture + GA₃ 50 ppm), T₈ (Micronutrient mixture + CPPU (5 ppm). The results of the experiment revealed that application of Treatment T₈ (micronutrient mixture + CPPU 5ppm) was significantly enhanced growth, yield attributes, and quality traits. The Treatment T₈ recorded the maximum vine length (39, 230, 364 cm) at (30, 60, 90 DAS), stem diameter (0.99 cm), inter-nodal length (13.02 cm), no. of leaves (132.34) and branches per plant (18.40). It also promoted early flowering (37.45 days) and first harvesting (48.35 days). Among yield attributes, T₈ produced the highest number of fruits per plant (36.60), fruit length (18.37 cm), fruit diameter (4.10 cm), average fruit weight (180.44 g), yield per plant (3.98 kg) and fruit yield (7.72 t/1000 m²). Quality parameters were also improved under T₈, with maximum shelf life (8.43 days), flesh thickness (3.72 cm), rind thickness (0.83 cm) and TSS (3.94 °Brix). As far as economic analysis indicated that T₈ generated the highest gross return (₹2,31,600), net return (₹1,71,630) and benefit-cost ratio (2.86) in the polyhouse for attaining the maximum return of cucumber under protected condition.

Keywords: Cucumber, protected cultivation, micronutrients, PGRs, growth, yield, quality, economics

Introduction

The word "cucumber" comes from the Latin word "cucumerem", which then passed through French as "cocombre" and then to English as "cucumber". But it was known as cow cucumber" during the 1790s in England as it was believed to cause some diseases in children and was only fit for animal consumption. Latimer, J.G. (1991) [7] In different Indian languages, it is also called by different names, like in Hindi and Punjabi, "Kheera", in Gujarati or Marathi, "Kakdi", in Bengali it is famously known as "Sosa", in Nepali, "Kakro". In Tamil, it is known as "Vellarikkay", in Malayalam, somewhat similar, "Vellarika", in Telugu it is named as "Dosakaya", and in Kannada it is "Sautekayi". A diploid species, cucumber has seven pairs of chromosomes (2n = 2x = 14) and a 367 Mbp genome (Huang *et al.*, 2009) [5]. North European cucumber is also sequenced later (Borszczagowski cultivar, lineB10).

Cucumber (*Cucumis sativus* L.) is one of the most important vegetables belonging to family Cucurbitaceae comprising 117 genera and 825 species endemics in warmer parts of the world. It is thought to be one of the oldest vegetable crops and has been found in cultivation for over 3000 years in India.

Vegetables play an important role in human nutrition and are indispensable part of human diet as they provide vitamins, carbohydrates and minerals needed for complete balanced diet. India is world's largest producer of vegetables next to China with an annual production of around 219 million tonnes from an area of 11.7 million ha. Cucurbits are day neutral, thermophilic and C3

vegetables occupying a large area in India as well as in the tropical countries. It consists of a wide range of vegetables viz., pumpkin, squashes, melons, gourd and cucumber. Cucumber (*Cucumis sativus* L.) is commonly known as 'khira', is extensively cultivated crop in tropics, subtropics and milder temperate zones of India. It belongs to family Cucurbitaceae having genus *Cucumis* and has been reported to originated in India and cultivated in almost all the continents (Kumar *et al.*, 2015) ^[6].

Micronutrients are vital for photosynthesis and chlorophyll formation in green plants. Foliar application of micronutrients shows better efficiency than soil application as the uptake and assimilation of micronutrients by later methods take more time (Pandev *et al.*, 2016). For plant's proper growth and development, mineral elements are very crucial. Trace elements or minor elements, such as boron, zinc, manganese, etc., are essential to plants for their natural life processes to function.

Cucumber can be produced year-round in protected environments with high fruit and minimal disease and pest incidence with efficient water and fertilizer utilization. It also aids in the improvement of photosynthetic efficiency and in the reduction of transpiration losses. In controlled conditions, parthenocarpic and gynoecious cucumber cultivars have a significant potential for producing a large fruit load, resulting in a high harvest index (Meena *et al.*, 2017) ^[10]. Cultivation under protected condition enables crop intensification and high-quality production, as well as environmental control. Farmers are growing cucumbers under such conditions to reap the benefits of the year-round productivity with good income.

Production of cucumber in India is mainly restricted to open field cultivation. Nevertheless, biotic and abiotic stresses are the main factors responsible for low yield and poor quality under open field cultivation particularly during rainy season crop. Now-a-days, greenhouse is most effective against adverse climatic conditions. There is an urgent need to increase production of vegetable to feed millions of mouths, which seems possible only by increasing productivity. Land is limiting factor, hence boom in production can be achieved only through vertical harvesting (Ameta *et al.*, 2019) ^[1].

Boron is a significant element for vegetative growth, development and a variety of other physiological activities such as nitrogen metabolism, protein synthesis, cell division, and cell wall production. It is regarded as an essential micronutrient for plants, with an extremely narrow toxicity range. Zinc is also important in the production of biomass. It is necessary for auxin IAA production as well as other functions such as carbohydrate metabolism, protein synthesis and internode elongation of stem growth. It is also needed for chlorophyll synthesis, pollen functioning, and fertilization). Some of the enzymes that need zinc include dehydrogenase, aldolase, isomerises, proteinases, peptidases, and phosphor hydrolase (Liu, J., Gao 2021) ^[8].

Cucumber is an important vegetable crop grown primarily in greenhouses to produce the best-quality tender edible fruits of slicing quality. However, in most cases, quality fruit production is limited due to widespread deficiencies of micronutrients in soils. Therefore, increasing the production and quality. Sex expression especially gynoecy is an important factor which has a positive effect on yield and constitutes a major component of cucumber improvement programs and this feature can easily be manipulated for production of Fi hybrids. Another important

feature which can be clubbed with gynoecy in cucumber is Parthenocarpic, which occurs within the species of *Cucumis sativus* L. as reported long back by. Parthenocarpic can be defined as the ability to develop fruits without pollination and thus fertilization. The term parthenocarpic was coined by and he was the first person to observe it in cucumber. Parthenocarpic varieties out yield normal types by about 20 per cent and have better quality. Parthenocarpic circumvents the inhibitory effect of seed creation on succeeding fruit development. The fruit of parthenocarpic cucumber are mild in flavour, without seeds and have edible skin that requires no peeling while eating (Tiwari, 2015) ^[18]. Cucumber is believed to have originated in India, where it has been cultivated for over three thousand years. It's also had a lengthy history in China, which is thought to be its secondary centre of origin. It has spread to Italy and Greece from India. It was grown in Italy, Greece, Asia Minor, and North Africa at the start of the Christian era. The crop was exported from Italy to other European countries by the Romans. Since the 9th century, cucumbers have been grown in France. Cucumbers had become fairly popular in Europe by the end of the 17th century. In 1494 Dhaliwal, 2017) ^[2].

Materials and Methods

The present investigation was carried out during autumn-winter season 2025-26. This chapter deals with the description of the material used and various techniques or methods adopted throughout the course of investigation. Details of material and methods employed during the investigation are given below.

Experiment Location and Season

The experiment was conducted at the Vegetable Research Farm, Department of Vegetable Science, C.S. Azad University of Agriculture and Technology, Kalyanpur, Kanpur, Uttar Pradesh, India during the autumn-winter season 2025-26.

Crop details and cultural practices

Parthenocarpic cucumber variety – Pant Parthenocarpic Cucumber-2 is an F1 hybrid high yielding cucumber variety developed by 'Gbpuat Pantnager University'. These variety is popular for commercial farming and suitable for growing in polyhouse at Kharif and Rabi both seasons. Was used for the study. Seeds were sown in nursery bed on 25 August 2025, and 20 days old seedlings were transplanted in 16 September 2025, under insect naturally ventilated polyhouse. The crop was transplanted at a spacing of 90 × 60 cm in plots size measuring 1.0m (width) x 4.0m (length), and seed rate is 2.3-3kg/ha. All recommended agronomic practices, including irrigation, pruning and nutrient application was applied in 30, 45 and 60 DAT, were followed throughout the crop seasons.

Experimental design and treatment details

The experimental design used in randomized block design with 3 replication and 8 treatments [T₁ Control, T₂ (Boric acid 0.1%), T₃ (ZnSO₄ 0.5%), T₄ (Micronutrient mixture ZnSO₄ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1%), T₅ (GA₃ 50 ppm, foliar spray), T₆ (CPPU-Forchlorfeuron 5 ppm, foliar spray), T₇ [(Micronutrient mixture ZnSO₄ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1%) + (GA₃ 50 ppm)], T₈ [(Micronutrient mixture ZnSO₄ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1%) + (CPPU 5 ppm)].

Treatment	Treatment details	Vine length 30 DAS (cm)	Vine length 60 DAS (cm)	Vine length 90 DAS (cm)	Stem diameter 90 DAS	Inter-nodal length (cm)	N0. of leaves/plant	N0. of branches/plant	Days taken to 1st flowering	No. of fruits/plant	Fruit length (cm)
T ₁	(Control)	22	164	290	0.66	7.98	106.29	12.34	45.66	26.9	12.45
T ₂	Boric acid 0.1%	31	194	331	0.84	11.24	127.66	16.12	39.78	31.58	16.26
T ₃	ZnSO ₄ 0.5%	29	186	325	0.79	11.01	126.46	15.86	39.23	29.88	15.92
T ₄	Micronutrient mixtures (ZnSO ₄ 0.5%+ Boric acid 0.1% + Fe-EDTA 0.1%)	34	207	343	0.89	11.98	128.54	16.66	38.12	32.7	16.89
T ₅	GA ₃ 50ppm	26	172	309	0.74	9.88	114.65	14.54	42.22	28.11	14.58
T ₆	CPPU 5ppm	28	177	316	0.75	10.87	120.54	14.88	40.64	28.25	15.18
T ₇	Micronutrient mixtures (ZnSO ₄ 0.5%+ Boric acid 0.1% + Fe-EDTA 0.1%) + GA ₃ 50ppm	37	219	351	0.95	12.67	130.22	17.78	38.89	34.7	17.51
T ₈	Micronutrient mixtures (ZnSO ₄ 0.5%+ Boric acid 0.1% + Fe-EDTA 0.1%) + CPPU 5ppm	39	230	364	0.99	13.02	132.34	18.4	37.45	36.6	18.37
SE(m)		0.279	2.735	5.627	0.009	0.193	2.036	0.252	0.747	0.413	0.217
C.D.		3.855	8.375	12.234	4.02	5.590	6.234	3.770	6.289	3.264	5.664

Treatment	Treatment details	Fruit diameter (cm)	Average fruit weight (g)	Yield per plant (kg)	Fruit yield (t/1000 m ²)	Shelf life (Days)	Flesh thickness (cm)	Rind thickness (cm)	TSS (°Brix)	B:C Ratio
T ₁	(Control)	2.16	134.36	2.75	4.52	6.1	3.09	1.03	3.04	1.26
T ₂	Boric acid 0.1%	3.72	159.61	3.11	6.05	7.29	3.54	1.00	3.67	2.02
T ₃	ZnSO ₄ 0.5%	3.64	155.34	2.99	5.81	7.53	3.40	0.96	3.61	1.90
T ₄	Micronutrient mixtures (ZnSO ₄ 0.5%+ Boric acid 0.1% + Fe-EDTA 0.1%)	3.88	166.7	3.27	6.17	7.61	3.46	0.90	3.79	2.08
T ₅	GA ₃ 50ppm	3.31	141.35	2.83	5.46	7.79	3.65	0.86	3.44	1.73
T ₆	CPPU 5ppm	3.49	148.49	2.89	5.73	7.87	3.36	0.83	3.52	1.86
T ₇	Micronutrient mixtures (ZnSO ₄ 0.5%+ Boric acid 0.1% + Fe-EDTA 0.1%) + GA ₃ 50ppm	3.93	176.29	3.63	6.35	7.84	3.43	0.90	3.87	2.17
T ₈	Micronutrient mixtures (ZnSO ₄ 0.5%+ Boric acid 0.1% + Fe-EDTA 0.1%) + CPPU 5ppm	4.1	180.44	3.98	7.72	8.43	3.72	0.83	3.94	2.86
SE(m)		0.045	2.611	0.080	0.111	0.124	0.072	0.027	0.059	
C.D.		4.139	7.997	0.246	4.33	0.380	0.221	0.082	2.180	

Results and Discussion

the treatment T₈ (Micronutrient mixture + CPPU 5 ppm) recorded the highest vine length with 39, 230 and 364 (cm) at 30, 60 and 90 (DAS). This was followed by T₇ (Micronutrient mixture + GA₃ 50 ppm), which produced vine lengths of 37 cm, 219 cm, and 351 cm at respective stages. The lowest vine length was observed in T₁ (Control) with 22 cm, 164 cm, and 290 cm at 30, 60, and 90 DAS, respectively. The results clearly demonstrate that combined application of micronutrients with CPPU or GA₃ was highly effective in promoting vegetative growth and increasing vine length of cucumber under protected cultivation conditions. Naeem *et al.* (2012) ^[11],

Among all treatments, T₈ (Micronutrient mixture + CPPU 5 ppm) recorded the maximum stem diameter (0.99 cm), followed by T₇ (Micronutrient mixture + GA₃ 50 ppm) with 0.95 cm. The enhanced stem girth under these treatments may be attributed to the synergistic effect of micronutrients (Zn, B, and Fe) along with growth regulators, which improved cell division, nutrient translocation, and vegetative growth. The control treatment (T₁) showed the lowest stem diameter (0.66 cm), indicating that foliar application of micronutrients and growth regulators considerably enhanced stem development in cucumber. Sultana *et al.* (2018) ^[17].

The maximum inter-nodal length (13.02 cm) was recorded in

treatment T₈ comprising micronutrient mixture + CPPU (ZnSO₄ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1% + CPPU 5 ppm), followed by T₇ (12.67 cm) with micronutrient mixture + GA₃ 50 ppm. The minimum inter-nodal length (7.98 cm) was observed in the control treatment (T₁) receiving only water spray. Naeem *et al.* (2012) ^[11].

The highest number of leaves per plant (132.34) was recorded in treatment T₈, which consisted of micronutrient mixture + CPPU (ZnSO₄ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1% + CPPU 5 ppm). This was followed by T₇ (130.22 leaves per plant), where micronutrients were combined with GA₃ 50 ppm. The lowest number of leaves per plant (106.29) was observed in the control treatment (T₁) receiving only water spray. Among the individual applications, micronutrient mixture alone (T₄) produced 128.54 leaves per plant, which was higher than boric acid alone (T₂, 127.66), ZnSO₄ alone (T₃, 126.46), CPPU alone (T₆, 120.54), and GA₃ alone (T₅, 114.65). Sharma *et al.* (2025) ^[14]

The maximum number of branches per plant (18.40) was recorded in treatment T₈, consisting of micronutrient mixture + CPPU (ZnSO₄ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1% + CPPU 5 ppm). This was closely followed by T₇ (17.78 branches per plant), where micronutrients were combined with GA₃ 50 ppm. The minimum number of branches per plant (12.34) was observed in the control treatment (T₁). Among the individual treatments,

micronutrient mixture alone (T_4) recorded 16.66 branches per plant, followed by boric acid alone (T_2 , 16.12), $ZnSO_4$ alone (T_3 , 15.86), CPPU alone (T_6 , 14.88), and GA_3 alone (T_5 , 14.54). Huang *et al.* (2017) ^[4] and Singh *et al.* (2018) ^[16],

The minimum number of days taken to first flowering (37.45 days) was recorded in treatment T_8 , comprising micronutrient mixture + CPPU ($ZnSO_4$ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1% + CPPU 5 ppm), indicating the earliest flowering among all treatments. This was followed by T_4 (38.12 days), where micronutrient mixture alone was applied, and T_7 (38.89 days) with micronutrient mixture + GA_3 50 ppm. The maximum number of days to first flowering (45.66 days) was observed in the control treatment (T_1). Among the individual treatments, $ZnSO_4$ alone (T_3) recorded flowering in 39.23 days, followed by boric acid alone (T_2 , 39.78 days), CPPU alone (T_6 , 40.64 days), and GA_3 alone (T_5 , 42.22 days). Huang *et al.* (2017) ^[4] and Singh *et al.* (2018) ^[16],

The minimum number of days taken to first harvesting (48.35 days) was recorded in treatment T_8 , comprising micronutrient mixture + CPPU ($ZnSO_4$ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1% + CPPU 5 ppm), indicating the earliest harvest among all treatments. This was closely followed by T_7 (49.63 days), where micronutrient mixture was combined with GA_3 50 ppm, and T_4 (50.59 days) with micronutrient mixture alone. The maximum number of days to first harvesting (60.23 days) was observed in the control treatment (T_1). Among the individual applications, boric acid alone (T_2) resulted in first harvesting at 51.77 days, followed by $ZnSO_4$ alone (T_3 , 52.38 days), CPPU alone (T_6 , 53.69 days), and GA_3 alone (T_5 , 54.27 days). Marschner (2012) ^[9].

The highest number of fruits per plant (36.60) was recorded in treatment T_8 , consisting of micronutrient mixture + CPPU ($ZnSO_4$ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1% + CPPU 5 ppm). This was followed by T_7 (34.70 fruits per plant), where micronutrients were combined with GA_3 50 ppm, and T_4 (32.70 fruits per plant) with micronutrient mixture alone. The lowest number of fruits per plant (26.90) was observed in the control treatment (T_1). Among the individual treatments, boric acid alone (T_2) produced 31.58 fruits per plant, followed by $ZnSO_4$ alone (T_3 , 29.88 fruits per plant), CPPU alone (T_6 , 28.25 fruits per plant). Huang *et al.* (2017) ^[4] and Robinson

The maximum fruit length (18.37 cm) was recorded in treatment T_8 , comprising micronutrient mixture + CPPU ($ZnSO_4$ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1% + CPPU 5 ppm). This was followed by T_7 (17.51 cm), where micronutrients were combined with GA_3 50 ppm, and T_4 (16.89 cm) with micronutrient mixture alone. The minimum fruit length (12.45 cm) was observed in the control treatment (T_1). Among the individual treatments, boric acid alone (T_2) produced fruits with a length of 16.26 cm, followed by $ZnSO_4$ alone (T_3 , 15.92 cm), CPPU alone (T_6 , 15.18 cm), and GA_3 alone (T_5 , 14.58 cm). Qian *et al.* (2018) ^[13] and Sidhu *et al.* (2020) ^[15],

The maximum fruit diameter (4.10 cm) was recorded in treatment T_8 , consisting of micronutrient mixture + CPPU ($ZnSO_4$ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1% + CPPU 5 ppm). This was followed by T_7 (3.93 cm), where micronutrients were combined with GA_3 50 ppm, and T_4 (3.88 cm) with micronutrient mixture alone. The minimum fruit diameter (2.16 cm) was observed in the control treatment (T_1). Among the individual treatments, boric acid alone (T_2) produced fruits with a diameter of 3.72 cm, followed by $ZnSO_4$ alone (T_3 , 3.64 cm), CPPU alone (T_6 , 3.49 cm), and GA_3 alone (T_5 , 3.31 cm). Qian *et al.* (2018) ^[13] and Sidhu *et al.* (2020) ^[15],

The highest average fruit weight (180.44 g) was recorded in treatment T_8 , comprising micronutrient mixture + CPPU ($ZnSO_4$

0.5% + Boric acid 0.1% + Fe-EDTA 0.1% + CPPU 5 ppm). This was followed by T_7 (176.29 g), where micronutrients were combined with GA_3 50 ppm, and T_4 (166.70 g) with micronutrient mixture alone. The lowest average fruit weight (134.36 g) was observed in the control treatment (T_1). Among the individual treatments, boric acid alone (T_2) produced fruits with an average weight of 159.61 g, followed by $ZnSO_4$ alone (T_3 , 155.34 g), CPPU alone (T_6 , 148.49 g), and GA_3 alone (T_5 , 141.35 g).

The highest yield per plant (3.98 kg) was recorded in treatment T_8 , comprising micronutrient mixture + CPPU ($ZnSO_4$ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1% + CPPU 5 ppm). This was closely followed by T_7 (3.63 kg), where micronutrients were combined with GA_3 50 ppm, and T_4 (3.27 kg) with micronutrient mixture alone. The lowest yield per plant (2.75 kg) was observed in the control treatment (T_1). Among the individual treatments, boric acid alone (T_2) produced a yield of 2.88 kg per plant, followed by CPPU alone (T_6 , 2.86 kg), GA_3 alone (T_5 , 2.81 kg), and $ZnSO_4$ alone (T_3 , 2.77 kg). The combined application of micronutrients with CPPU or GA_3 proved superior to their individual application, indicating a synergistic effect on vegetative growth, flowering, fruit set, and fruit development.

The highest fruit yield (7.72 t/1000 m²) was recorded in treatment T_8 , comprising micronutrient mixture + CPPU ($ZnSO_4$ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1% + CPPU 5 ppm). This was followed by T_7 (6.35 t/1000 m²), where micronutrients were combined with GA_3 50 ppm, and T_4 (6.17 t/1000 m²) with micronutrient mixture alone. The lowest fruit yield (4.52 t/1000 m²) was observed in the control treatment (T_1). Among the individual treatments, boric acid alone (T_2) produced a yield of 6.05 t/1000 m², followed by $ZnSO_4$ alone (T_3 , 5.81 t/1000 m²), CPPU alone (T_6 , 5.73 t/1000 m²), and GA_3 alone (T_5 , 5.46 t/1000 m²).

The shelf life of fruits ranged from 6.10 days to 8.43 days. The highest shelf life (8.43 days) was recorded in Treatment T_8 , followed by Treatment T_6 (7.87 days), Treatment T_7 (7.84 days), and Treatment T_5 (7.79 days). In contrast, the lowest shelf life (6.10 days) was observed in Treatment T_1 . The increased shelf life in superior treatments may be attributed to improved fruit firmness, better moisture retention, higher dry matter content, and enhanced physiological condition of fruits resulting from optimum nutrient availability and favourable growing conditions under the protected environment.

The flesh thickness ranged from 3.09 cm to 3.72 cm. The maximum flesh thickness (3.72 cm) was recorded in Treatment T_8 , followed by Treatment T_7 (3.65 cm) and Treatment T_5 (3.54 cm). The minimum flesh thickness (3.09 cm) was observed in Treatment T_1 . Increased flesh thickness in the superior treatments may be attributed to enhanced cell division and cell enlargement resulting from better nutrient uptake and favourable microclimatic conditions under protected cultivation.

The rind thickness ranged from 0.83 cm to 1.03 cm. The maximum rind thickness (1.03 cm) was recorded in Treatment T_1 , followed by Treatment T_2 (1.00 cm) and Treatment T_3 (0.96 cm). The minimum rind thickness (0.83 cm) was observed in Treatments T_6 and T_8 , while Treatments T_4 and T_7 recorded an intermediate rind thickness of 0.90 cm. The variation in rind thickness among treatments may be attributed to differences in nutrient availability, growth regulation, and fruit developmental processes under protected cultivation conditions.

The highest T.S.S. value (3.94 °Brix) was recorded in treatment T_8 , comprising micronutrient mixture + CPPU ($ZnSO_4$ 0.5% + Boric acid 0.1% + Fe-EDTA 0.1% + CPPU 5 ppm). This was followed by T_7 (3.87 °Brix), where micronutrients were combined with GA_3 50 ppm, and T_4 (3.79 °Brix) with micronutrient mixture

alone. The lowest T.S.S. value (3.04 °Brix) was observed in the control treatment (T₁). Among the individual treatments, boric acid alone (T₂) recorded a T.S.S. value of 3.67 °Brix, followed by ZnSO₄ alone (T₃, 3.61 °Brix), CPPU alone (T₆, 3.52 °Brix), and GA₃ alone (T₅, 3.44 °Brix).

The data indicated significant differences among the treatments with respect to economic returns. The highest B:C ratio of 2.86 was recorded in Treatment T₈, indicating that every ₹1.00 invested returned ₹2.86, thereby proving to be the most economically viable treatment. This was mainly attributed to higher marketable yield and better net returns obtained under this treatment. The next highest B:C ratio was observed in Treatment T₇ (2.17). Lower B:C ratios were observed in T₁ (1.26) suggesting comparatively lower economic efficiency due to reduced yield and net returns.

Conclusion

Based on the results of the present investigation, it can be concluded that the foliar application of Micronutrient mixture [ZnSO₄ (0.5%) + Boric acid (0.1%) + Fe-EDTA (0.1%)] along with CPPU (5 ppm) (T₈) was the most effective treatment for improving the growth, phenological development, reproductive performance, yield, quality, and economics of parthenocarpic cucumber under protected cultivation. This treatment significantly enhanced vine length, stem diameter, internodal length, number of leaves, and branches per plant. It also promoted earlier flowering and harvesting, resulting in improved crop earliness. Furthermore, T₈ recorded the highest number of fruits per plant, fruit length, fruit diameter, average fruit weight, yield per plant, and fruit yield per 1000 m². Superior fruit quality was achieved through increased shelf life, flesh thickness, and TSS, along with reduced rind thickness. Economic analysis also revealed the highest B:C ratio and net returns under T₈. Therefore, the combined foliar application of micronutrients and CPPU can be recommended for maximizing productivity, fruit quality, and profitability of cucumber under protected cultivation conditions.

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